Technology Catching-up and the Role of Institutions

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Abstract: The aim of the paper is to investigate the role played by differences in Institutional Quality on the process of technology catch-up across countries. Empirical evidence shows how countries endowed with better institutions are those experiencing higher TFP growth rates, faster rates of technology adoption and hence being those more rapidly closing the gap with the frontier. Conversely, countries lacking some minimum institutional level are shown to diverge in the long run and not to catch-up. Some institutions, however, play an ambiguous role in the creation and adoption of technology. We find that the tightening of Intellectual Property Rights reduces the ability of followers to freely imitate technology slowing down their catch-up rate. This negative effect is stronger the farther the countries are found from the frontier. Other institutional categories such as openness to trade, instead, benefit both leaders and followers.

Key words: TFP, Growth, Institutions, IPRs.

JEL codes: O33, O38, O40.

1 Introduction

In 1966 Richard Nelson and Edmund Phelps formalized one of the most appealing ideas in modern economic growth, that of technological catching up across countries. The idea, which is originally due to Gerschenkron (1962), is at the same time powerful and simple. Countries lagging behind the world technological frontier may reduce their gap from it by simply imitating technologies discovered in leader countries. As in Barro and Sala-i-Martin (1997) this happens since the cost of imitation in the follower country is usually lower than that of innovation at the frontier. Usually it is assumed that the wider the technology gap and the more the scope for adopting new technologies and therefore the higher, ultimately, the technology growth rates of the lagging country. Crucially, however, the catch-up process is not immediate. Simply lagging behind the leader is not a sufficient condition in order to ensure high growth and catch-up.

Nelson and Phelps (1966), and later Abramovitz (1986) rearranged the catching up hypothesis of Gerschenkron (1962) suggesting how the rate at which the technological gap is closed should be linked to the followers' ability to receive technology flows from the frontier, that is, in their particular case, a function of each country's human capital stock. More recently, the work of Benhabib and Spiegel (1994, 2005) empirically grounded the Nelson and Phelps (1966) hypothesis showing how differences in human capital stocks may help explaining the observed differences in the speed of technology catch-up across countries.

Crucially for the motivations of our own contribution, even after accounting for human capital differences across countries, large differentials in productivity levels and growth rates are still observed[1]. Interestingly, for example, we show how no correlation is found between a country's distance from the technological frontier and its GDP or TFP subsequent growth rates even when human capital differences are taken into account in the computation of the gap. We believe this is suggestive of the fact that some other variables may be fundamental, along with human capital, in igniting and promoting TFP growth and catch-up across countries.

In what follows we will assume how Institutional Quality differences explain, to a large extent, the differences in the speed by which countries imitate and adopt technologies discovered at the frontier. Hence, we build on the recent contributions of Hall and Jones (1999) and Acemoglu et al. (2001), by assuming not only that good institutions are associated to better economic performances but also that they represent the necessary condition for technology adoption and catch up of follower countries.

This said, however, another recent strand of literature argue how certain institutions which foster economic growth in developed countries may actually

[1]See for example, Hall and Jones (1999), Easterly and Levine (2001), Klenow and Rodriguez-Clare (1997) or Caselli (2005).

hinder the growth of least-developed ones. Acemoglu et al. (2006), Aghion et al. (2001) or Aghion and Howitt (2005) argue how countries lagging behind the technological frontier, and that perform technology imitation, may be better off by some non-competitive policies in the early stages of their development[2].

Hence, in the present contribution, we will analyze the impact that different institutional arrangements may play on both the production of innovation and on its diffusion across countries. Evidently, countries at different development stages are also endowed with different economic fundamentals which, then, shape their innovative and imitative possibilities. We try to assess which institutional arrangements are fostering innovation creation and which are, instead, hindering technology adoption and ultimately economic growth.

Both theoretical and empirical literature have focused on the role played by Intellectual Property Rights protection in the diffusion of technology across countries. On one hand, despite the increasing *consensus* on the positive long-run effect of property rights enforcement, *dissensus* arises when the analysis focuses on the short and medium run effect of a tightening of Intellectual Property Rights (IPRs) over countries which differ in their economic development.

From a general point of view IPRs are legal mechanisms designed to represent a barrier to the possibility of free riding and imitation of new ideas, blueprints or technologies by agents which did not incurred in the costs of producing these innovations. Maskus (2000) argues how "*absent such rights, economically valuable information could be appropriated by competitive rivals*". It is straightforward to understand, therefore, how IPRs are aimed at ensuring the innovator with an adequate monetary compensation for the investment in R&D. At the same time IPRs work on the imitators' side by prohibiting free imitation and, therefore, rising the relative costs of copying new blueprints.[3]

Ceteris paribus within the same economy, the enforcement of IPRs implies a trade-off between the positive incentive given to the R&D sector and the negative effect coming from an increase in the cost of imitation. Previous empirical investigation has already pointed out the costliness of imitation. Levin et al. (1988) and Gallini (1992), for instance, argue how "*patents raise imitation costs by about forty percentage points for both major and typical new drugs, by about*

[2] This literature focused especially on the positive role of anticompetitive product market regulations and on that of financial constraints on the economic growth of countries which perform imitation in order to catch-up with the frontier. This said, however, empirical evidence on these regards seems to be still mixed and not conclusive. See for example the works of Gust and Marquez (2004), Conway et al. (2006), Nicoletti et al. (2003) which, differently from Acemoglu et al. (2006) or Aghion et al. (2005, 2000) empirically point to the scenario where pro-competitive regulations amplify the speed of technology catch-up. In the former papers it is shown how technology adoption may be up to 25% less in countries adopting the same product market regulation as in the most restrictive OECD country.

[3] Recently, moreover, Grossman and Lai (2004) analyze a North-South environment where both regions owns an innovative sector. Among the others, their results show how, enforcing IPRs in the South increases the gain for the North at the expenses of the South.

thirty precentage points for major new chemical products, and by twenty-five percentage points for typical chemical products". Also, Helpman (1993) and Lai (1998), among others, link negatively the speed of imitation to the extent by which IPRs are enforced in the follower country.

As pointed out by Connolly and Valderrama (2005) a similar trade-off exists, on a cross-country basis, between developed countries (the innovators) and developing ones (the imitators). Developed countries, those where virtually all the innovation is performed, have pushed strongly for international enforcement of IPRs while many of the developing countries have been opposing this scenario by arguing how too tight IPRs may end up slowing down economic growth and harming their development by reducing drastically the access to new technologies.

Ginarte and Park (1997) provide evidence of threshold levels in the effects of IPRs on growth. Differently from them we simultaneously test the impact of IPRs on both innovative and imitative activities on a cross section of countries when also controlling for other institutional arrangements. Our aim is therefore to analyze both theoretically and empirically the ambigous effect that IPRs may have on growth through their specific effects on innovation production and imitation.

Along with IPRs, also Trade Openness has been shown in the literature to be an important determinant of innovation and of innovation diffusion. More open economies are able to discover new products more easily and then to be able to perform much of the reverse engineering which is somehow at the basis of technology imitation and adoption. Also, on the other hand, we expect trade openness to be important in shaping the incentives for imitation just because much of the imitated goods are usually sold in international markets (and not in the imitator country). The cases of the chinese or indian economies are educational in this sense to understand the importance that being able to compete in international markets may play for technology imitation and diffusion. On this line, also, Falvey et al. (2002) show how international trade may be a major source of knowledge spillovers but they do not address their impact along with that of IPRs within a technology catching up empirical model.

Noticeably, despite its importance, previous empirical literature has not yet provided clear empirical evidence of whether (and how) differences in Institutional quality (IQ from now on) play a role in the speed and diffusion of technology from the world frontier to the laggard countries. Among the exceptions stand the works by Keefer and Knack (1997) and by Olson, Sarna and Swamy (2000) who confine, not without drawbacks, their study to the impact of overall IQ on catch-up.[4]

[4]Both of them own major drawbacks which we target in our own contribution. The first reason of concern is that these previous contributions do not properly control for simultaneity

Hence, with our work we aim at merging two strands of literature by testing the impact of institutional quality within the technology catching up framework directly. The main question we pose here is the following: do countries endowed with better institutions experience a faster rate of technological catch-up than those with poor institutions? If yes, is there a particular institutional arrangement or policy which is more willing to deliver this outcome?

From a methodological point of view we will rely on the catching-up framework proposed by Benhabib and Spiegel (2005) for a variety of reasons. The most important is that this can be easily generalized to a vast range of hypotheses. Secondly, this framework is parsimonious enough in the number of variables to allow us to address the problem of endogeneity between TFP and institutional quality quite straightforwardly.

The remainder of the paper is the following. In section 2 we review the link between institutional quality and technology transfers by giving some example of how good institutions may lead to faster technology adoption. In section 3 we deal with the technology catching-up model specification. Here we explore a logistic functional form modeling the diffusion of technology from the frontier to the followers. In particular we show how this formalization allows us to compute the catch-up condition as a function of both the overall IQ and of the strength by which IPRs are enforced in follower countries. In section 4 we provide the analysis of the catch-up conditions derived from the logistic theoretical formalization we use in the model and we discuss the role played by IPRs and by the specific development stage of each country on catch-up. In section 5 we briefly review some data issues while in section 6 we provide regression results of the technology catching-up specification. A substantial part of the paper will be devoted to the extensions of the technology catching-up model. In section 7 we will try to assess what institutional arrangements are particularly affecting technology flows from leader to followers are. In particular we will be looking at the consequences on productivity growth of tightening or relaxing some policies (such as the enforcement of property rights or a country's trade openness) which previous theoretical literature has highlighted as fundamental for technology change and economic growth. In section 8 we will discuss the empirical test of the Institutional threshold analysis. At the end some conclusions.

bias in their estimates. Instead, we employ appropriate Instrumental Variables techniques, as it has become increasingly popular in this kind of literature, not only to control for endogeneity of productivity w.r.t. institutions but also to address measurement errors problems. Secondly the lack of robust data on institutional quality used previous contributions makes OLS results questionable. Due to the lack of data, for example, previous empirical works controlled for the impact of institutional quality on technology transfers by using end of the period values for institutions, instead of averages for the whole period, hence *de facto*, not properly testing the catching-up hypothesis.

2 From Institutional Quality to Technology Transfers

Technology transfers and catch-up do not happen spontaneously. As emphasized by Abramovitz (1986), being a laggard carries a *potential* for rapid advance. This potential, however, may remain unexpressed when the recipient country does not own the appropriate characteristics to exploit it. As pointed out by Abramovitz (1986) and Nelson and Phelps (1966), the opportunity for rapid growth is taken by those who own specific qualities such as technical competencies or political, commercial, industrial and financial developed institutions.

Hence, before turning to the model estimations we propose a simple correlation test on some of the main variables we will be using throughout this work. The variables in the correlation matrix proxy for (i) the average institutional quality (Economic Freedom of the World index, EFW) [5], (ii) TFP gap in the initial year[6], TFP and GDP per capita annual growth rates.

Table 1 about here

The correlation between TFP and GDP per capita growth is, as expected, very high. Also the correlation matrix reveals how countries with better institutions are those which are growing faster both in terms of productivity and GDP per capita with correlation indexes higher than 0.5 in the two cases. Of crucial relevance for our work is, however, the relationship between productivity growth and the technological gap with the frontier. The correlation index clearly shows how being a follower country (lagging behind the frontier) is not a sufficient condition *per se* in order to experience higher GDP and TFP growth rates than other countries. The correlation between GDP or TFP growth with the initial technology gap is, in fact, close to zero. Our empirical investigation starts from this result with the aim of investigating the mechanisms and the determinants that promote fast technology catch-up in follower countries. In what follows we will suggest how institutional quality may be this promoting factor.

From a "technology catch-up" point of view there are several channels through which differences in the quality of institutions may shape the speed and extent of technology adoption.

Kaufmann and Kraay (2002) show the existence of a high correlation between the quality of governance and economic performance over 175 countries for the year 2000-01. Keefer and Knack (2002) link social polarization to less

[5] A full description of the EFW index will be given in the next sections.

[6] The TFP gap is expressed as the ratio of each country's Total Factor Productivity to the U.S. TFP value in the initial year. Growth accounting methodology accounts for the contribution of human capital in the computation of the Solow residual.

secure institutional environments and ultimately to lower output growth rates. Institutional quality seems to be a fundamental variable defining productivity differentials across countries.

As emphasized by Falvey et al. (2002) Alcalà and Ciccone (2004) or Dollar and Kraay (2003) there exists a positive relationship between good institutions, openness to trade and growth. By trading, follower countries are actually enabled to do reverse engineering of the products received in their home countries. Within an autarkic framework both the adoption and imitation of world leading technologies may be much more difficult.

Also, and maybe more importantly, a firm in a follower country may decide to imitate or adopt a new technology (and spend some resources in this process) when it is going to be able to re-sell the adopted technology-item in international markets. As pointed out by Helpman (1993) less developed countries own a relative advantage in manufacturing due to the lower cost of labor. This is reflected in the relatively lower prices of the replicas which allow follower countries to advantageously compete in international markets. Hence, being able to freely trade helps in setting some important economic incentives for the adoption and implementation of new technologies in follower countries which otherwise would be missing.

Having good institutions is also important in setting the right economic environment for the domestic R&D sector. Parente and Prescott (2000) explain the huge differential in productivity levels across countries by not well defined property rights and monopoly power which would raise "institutional barriers" to the adoption of new technologies in developing countries. In the same line of reasoning the work of Maskus (2000) and of many others which usually argue how IPRs are institutional mechanisms which compensate (and incentivize) the producers of innovation for incurring in this risky activity.

Organizational factors such as the incentives to start up a new business, labor regulations, access to credit, control of diversion, property rights enforcement and so on surely play a fundamental role in the possibility for a firm to adopt a new technology and fully exploit its potentials. A country lacking all these institutional elements may not be able to adopt the new technology even in the presence of a qualified workforce. Bailey and Gersbach (1995) or Prescott (1998) point out, for example, how Ford Europe, differently from Ford U.S.A, failed to adopt the just-in-time organizational technology from Japan mainly beacuse of the more restrictive labor and market regulations vigent in Europe. Also, they argued how german breweries could not adopt and run the better technologies that are used in the U.S. or Japan (but that paradoxically have been discovered in Germany) because of explicit rules and regulations that govern the production of beer in Germany.

Hence, many institutional aspects (from IPRs protection to Trade Openness) are likely to play a crucial role in the diffusion of technology. We aim to study the overall impact of IQ as well as the specific impact of each one of the mentioned institutional subcategories on the process of technology creation and adoption within the well established catching-up framework.

3 The model

We study the role played by institutional quality on the TFP catching up process by means of a logistic model of technology diffusion building upon the analytical formalization of Romer (1990) and Benhabib and Spiegel (2005).

Let us assume the world is of two countries denoted by $i = 1, 2$ in which 1 represents the North and 2 is the South. The production function for each country takes the usual Cobb-Douglas form as follows:

$$Y_i(t) = K_i^{\alpha}(t)[A_i(t)L_{y,i}(t)^{1-\alpha}] \tag{1}$$

where, as in the endogenous growth model of Romer (1990), $L_{y,i}$ represents the fraction of labor used in the production of good Y in country i. Both North and South run an innovative sector and, according to their relative possibilities they may produce more or less innovation. The law of motion for the stock of knowledge in the two countries is given by a Romer-type function as follows:

$$\dot{A}_i(t) = \delta A_i^{\phi}(t)L_{a,i}^{\lambda(i)}(t) \tag{2}$$

where A_i represents the accumulated stock of ideas (or technology). L_a is the fraction of population engaged in the R&D sector producing new technologies. The parameter ϕ captures the returns from previously accumulated technology stocks on the change of A while λ captures the returns of the R&D sector in each country. As a simplifying assumption we assume ϕ to be the same across countries.[7]

Along the BGP, it can be shown that economies which only innovate grow at a constant rate given by the following:

$$\gamma_{A,i} = \frac{\lambda(i)n}{1-\phi} \tag{3}$$

where n represents the growth rate of population which, for simplicity, we assume to be the same across countries.

Crucially, the identifying assumption of our formalization is that the parameter λ, the productivity of the R&D sector, changes accordingly to country-specific conditions, in our case, country specific institutional quality. In particular we assume the following:

[7] That is, given the same amount of accumulated stock of technology in two different countries, the intensity of the returns stemming from it will be the same across countries. On this see the discussion of Jones (2002) p.99.

$$\lambda(1) = f(S_1) \tag{4}$$

$$\lambda(2) = f(S_2) \tag{5}$$

where, S_i defines the country specific institutional quality. In this framework the North represents the technological "leader" because $\lambda(1) > \lambda(2)$ while the South will be the "follower"[8]. More formally, combining eq. (4) with eq. (5) and eq. (3) we can show the following:

$$\lambda(1) = f(S_1) \Longrightarrow \gamma_{A,1} = \frac{\lambda(1)n}{1-\phi} = g(S_1) \tag{6}$$

$$\lambda(2) = f(S_2) \Longrightarrow \gamma_{A,2} = \frac{\lambda(2)n}{1-\phi} = g(S_2) \tag{7}$$

and

$$g(S_1) > g(S_2) \tag{8}$$

The intuition behind this result is rather simple. Assume, for example that the same share of researchers is engaged in the R&D sector in the North and in the South. Better institutional quality in the North may allow Northern researchers to be more productive than Southern's ones[9]. This is to say that, in our settings, differences in IQ across countries incentivize researchers differently determining higher returns in one country w.r.t. the other even in a situation where the relative size of the R&D sector may be the same across countries (even if this need not to be the case however).[10]

On the "incentives side" to the production of innovation, those countries with tighter IPRs regimes will theoretically experience higher rates of innovation production. This justifies the empirical evidence that the Northern countries (the developed ones) are both the biggest innovators pushing on the technologial frontier and the institutional leaders, while very little innovation is performed in developing countries.

[8] We will use the terminology "leader" and "North" interchangeably in the rest of the paper. The same applies to "follower" and "South".

[9] That is, even if $L_{a,1} = L_{a,2}$, it needs not to be the case that $\lambda(1) = \lambda(2)$. Instead we will assume below that the parameter λ is a function of country specific institutional quality. Hence, in the particular example above we assumed $\lambda(2) < \lambda(1)$ where better incentives to research in the North country lead to higher returns to productivity w.r.t. South.

[10] This reasoning is consistent with the critique made by Jones (1995) on the standard endogenous growth model of Romer (1990) or Aghion and Howitt (1992) about the "scale effects" of R&D effort on productivity and TFP growth. If in Romer or Aghion and Howitt's settings doubling the effort in R&D also doubles the growth of producitivity, this need not to be the case in our framework where the growth of productivity is a function of the country institutional quality. Also, our simple modification to the standard endogenous growth model helps to relax the counterfactual conclusion of Jones (1995) in which the TFP growth rate of a country is ultimately only a function of the growth rate of its workforce.

Hence, up to now we set the conditions for which the South grows slower than the North from which it is progressively diverging due to the institutional quality gap $S_1 > S_2$. [11]

This is not the whole story however. Follower countries need not to diverge in the long-run due to the possibility of technology adoption from the world frontier. Let us assume, in fact, that the South is able to imitate technologies from the North[12]. The growth rate of South should be then modified as follows:

$$\gamma_{A,2}(t) = g(S_2) + c\,(S_2)\left[\frac{A_1(t)}{A_2(t)} - 1\right]\left(\frac{A_2(t)}{A_1(t)}\right) \tag{9}$$

As shown in eq. (6) and eq.(7) $g_i(S_i)$ represents the long run growth that the economy i would experience in the absence of technology flows. This is assumed to depend on each country's specific institutional quality[13]. When also we allow for technology flows from the technological frontier the growth rate of the follower is augmented by the $c(S_2)\left[\frac{A_1(t)}{A_2(t)} - 1\right]\left(\frac{A_2(t)}{A_1(t)}\right)$ term which captures the technology catching up effect. $c(S_2)\left[\frac{A_1(t)}{A_2(t)} - 1\right]$ represents specifically the rate of technology diffusion from the North to the South.

Crucially, the rate at which the technology gap is closed is, in our formalization, a positive function [14] of the follower overall institutional quality. As pointed out by Hall and Jones (1999), for example, *"in addition to its direct effects on production, a good social infrastructure may have important indirect effects by encouraging the adoption of new ideas and new technologies as they are invented throughout the world* ". Good institutions facilitate both specialization and flexibility such that imitators find it easier to adapt their organizational processes to the new products to be produced eventually paying a lower cost for imitation.

Additionally, countries with better institutions are usually more open to international markets and, hence, able to do more reverse engeneering. That

[11] Noticeworthy, institutions are here assumed to be exogenously given. This is the usual assumption in empirical literature such as in Keefer and Knack (1997), Barro (1997), and many others. More likely, instead, as pointed out by Acemoglu et al. (2005), institutions are endogenous and determined by collective choices or by the allocation of political power based on the economic interests of powerful political lobbies. However, Acemoglu (2004) also points out how a complete theory on the causes of institutional differences across countries is still missing and invoked. This task, even tough of much interest, is however far beyond the scope of the current paper.

[12] In order to keep the reasoning as simple as possible we eliminate the possibility that the leader may imitate technologies from the follower as in Barro and Sala-i-Martin (1997) where the pool of blueprints known by the South is a subset of those known by the North.

[13] This is also consistent with some recent empirical evidence shown by Hall and Jones (1999), Alcalà and Ciccone (2002) or Dollar and Kraay (2002) which empirically show how institutional quality plays a fundamental role in defining productivity cross-country differentials.

[14] We assume both g and c to be increasing functions.

is, economic agents or firms which operate in better institutional frameworks are able to exploit trade-embedded technology spillover much more than others which operate in countries with poor institutions. The formers, therefore, face lower costs in adopting new technologies or in using the newly produced public knowledge at the frontier. Also, having more stable economic and political frameworks decrease the need for economic agents to spend consistent resources in protecting themselves from activities such as thievery and squatting while it enables them to devote these resources to productive activities such as technology adoption.

This said, however, if the effect of overall institutional quality on productivity growth ($g_i(S_i)$) is unambigously positive, some specific institutional arrangements such as the enforcement of IPRs may play an ambigous role in the diffusion and adoption of innovation for the follower countries, $c(S_2)\left[\frac{A_1(t)}{A_2(t)} - 1\right]$. As already pointed out, in fact, IPRs regimes are implemented in order to limit the possibility of free riding by imitators of the blueprints discovered at the frontier.

Hence, on one hand, IPRs may theoretically reduce the speed by which technology can be imitated in the follower country. Evidence on these regards is somehow mixed. The work by Ginarte and Park (1997) or the theoretical formalizations by Boldrin and Levine (2005) show a non-lineal (or negative) impact of IPRs on productivity growth.

Hence, if on one hand tighter IPRs may be harming growth because they are distortionary and create monopoly power and unnecessary rents for the innovators, on the other hand, they compensate the cost of innovation and may eventually also foster technology diffusion by the FDI channel.

FDI are usually one of the means by which technology spills over to developing countries. Usually one of the determinants of the MNEs locational choices is exactly the protection of their IPRs in the recipient country. Hence, it is possible that some degree of IPRs protection may be beneficial to imitators through the FDI spillover channel and that the overall impact of IPRs on technology diffusion may be mixed and eventually depend on the development stage of the follower.

Since, at this stage, we are agnostic about the balance between the positive or negative effects that IPRs may have on technology adoption we propose an alternative interpretation of eq. (9) where the specific negative effect of tighter IPRs is made explicit in the catch-up formalization. This leads to the following alternative specification for the growth rate of the follower:

$$\gamma_{A,2}(t) = g(S_2) + c\left(\frac{\tilde{S}_2}{\nu_2}\right)\left[\frac{A_1(t)}{A_2(t)} - 1\right]\left(\frac{A_2(t)}{A_1(t)}\right) \tag{10}$$

Here, v_2 proxies for the IPRs regime applied in the South. IPRs here enter as a cost for the follower (or better, as a barrier to free imitation) which reduces the speed of the technology transfers from the frontier. $\tilde{S}_2$ is instead representing all the other institutional arrangements which are unambigously impacting positively the speed of technology imitation.

As in Benhabib and Spiegel (2005), we formalize the diffusion of technology across countries by using a logistic model. Due to the way we formalize this diffusion, the strength of the catching up mechanism is reduced by the term $\left(\frac{A_2(t)}{A_1(t)}\right)$ which dampens the rate of technological diffusion as the distance from the leader increases. That is, holding constant the institutional quality of a country, if differences in technological proportions between the leader and the follower are large, the technology diffusion process will be slower reflecting the difficulty of adopting distant and more complex technologies.

4 Cathing-up condition, overall IQ, IPRs effects and development stage.

In order to study the conditions under which IQ (or IPRs) lead to catch-up or divergence we define the difference between the growth rate of the follower and that of the leader as follows:

$$\gamma_B = \frac{\dot{B}}{B} = \left[\frac{\dot{A}_2}{A_2} - \frac{\dot{A}_1}{A_1}\right] = g(S_2) + c(S_2)(1-B) - g(S_1) \tag{11}$$

or, similarly, for the case where we specify the specific effect of IPRs, as follows:

$$\gamma_B = \frac{\dot{B}}{B} = \left[\frac{\dot{A}_2}{A_2} - \frac{\dot{A}_1}{A_1}\right] = g(S_2) + c\left(\frac{\tilde{S}_2}{\nu_2}\right)(1-B) - g(S_1) \tag{12}$$

where in both cases:

$$B = \frac{A_2}{A_1} \tag{13}$$

Similarly to Benhabib and Spiegel (2005) we are interested in the study the steady state value for the technology gap between North and South, B. This is given by the following:

$$B^* = \frac{c(S_2) - g(S_1) + g(S_2)}{c(S_2)} \tag{14}$$

or, in the case we analyze directly the effects of IPRs (assuming that they can slow down the rate of technology adoption) by the following:

$$B^* = \frac{c(\tilde{S}_2/\nu_2) - g(S_1) + g(S_2)}{c(\tilde{S}_2/\nu_2)} \tag{15}$$

Similarly to Benhabib and Spiegel (2005), from eq. (14) or eq. (15) it is possible to derive the conditions for which the technology gap will reach a steady state value (the "catch-up condition") and those for which divergence, instead will be achieved. More precisely we have the followings conditions:

$B^* = \bar{B}$ if $c(S_2) > g(S_1) - g(S_2)$
or conversely
$\tilde{B}^* = \bar{B}$ if $c(\tilde{S}_2/\nu_2) > g(S_1) - g(S_2)$
and
$B^* = 0$ if $c(S_2) = g(S_1) - g(S_2)$
or conversely
$B^* = 0$ if $c(\tilde{S}_2/\nu_2) = g(S_1) - g(S_2)$

In the first (or second) case, the steady state assumes a positive value (and therefore, catch-up is achieved) when $c(S_2) > g(S_1) - g(S_2)$ (or $c(\tilde{S}_2/\nu_2) > g(S_1) - g(S_2)$) while, in the third (or fourth) case if $c(S_2) = g(S_1) - g(S_2)$ (or $c(\tilde{S}_2/\nu_2) = g(S_1) - g(S_2)$) the value of B converges to zero[15] and the follower never catches up with the leader.

When IPRs have an univocal positive effect both on the production and adoption of technology the result can be interpreted quite straightforwardly: for defined low levels of institutional quality, the follower country will not be able to fill the gap between its growth rate and that of the leader in their respective innovative sectors due to their inability of exploiting the technology catch-up possibilities. Hence, having very poor institutional levels will impede the South to robustly imitate the leader with the overall result of continuously falling behind and never catching up[16].

The result when IPRs protection, among the other institutional arrangements, is instead assumed to play an ambigous role over the production and over the adoption of technology is somehow more complex and deserve more analysis.

From eq. (12) we can define the condition for which the technology gap between the leader and the follower is decreasing (the follower is catching-up during the transitional dynamics) as follows:

$$c\left(\frac{\tilde{S}_2}{\nu_2}\right)\left(1-\frac{A_2}{A_1}\right) > g(S_1) - g(S_2) \tag{16}$$

[15] Notice here that B is only defined within the $\Re^+$ set. This implies that the only solution for the steady state when $c(S_2)$ is not greater than $g(S_1)-g(S_2)$ is actually $c(S_2) = g(S_1)-g(S_2)$.

[16] It is worth mentioning how this result is peculiar to the functional form chosen for the diffusion of technology. If we chose a confined exponential function in order to model technology flows we would have ended up with a unique positive solution for the steady state of B as shown in Benhabib and Spiegel (2005).

We can see how the marginal effect of an increase in the strenght of IPRs (an increase in the value of ν_2) will imply a reduction of the rate of catch-up (the term on the left hand side of the disequality (16)) since the IPRs are assumed to play as a barrier to the free imitation of technology. At the same time, a tightening of IPRs regimes will also lead to an increase in the production of innovation in the follower economy (an increase of $g(S_2)$ on the right hand side of the disequality (16)[17] contextually reducing the institutional gap between the leader and the follower.

Crucially, the overall effect of strenghtening IPRs will depend on the development stage of the follower A_2/A_1. It can be noticed, in fact that, as the follower approaches the technological frontier, the negative marginal effect of an increase in the protection of IPRs on technology diffusion will be less and less important while convergence will be, instead, achieved by means of an increase in innovation production rather than imitation.

To summarize, what we expect to see in the data is the confirmation of three basic hypothesis:

- An overall positive effect of IQ on both the creation and diffusion of technology as in eq.(9)
- A partial negative effect of a strenghtnening of IPRs on the catch-up term (the speed by which technology flows from the frontier to the followers) when we, in fact, disaggregate institutional quality into specific institutional aspects and allow them to impact differently the creation and the diffusion of technology.
- A relatively stronger negative effect of a tightening of IPRs on the adoption of technology for those countries farther from the technological frontier (as in eq.(16), "development stage hypothesis")
- A positive impact of a tightening of IPRs on the creation of technology, that is a positive partial effect on the term proxying for $g(S_2)$ also for those countries which are "imitators" and that are lagging far from the frontier. The effect will be however stronger the closer the imitators are to the technology frontier.

5 Some data issues

Empirical works concerned with the explanation of cross-country productivity differentials usually face some major data problems. These are, first of all, due to the fact that the standard measure of productivity or technology (in our case, Total Factor Productivity or TFP) is usually computed as a residual

[17] Since S_2 is increasing in ν_2.

from the observables within a specified production function[18]. Hence, both the assumptions made on the functional form of the production function and those on the variables to be inserted within it may lead, in some cases, to some discrepancy in the TFP estimates[19].

Despite these problems a growing empirical literature focused on the determinants of TFP differential across countries. Within this recent empirical literature there are the already mentioned Benhabib and Spiegel (2005), Hall and Jones (1999), Easterly and Levine (2001) and many others. The TFP estimates we use in our work in order to proxy for countries' technology stocks come from the paper of Baier, Dwyer and Tamura (2006) (BDT from now on). The choice of using their dataset is based on several methodological issues which we believe to be important in our context.

To start with, the authors follow the methodology of Hall and Jones (1999) and Klenow and Rodriguez-Clare (1997) to decompose output into its productive factors and the residual. That is they use income per worker, rather than income per capita, in measuring economic performance. It is assumed the following production function:

$$Y(t) = A(t)F(K(t), H(t)) \tag{17}$$

where the output $Y(t)$ is produced by using the stock of physical capital $K(t)$ and human capital $H(t)$. $A(t)$ represents a Hicks neutral measure of productivity or TFP. If social marginal products equal private ones and there is perfect competition eq. (17) implies that:

$$a = y - \alpha k - (1 - \alpha)h \tag{18}$$

where lower case letters denote variables in growth rates while α and $1 - \alpha$ represent factor shares. Notice that no particular functional form is specified for the production function such that deviations of social marginal products from private ones may (but this need not to be the case) be captured by changes in TFP[20]. Recent empirical evidence, however, seems to show how these de-

[18] Some other approaches follow a different way in computing TFP. DEA approaches, for example, compute TFP as the distance of each economy from a non-parametrically constructed world frontier. See for example Cherchye and Moesen (2002) or Kumar and Russel (2002).

[19] Caselli (2005) gives a very detailed and useful review of most of the problems arising in the context of productivity measurement. Nonetheless, even after accounting for the majority of these issues he argues how the biggest bulk of economic growth cross-country differentials has still to be explained by productivity (Solow-Residual) differences.

[20] Hall (1990), for instance, points to the fact that, under imperfect competition there exists a gap between price and marginal costs at the firm level. This, in turn, implies that an increase in primary inputs would lead to an increase in productivity uncorrelated to shocks in technology. Basu and Fernald (1997) argue that: "if firms have different markups of price over marginal cost, or pay different wages, then society may value resources differently in different uses. Reallocating resources towards highly valued uses raises aggregate productivity, without necessarily reflecting changes in technology". Hence, under imperfect competition, there is no need to immediately rely on technological change for an explanation of an increase in aggregate measured productivity.

viations may be negligible. Basu and Fernald (1997) and Basu and Kimball (1997), present a growth accounting framework which identifies several non-technological gaps between observed TFP and "pure technology". The authors' empirical results, however, point out how adjusted measure of technology is very close to the usual Solow's technology residual computed by using C.R.S.[21].

A second important reason justifying the use of BDT dataset is the particular care used in computing Human Capital series. The stock of Human capital per worker is accurately computed by taking into account both a measure of average nominal education E_d as in Barro and Lee (1993) and an average of years of experience E_x. We argue how, due to this feature, the BDT measure of Human capital encompasses some of the others previously used in similar empirical literature[22].

From a methodological point of view, as suggested by Benhabib and Spiegel (2005), human capital can either be intended as a factor of production to be inserted into the Cobb-Douglas production function (where, in that case, an increase in H only affects the economy by its marginal product) or as a factor enhancing technological flows across countries where its role, as in eq.(9) would be that of increasing the rate of technology diffusion.

We are agnostic about what the correct interpretation of the role of human capital stocks should actually be. It may well be the case that both human capital stocks and institutional quality should be theoretically regarded as distinct factors enhancing technological flows across countries and therefore directly inserted into the catching up regression as a determinant of the speed of technological convergence. However, from a purely econometric point of view, inserting both human capital and institutions into the same regression as separate explanatory variables explaining technology growth may create unsolvable endogeneity problems. In particular, it is difficult to assume a priori exogeneity of Human Capital w.r.t. Institutional Quality and, in turn, of each one of these two variables w.r.t to productivity growth. The solution of this simultaneous relations would indeed need a three stage least squares estimation. Hence, we would have to find distinct instruments for the two suspected endogenous variables.

Crucially, not only one would have to find such instrumental sets but also instruments would need to be orthogonal one another and not collinear. The task seems rather difficult and instruments may be very weak precluding the possibility of correctly estimating the basic relation we want to test. Therefore

[21] Basu and Fernald (1997) p.7 on U.S. data. Basu and Kimball (1997) p. 16.

[22] We send the interested reader to Baier, Dwyer and Tamura (2006) for a more detailed description of computation methodology. Some seemingly superior measures of human capital are given by de la Fuente and Doménech (2002). However, the short longitudinal dimension of their dataset (only 21 OECD countries) precludes their use in this context.

we chose to control for differences in educational levels across countries by using TFP estimates which already account for human capital stocks within the production function as it is usually done in many other empirical works[23].

Concerning the definition of IQ, the institutional proxy we use come from the Economic Freedom of the World index (EFW) elaborated by the Fraser institute (www.fraserinstitute.ca). This is a cross-country index based on survey data are from two annual publications: the *Global Competitiveness Report* and the *International Country Risk Guide*.

The index measures the degree of economic freedom with 5-year span intervals in between 1970 and 2000 in five major areas: (i) Size of Government: Expenditures, Taxes, and Enterprises, (ii) Legal Structure and Security of Property Rights, (iii) Access to Sound Money, (iv) Freedom to Trade Internationally and (v) Regulation of Credit, Labor, and Business. Within the five major areas, 21 components are incorporated into the index but many of those components are themselves made up of several sub-components. Counting the various sub components, the EFW index utilizes 38 distinct pieces of data.

This is one of the main advantages[24] of using this index which provides both (i) the overall index of each country's Institutional Quality and (ii) the disaggregated data used to compute it. Hence, it will be possible in what follows to test which of the 5 main areas that compose the EFW are more important in the catch up process and therefore to highlight what particular aspects of the broader IQ index is more willing to play a role in technology flows from leader countries to laggards.

However, due to data availability our sample size is of 50 countries for which data are available for the years in between 1970 and 2000[25]. This is a relatively small number of countries. Nonetheless, the 50 countries within our sample sum up to almost 75% of the world GDP in PPP for the years considered. We

[23] Hence, we do not discard the contribution of human capital differences in the process of technology growth. These differences are considered within the estimation of TFP levels while the effects of IQ differences will be on the speed of technology catch up. The estimation of "human capital corrected TFP level" is nowadays almost a standard procedure. See for instance Hall and Jones (1999), Klenow and Rodriguez-Clare (1997), Caselli (2005) only to mention some.

[24] Another one is that, differently from other indexes, the EFW propose a chain-linked index which is more suitable for cross-country comparison since data are consistent over time in the sense that an estimate of institutional quality for a certain country is provided only if adjacent years are available for the same country and sub-institutional variables. We avoid, this way, to compute averages of institutional quality which rely on different variables' baskets.

[25] All available countries were inserted into the sample for which at least 25 years observation were available for all the main variables. Countries in our sample are: Argentina, Australia, Austria, Bangladesh, Belgium, Brazil, Burundi, Canada, Chile, Cyprus, Denmark, Fiji, Finland, France, Germany, Ghana, Greece, Hong Kong, India, Indonesia, Ireland, Israel, Italy, Japan, Jordan, Malawi, Malaysia, Mali, Mauritius, Morocco, Netherlands, Newzealand, Nigeria, Norway, Pakistan, Panama, Peru, Philippines, Portugal, Singapore, South Africa, Spain, Sweden, Switzerland, Tanzania, Thailand, Trinidad, Turkey, United Kingdom, Usa.

will also show how the main empirical results are invariant when we enlarge sample size by using the institutional index of Hall and Jones (1999) for which we have a higher number of countries but which relies on a single year estimate of institutional quality (the year 1988) which proxies for the whole period[26]. We will also show how the results hold when we restrict the sample to a smaller pool of developing countries which more than others may be affected by the process of technology catch-up.

6 The empirical framework

6.1 Empirical model

We use the empirical specification provided by Benhabib and Spiegel (2005) in order to test eq. (9). This is given below in a form which nests both a logistic ($\rho = 1$) and a confined exponential diffusion of technology ($\rho = -1$):

$$\Delta a_i = b + \left(g + \frac{c}{\rho} \right) \bar{s}_i - \frac{c}{\rho} \bar{s}_i \left(\frac{A_i}{A_l} \right)^{\rho} + \varepsilon_i \tag{19}$$

with $\varepsilon_i \sim i.i.d.N(0,1)$. The subscript i denotes a generic follower country within the set I denoting the whole pool of followers with $i = 2, 3.., F$ and $i \neq l$. Δa_i is the average annual TFP growth rate of country i. The subscript l represents the leader country, that is, the U.S. while $\bar{s}_i$ is the log average institutional endowment of country i.

As in Benhabib and Spiegel (2005) we can rearrange the catch-up condition in eq.(14) as follows for the logistic case:

$$S^*_{i,t} = \exp \left(\frac{g \bar{s}_{l,t}}{g + c} \right) \tag{20}$$

where $\bar{s}_{l,t}$represents the log of average institutional quality of the leader. $S^*_{i,t}$ is therefore the threshold level of institutional quality that a country must own in order to theoretically catch-up with the leader. A level of institutional quality lower than the threshold implies, theoretically, divergence from the frontier.

[26] The main problem with the index proposed by Hall and Jones (1999), and which is the reason we chose not to use it as main index for our work, is that this does not match the time span we analyzed in our work. However, it may be argued that institutional quality changes over time only slowly and that the analysis ran by using these data still provides a good approximation for the hypothesis we are here testing. Moreover, the EFW index proves to be better than the Social Infrastructure index of Hall and Jones (1999) in the fact that it can be disaggregated into its main sub-components. This feature will be very useful in disentangling the partial effects of different institutional arrangements on technology flows in what will follows.

6.2 Endogeneity issues

As briefly pointed out before, endogeneity between economic institutions (EFW) and productivity is likely to arise in our context. Put it in other words, it is going to be difficult to correctly estimate the partial effect of institutional quality on the technology catching up process since the relation between institutions and productivity is likely to be simultaneous and suffer from reverse causality.

We address this problem by making use of appropriate instrumental variables estimation techniques (IV). Our choice of the instrumental set relies on previous empirical work. The institutional quality of a country has been often put in relation with its colonial history. In particular, Hall and Jones (1999) and Acemoglu, Johnson and Robinson (2001) interestingly point out how those regions which have been colonized by European countries are more likely to have developed social infrastructures similar to the motherland. Assuming that European countries have better institutional infrastructures for trade, research (protection of IPRs) and economic growth, we may observe a positive correlation between a country's institutional quality and its linguistic characteristics which proxy for the influence exerted by the motherland.

In particular it is often assumed (see Hall and Jones (1999)) that the bigger is the fraction of a country's population speaking one of the 6 major European languages (or English) and the higher will be its institutional quality[27]. The latitude of a country, on the other hand, may be providing useful information about the kind of colonialism to which regions and countries have been exposed to. In particular, it is argued that if a country lies on similar latitudes of major European countries (in the range of, let us say, France, England and Spain) this may be a signal of the presence, in those regions, of a "non-predatory" colonialism. To put it in other words, it is more likely that colonialists actually settle down in regions with similar climate conditions as the motherland ultimately bringing with them their home-country institutions. Instead, being located in more isolated regions and with very different climate conditions from the motherland may have resulted in a predatory colonialism which led to the establishment of "*extractive*" poor institutions.

Also, the degree of trade openness of a country may help to judge the goodness of a country's IQ as long as this instrument is proven to be orthogonal to the error process in the regression. Usually, empirical works use a measure of trade openness coming from gravity equations. Here, instead we use the measure of trade openness coming from the work of Sachs and Warner (1995) which we will prove to be strongly orthogonal to the error process and therefore truly exogenous[28].

[27] Hall and Jones (1999) and many others.

[28] The Sachs-Warner index measures the fraction of years during the period 1950 to 1994 that the economy has been open and is measured on a [0,1] scale.One may be skeptical about the true exogeneity of this instrument. However, we perform a C-test checking its exogeneity finding this instrument to be strongly orthogonal in the IV regression with a p-value of .95.

6.3 Econometric results

We initially choose to estimate the logistic diffusion process of technology of eq.(14) by imposing (rather than estimating) the coefficient $\rho = 1$. We give the results in table 2.

Table 2 about here

Coefficients in column (i) enter with the expected sign and are all econometrically robust at 1 percent confidence levels confirming how institutional quality seems to act as an enhancing factor in the flows of technology from the leader to the followers. The main result shows how, holding constant the distance from the frontier, those countries endowed with better institutions are, on average, catching up faster with the leader by means of positive (and higher) TFP growth rates.

Also, the positive and statistical coefficient on the variable capturing institutional quality alone, namely $g(S_i)$, points to the fact that, as we expected, better institutions are the fundamental determinants for economic growth *per sè* even outside the context of technological catch-up.

Instruments pass the standard over-ID test while, differently from what suspected, we cannot reject the hypothesis of exogeneity of institutional quality at 10% confidence levels. This comes somehow as a surprise. However, the fact that institutional indexes are only a proxy of real institutions leads us to be careful in going back to OLS estimations. In particular, as pointed out by Hall and Jones (1999), IV estimation may be of help in solving both endogeneity and measurement error problems so that we prefer to stick to the IV estimation results rather than a simpler OLS estimation. From an econometric point of view, due to the presence of heteroskedasticity signaled by the Pagan-Hall test we make use of heteroskedasticity robust standard error estimates.

To the initial specification we add control variables which are commonly used in growth regression in order to capture β-type convergence mechanisms. The insertion of these variables into our framework is of particular interests since it allows us to empirically check whether the technology catch-up mechanisms may be responsible for β-convergence detected across countries.

As a first check, hence, we run our baseline specification by dropping the catch-up term (the interaction of institutions with the technology gap) and only leave the variables for the initial level of log GDP per capita and investment rate and the institutional quality of each country. Our result are strongly indicative of β-convergence. The convergence is conditional to the institutional level of each country with the coefficient associated to the initial GDP being negative and statistically significant at 1% confidence level.

Crucially, we are then interested in understanding whether the observed β-convergence may be actually driven by catching-up in productivity. In column (iii) we re-insert the the interaction of institutions with the technology gap. Results show the catch-up term to be again statistically significant and with the expected negative sign as in the baseline specification. More interestingly, instead, the log of initial GDP changes from a negative to a positive coefficient maintaining the same statistical significance. The result, then, points to the fact that much of the observed β-convergence could be actually ascribed to technology catch-up.

6.4 Some robustness checks

As an additional robustness check of the results obtained in the baseline specification we test also the confined exponential specification of technology diffusion by imposing $\rho = -1$[29]. The results are given in table 3.

Table 3 about here

Again coefficients are statistically significant at 1 percent confidence intervals. The coefficient associated to the term $\ln \bar{S}_{1970-200} * (TFP_i/TFP_l)^\rho$ enters with a positive sign, as expected. That is, the larger the technological gap from the frontier and the higher TFP growth rate of the follower. Crucially, however, the flow of technology from leader to follower is again mediated by country specific institutional quality. That is, the follwer country exploits its potential for high growth in the presence of good institutional infrastructures which allows it to adopt technology and innovations faster.

Another way of checking the robustness of our results is that of using alternative measures of institutional quality. We run the baseline specification by exploiting different measures of institutional quality widely used in the literature. We use both the institutional index proposed by Hall and Jones (1999) called (i) "social infrastructures" and (ii) its sub-index, GADP (Government Anti-Diversion Policies index).[30]

The correlation between the EFW index used in the baseline regression and these other two institutional proxies is high (as expected) but not perfect. The

[29] Differently from the logistic formulation, here the larger the technology gap and the higher the potential for rapid growth independently from the fact that distant technologies may be more difficult to be adopted.

[30] The use of these two alternative measures allows us to increase the sample size (from 50 to 97 countries) at the cost of having to use a point estimate (for the year 1988) for the Instituttiona proxy instead of using the average of the period 1970-2000 as for the EFW index we use in the baseline specification. Moreover, the use of the Hall and Jones' indexes required to use a different instrument (the log of Frankel and Romer trade predicted share) in order to avoid multicollinearity with regressors.

results obtained by using these two alternative measures of institutional quality confirm robustly our hypothesis. Institutional quality seems to play a crucial role in the speed by which the technology gap is closed by followers and, also, it is a promoting factor of productivity growth *per se*. Interestingly, the baseline results are then robust to different specifications and use of alternative proxies for institutional quality. Even when the sample size increases quite considerably the main results hold with very strong statistical significance. This is shown in table 4.

Table 4 about here

7 Extensions of the model

7.1 Disaggregating institutions

Up to now we provided empirical evidence of the positive impact of overall institutional quality on productivity growth. The effect of sound institutional framework seems to work on two separate channels. On one hand, having higher institutional quality fosters TFP growth *per se* by ensuring the adequate economic environment conductive to productivity growth and technology creation by innovation activities.

On the other hand better overall institutions enhance the transmission of technology from the leaders to the followers. Empirical tests seem to show how followers with good institutional frameworks are those experiencing a faster rate of technology catch-up on the average.

As already argued before, however, we are interested in deepening the analysis trying to discern which are the best policies and institutional arrangements for technology diffusion and catch-up across countries and what their disjoint impact may be. In particular, our theoretical framework (and previously mentioned contributions) argue for an ambigous effect of IPRs protection on productivity growth since IPRs would act as a barrier to the free flow of technology from the frontier (reducing productivity growth) but at the same time they should incentivize the creation of innovation (increasing productivity growth).

Our empirical strategy will consist of estimating a modification of the baseline specification in which the catch-up term will be built as the interaction between the technology gap and each one of the institutional sub-categories which compose the overall IQ index used in the previous section.

In the case of the EFW index we can decompose the IQ proxy into 5 main sub-components: (1) Size of Government: Expenditures, Taxes, and Enterprises, (2) Legal Structure and Security of Property Rights, (3) Access to Sound

Money, (4) Freedom to Trade Internationally and (5) Regulation of Credit, Labor, and Business. We then interact these "institutional aspects" with each followers' technological gap to test the role played by each one of these interactions in promoting technology catch-up.

More formally we propose to estimate the following modification of eq.(19):

$$\Delta a_i = b + \left(g + \frac{c}{\rho}\right)\bar{s}_i - \frac{c}{\rho}Z_i^{'}\left(\frac{A_i}{A_l}\right)^{\rho} + \varepsilon_i \tag{21}$$

where $Z_i^{'}$ represents a vector of the 5 countries' specific institutional sub-indexes taken in logs.

Also, following the hypothesis of our theoretical model we will check whether there are substantial differences in the impact of each one of the institutional sub-categories when countries are examined at different stages of their economic development.

For this reason, along with the analysis carried out over the whole sample, we will also isolate the group of countries farther from the technological frontier in order to check whether differences in the development stage actually imply differences in the magnitude of the impact of, for instance, IPRs protection on technology flows.

We define the group of followers by a measure of their relative development stage proxied by the distance from the technological frontier in order to avoid *a priori* sample grouping biases. Here we consider as "followers" all the countries for which a technological gap from the U.S. is of 10% or more in the initial year. This leads to a group of 35 followers and 15 leaders. Results are given in table 5.

Table 5 about here

In column (i) we propose the results of the IV estimations where all the institutional sub-categories are inserted within the same regression along with overall institutional quality in the BGP term of eq.(21). As expected, overall institutional quality is again statistically significant in explaining cross-country productivity growth rates *per se*.

Additionally, as suspected, when we disaggregate the institutional quality index, some of the institutional sub-components do not seem to explain the speed of the technology catching-up process. In particular, the results show how cross-country differences in (1) Size of Government: Expenditures, Taxes, and Enterprises, and (5) Regulation of Credit, Labor, and Business never enter the regressions with significant coefficients for whichever model specification and that, therefore, seem to be of negligible importance in explaining differences in technology flows across countries.

Interestingly, our empirical investigation points to three major institutional arrangements as being fundamental in the process of technology cacth-up across countries. These are (i) " Legal Structure and Security of Property Rights"[31], (ii) "Freedom to trade internationally"[32] and (iii) " Access to sound money"[33].

The most striking result is shown for the variable proxying for Legal Structure and Security of Property Rights. Once we control for the overall IQ of a country, a tightening of property rights protection seems to reduce the speed of technology adoption both for the "All" and for the "Followers" samples. The coefficient for the variable capturing the interaction between the distance from the technology frontier and the enforcement of property rights enters with a positive sign (in the logistic formulation meaning a negative elasticity on TFP growth). This coefficient is estimated to be statistically significant at 1 percent confidence levels. Our point estimates show how, *ceteris paribus*, an increase of 1 percent in the enforcement of property rights, as measured in the EFW index, will reduce the rate of technology adoption by a value in between 2 percent (for the whole sample) and 4 percent (for the followers' group).

The difference between the magnitude of the estimated IPRs coefficient for the All sample and for that of the Followers is providing evidence that, as hypothesized in the theoretical model, stronger IPRs regimes are going to act as a barrier to the free flow of technologies especially for those countries which are farther from the frontier and for which technology spillover usually take the form of pure technological imitation.

Our result comes as an indirect confirmation of the evidence by Kwan and Lai (2003) , Grossman and Lai (2004) and Connolly and Valderrama (2005) who argue how, when the transmission of technology works through the imitation channel, an increase in the protection of intellectual property rights may end up reducing the speed of technology adoption. *Ceteris paribus* within the same economy, the enforcement of IPRs implies a trade-off between the positive incentive given to the R&D sector and the negative effect coming from an increase in the cost of imitation.

[31] This index is an average of: (i) Judicial independence, (ii) Impartial courts, (iii) Protection of intellectual property rights, (iv) Military interference in the rule of law, (v) Integrity of legal system (rule of law) which are all expected to control for the extent to which property rights are ensured within an economy.

[32] This index is an average of 5 minor sub-categories: (i) Taxes on international trade, (ii) Regulatory trade barriers, (iii) Actual size of trade sector compared to expected size, (iv) Difference between official exchange rate and black market rate, (v) International capital market controls.

[33] This index is an average of: (i) Average annual growth of money supply, (ii) Standard inflation variability during last five years, (iii) Recent inflation rate, (iv) Freedom to own foreign currency bank accounts domestically and abroad.

Countries closer to the technological frontier will be less harmed by a tightening of property rights than the followers since the innovative effort in these countries is very low. In this situation economic and political interests usually opt for weak protection of IPRs. As income and technical capabilities increase at higher development stages, the impact of tighter IPRs become less and less detrimental since demand shifts towards higher-quality products and innovative activities become predominant.

Column (ii) in table 5 also shows a positive impact over the TFP catching-up process of the variable "Access to sound money" which proxies for Inflation controls and sound macroeconomic framework in each country. The economic intuition behind this result is that high and unpredictable inflation rates drastically rise the risks of doing business and internal and external trade may be significantly hampered.[34]

Finally, "Freedom to trade internationally" and all the policy arrangements which enhance trade openness are shown to be beneficial for economic growth and productivity catch-up. The coefficient for the variable capturing trade openness is significant for the group of followers in our sample. As pointed out, for instance, by Alcalà and Ciccone (2004) or Dollar and Kraay (2003) there exists a positive relationship between good institutions, openness to trade and growth[35]. Also the work of Sachs and Warner (1995) shows how open, but still developing, countries are found to grow by 4.5% per year in the 1970s and 1980s, that is, 4 percentage points more than their closed counterparts.

Hence, from the perspective of technology catching-up analysis, the positive effect of trade on the growth of productivity is expected to be especially true for follower countries since opening up to trade may allow some significant reverse engineering and faster technology imitation[36]. This is actually the result we get in our estimates and that confirms the evidence of other studies such as Falvey et al. (2002). The coefficient for trade openness is statistically significant at 1% confidence level for the sub-sample of followers.

[34] From a technology catching-up perspective, the costs of high inflation levels on productivity flows from leaders to followers might negatively work through the reduction of FDI and internal investments in those countries experiencing inflation crisis. This result is highlighted by many empirical works such as Fischer (1993), Levine and Renelt (1992) or Rogoff and Reinhart (2003). This result is stronger for the whole sample specification while it is not significant for the group of followers where, as mentioned, technology spillovers may be assuming the form of technology imitation rather than that of adoption.

[35] Countries that trade more are those which more benefit from technological spillovers and therefore tend to grow faster than others ultimately being more productive. This result holds both for the innovative and imitative sectors.

[36] We claim that the positive impact of trade on productivity growth may especially true for developing countries due to the fact that usually this result holds in very large samples where the share of developing countries over developed ones is very high. Also, Alcalà and Ciccone (2002) show how trade and institutional quality have a positive and statistically robust impact on GDP growth when the sample is restricted to former colonies (which are usually developing countries). With the same result the work of Dollar (1992) for a sample of 95 LDCs.

7.2 Isolating IPRs and Trade effects

A stronger protection of property rights not only reduces the rate of technology adoption but, at the same time, it increases the overall institutional quality of a country. The effect, as already pointed out is then ambigous on the creation and adoption of technology especially for follower countries.

The reasoning is instead different for the Trade Openness institutional proxy. In follower countries we showed that Trade Openness works as an enhancing factor for technology adoption following the idea that, by trading, least developed countries may do more reverse engineering and have more incentive to imitation since they will eventually sell the "copies" in international markets. Also, trade openness is going to positively affect the creation of innovation by increasing competition pressure. Its effect, then, differently from that of IPRs protection is unambigously positive.

Since these two institutional aspects seems to be rather fundamental, we are here interested in isolating their impact from that of the other IQ sub-categories. We build a composite institutional index which only takes into account the role played by trade and IPRs protection and re-run the estimates on these two channels only. We present the result in table 6

Table 6 about here

Results seem to confirm the hypothesis that IPRs protection and Trade Openness act as major determinants of technology catch-up. Both variables enter with the the expected sign and with a statistically significant coefficient. Crucially, again, their effect is stronger in the follower sub-sample as we would expect with the partial effect of a tightening of IPRs reducing the rate of technology adoption while trade openness instead increases technology flows.

8 Institutional threshold analysis

As proposed by Benhabib and Spiegel (2005), once the empirical model in eq. (19) has been estimated it is possible, within the logistic diffusion formalization, to compute the minimum institutional level below which followers will not theoretically catch-up with the frontier accordingly to the model.

Our point estimates for the logistic diffusion of technology given in figure 1 imply an insitutional threshold value of 5.18 (on a potential scale from 0 to 10 with the U.S. scoring 7.8). In our case, those countries with an average institutional quality below 0.66% w.r.t. the leader will theoretically fall behind without catching up. Out of the 50 countries examined 15 experience an institutional level lower than the estimated threshold. These are Ghana, Nigeria, Bangladesh, Brazil, Tanzania, Burundi, Malawi, Peru, Turkey, Argentina, Israel ,Pakistan, India Mali and Morocco. Out of these, only Turkey, Israel and India experience a positive TFP growth while the others, experiencing negative productivity growth, are clearly diverging from the leader.

The distance from the threshold experienced by Argentina, India, Israel and Turkey is however small. This points to the fact that with even moderate institutional improvements these countries may invert their diverging patterns. For the other countries, instead, major improvements in institutional quality seem to be required in order to be pushed out from a self locking divergence club. The overall picture, nonetheless, seems to point to cross-country convergence and catch up with some cases of self locked diverging countries.

As an additional robustness check we use the computed gap from the IQ threshold level as a regressor for TFP growth both for the All and Followers sub-sample finding that the more a country is found above the IQ threshold level and the higher will be its TFP growth rate. We also regress the TFP growth differentials among the U.S. and all the followers on the distance from the IQ estimated threshold level for each country finding how those countries above the threshold level are actually catching-up with the frontier.

Table 7 about here

9 Conclusions

The paper addressed the issue of technological catching-up across countries by focusing on the role of institutional quality. Differences in institutional quality across countries are found to be of crucial importance in explaining the speed of technology flows from leaders to followers. Empirical estimates show how institutional quality acts as an enhancing factor for technology transfers from the world frontier to the laggards allowing the latters to theoretically catch-up with the leaders. Instead, countries lagging behind the technological level of the leader and, at the same time, owning poor institutions are showed to experience relatively lower GDP and productivity growth rates.

Overall institutional quality is not only found to be of importance in determining technology transfer from the leader to the follower. Also, having good institutional quality acts as a promoting factor for the technological innovation of an economy *per se*. This result has already been established by a variety of models and empirical works where TFP growth rates are found to be highly correlated to good institutions.

We observe evidence of β-convergence in our sample. This, noticeably, seems to be driven by the process of technology catch up highlighted in our framework.

In particular, when we account for possibility of technology catch up, the negative coefficient associated to the initial levels of GDP changes its sign to positive implying a fundamental role of technology catch up within the β-convergence process.

Following a recent strand of literature opened by Acemoglu, Aghion and Zilibotti (2006) or Aghion and Howitt (2005) we analyzed the different impact that the same institutional arrangements may have on countries differring in their development stage.

In particular, IPRs protection is found to exert an ambigous effect on productivity growth by, on one hand, incentivizing the creation of new technology and, on the other hand, slowing down the pace of technology adoption from the frontier. This assumption has been formalized into a growth model *à la* Romer (1990) which also exploits some of the features of the empirical model of Behnabib and Spiegel (2005).

In our basic assumption, enforcing property rights boosts the innovative activity by raising overall institutional quality and raising TFP growth rates. However, when property rights are tightened followers find more difficult to imitate technologies discovered elsewhere due to a relative increase in the costs of imitation. Empirical results show how IPRs protection statistically decreases the speed by which followers are going to adopt technology from the frontier. This is especially true for those countries lagging farther from the frontier while, the positive incentives to the R&D of a tightening of IPRs are stronger for those countries closer to the technological frontier.

Our empirical results provide robust evidence to the hypothesis that some institutions may enhance (or inhibit) economic growth depending on the development stage of the country and their effect may in fact ambigous. This is especially true in a context where countries can grow either by innovation or by technology imitation.

Theoretical and empirical literature point to openness to trade as another fundamental institutional arrangement fostering technology adoption. Our empirical result confirm this hypothesis. More open countries are growing faster on average by exploiting the technology catch-up mechanism. On the sub-sample of followers which are found farther from the frontier both the Trade and IPRs effects are stronger as the theoretical model would predict.

Finally, we showed how, by assuming that technologies are adopted through a s-shaped logistic diffusion curve some restrictive catching-up conditions arise. We adapt the Benhabib and Spiegel (2005) framework so as to define a minimum institutional level below which followers do not theoretically catch-up. Out of the 50 countries examined for the period in between 1970 and 2000, 15 are found below the theoretical institutional threshold. These countries experience a decline in productivity over the period and therefore diverging from the frontier. The distance from the estimated institutional threshold level is shown also to be a strong predictor of TFP growth differentials.

Tables

Table 1: Correlation matrix

	TFP growth 1970-200 (annual)	*GDP growth in PPP 1970-2000*	*Institutional Quality average 1970-2000*	*TFP(i)/TFP(US) Technology gap*
TFP growth 1970-200 (annual)	*1*			
GDP growth in PPP 1970-2000	*0.866*	*1*		
Institutional Quality average 1970-2000	*0.543*	*0.554*	*1*	
TFP(i)/TFP(US) Technology gap	*0.074*	*0.084*	*0.555*	*1*

Table 2: IV estimates of eq. (14)

Logistic diffusion function

Dependent Variable: Annual TFP growth 1970-2000	(i)	(ii) β-Convergence	(iii)
Constant	-0.108 (0.028)***	-0.012 (0.025)	-0.142 (0.042)***
Ln IQ	0.070 (0.021)***	0.046 (0.013)***	0.056 (0.016)***
*Ln IQ*TFP gap*	-0.014 (0.007)**	-	-0.031 (0.009)***
Set of controls			
Ln Ypp 1970		-0.005 (0.002)***	0.010 (0.003)***
Ln invest.Rate 1970		0.012 (0.004)***	0.003 (0.004)
Un-Centered R2	0.36	0.39	
Over-ID coeff. *P-value*	5.74 0.12	2.37 0.49	5.12 0.16
F-test of excluded instruments	12.44		
D-W-H endogeneity test *p-value*	3.72 (0.05)		
Wu-Hausman stat.	3.70 (0.06)		
Pagan-Hall Heterosk. Test *p-value*	29.75 (0.07)		
n. Obs	50	50	50

****, ** Statistically significant respectively at 1%, 5%*
Standard errors are corrected for heteroskedasticity and reported in parenthesis.

Ln IQ represents log of average institutional quality over the period 1970-2000.

TFP gap represents the ratio of each country's TFP initial level to U.S as TFPi/TFPm

Instruments: (i)Fraction of population speaking English (ii) Fraction of population speaking one of the 6 major European languages, (iii) Latitude, (iv) Years open to Trade as specified in the text.

Table 3: IV estimates of eq. (14)

Confined exponential diffusion function

Dependent Variable: Annual TFP growth 1970-2000		
	(i)	(ii)
Constant	*-0.09* *(0.018)****	*-0.05* *(0.031)***
Ln IQ	*0.050* *(0.009)****	*0.038* *(0.013)****
*Ln IQ*TFP gap*	*0.002* *(0.001)****	*0.003* *(0.002)***
Set of controls		
Ln Ypp 1970		*-0.000* *(0.00)*
Ln invest.Rate 1970		*0.010* *(0.004)****
Un-Centered R2	*0.35*	*0.58*
Over-ID coeff. *P-value*	*5.74* *0.12*	*5.12* *0.16*
F-test of excluded instruments	*22.58*	*10.58*
D-W-H endogeneity test *p-value*	*4.23* *(0.04)*	
Wu-Hausman stat.	*4.25* *(0.04)*	
Pagan-Hall Heterosk. Test *p-value*	*26.91* *(0.14)*	
n. Obs	*50*	*50*

****, ** Statistically significant respectively at 1%, 5%*
Standard errors are corrected for heteroskedasticity and reported in parenthesis.

Ln IQ represents log of average institutional quality over the period 1970-2000.

TFP gap represents the ratio of each country's TFP initial level to U.S as TFPi/TFPm

Instruments: (i)Fraction of population speaking English (ii) Fraction of population speaking one of the 6 major European languages, (iii) Latitude, (iv) Years open to Trade as specified in the text. .

Instruments: (i)Fraction of population speaking English (ii) Fraction of population speaking one of the 6 major European languages, (iii) Latitude, (iv) Years open to Trade as specified in the text.

Table 4: IV estimates of eq. (14)
on Social Infrastructure and GADP indexes
Logistic diffusion function

Dependent Variable: Annual TFP growth 1970-2000		
	(i)	(ii)
Constant	*-0.04* *(0.009)****	*-0.08* *(0.017)****
Ln Social Infrastr.	*0.031* *(0.08)****	
*Ln Social Infrastr.*TFP gap*	*-0.012* *(0.003)****	
Ln GADP		*0.048* *(0.011)****
*Ln GADP*TFP gap*		*-0.01* *(0.002)****
Un-Centered R2	*0.48*	*0.48*
Over-ID coeff. *P-value*	*3.92* *(0.26)*	*2.95* *(0.40)*
F-test of excluded instruments	*4.47*	*5.33*
D-W-H endogeneity test *p-value*	*0.63* *(0.42)*	*1.28* *(0.25)*
Wu-Hausman stat.	*0.61* *(0.43)*	*1.24* *(0.26)*
Pagan-Hall Heterosk. Test *p-value*	*21.24* *(0.39)*	*21.69* *(0.36)*
n. Obs	*97*	*97*

****, ** Statistically significant respectively at 1%, 5%*
Standard errors are corrected for heteroskedasticity and reported in parenthesis

Social Infrastructures and GADP (Government Anti-Diversion Policy) indexes are taken from Hall and Jones (1999).
TFP gap represents the ratio of each country's TFP initial level to U.S as TFPi/TFPm

Instruments: (i)Fraction of population speaking English (ii) Fraction of population speaking one of the 6 major European languages, (iii) Latitude, (iv) Years open to Trade as specified in the text.

Table 5: IV estimates of eq. (16)
on "All" and "Followers" sample
Logistic diffusion function

Dependent Variable: Annual TFP growth 1970-2000	**ALL**	**ALL**	**Followers**	**Followers**
	(i)	(ii)	(iii)	(iv)
Constant	-0.098 (0.021)***	-.113 (.027)***	-0.111 (0.29)***	-.101 (.025)***
Ln IQ	0.066 (0.014)***	.073 (.020)***	0.070 (0.02)***	.064 (.020)***
*Ln Size of Govt.*TFP gap*	-0.002 (0.007)		0.014 (0.01)	
*Ln Property Rights*TFP gap*	0.034 (0.011)***	.022 (.007)***	0.049 (0.014)***	.041 (.011)***
*Ln Inflation and money*TFP gap*	-0.026 (0.010)***	-.034 (.010)***	-0.014 (0.013)	
*Ln Trade Openness*TFP gap*	-0.002 (0.014)		-0.052 (0.023)***	-.050 (.015)***
*Ln Business- labour Reg *TFP gap*	-0.020 (0.018)		-0.004 (0.033)	
Un-Centered R2	0.52	0.45	0.61	0.56
Over-ID coeff. *P-value*	3.95 (0.26)	6.18 (0.10)	3.39 (0.33)	2.18 (0.33)
F-test of excluded instruments	9.66	11.69	4.09	12.07 #
D-W-H endogeneity test *p-value*	2.04 (0.15)	2.81 (0.09)	0.65 (0.42)	1.31 (0.25)
Wu-Hausman stat. *p-value*	1.79 (0.18)	2.68 (0.10)	0.51 (0.48)	1.17 (0.28)
Pagan-Hall Heterosk. Test *p-value*	36.85 (0.96)	28.74 (0.37)	25.81 (0.99)	20.52 (0.42)
n. Obs	50	50	35	35

****, ** Statistically significant respectively at 1%, 5%*
Standard errors are corrected for heteroskedasticity and reported in parenthesis.

Ln IQ represents log of average institutional quality over the period 1970-2000.

TFP gap represents the ratio of each country's TFP initial level to U.S as TFPi/TFPm

Instruments: (i)Fraction of population speaking English (ii) Fraction of population speaking one of the 6 major European languages, (iii) Latitude, (iv) Years open to Trade as specified in the text. #Latitude has been eliminated from the instrumental set since not truly orthogonal to the error process.

Table 6: IPRs and Trade catch-up effect

Dependent Variable: Annual TFP growth 1970-2000	***ALL***	***ALL***	***Followers***	***Followers***
Ln IPRs+Trade proxy	.024 (.0140)*	*.081* *(.030)****	*.016* *(.015)*	*.059* *(.025)***
*Ln Property Rights*gap*	*.053* *(.023)***	*.047* *(.021)***	*.035* *(.023)*	*.060* *(.019)****
*Ln Trade Openness*gap*	*-.093* *(.039)****	*-.030* *(.022)*	*-.066* *(.025)***	*-.038* *(.021)**
Ln_Ypp_70		*-.027* *(.010)****		*-.021* *(.008)****
Un-Centered R2	*-2.69*	*-0.86*	*-0.98*	*-0.33*
Over-ID *P-value*	*4.68* *(0.19)*	*2.54* *(0.46)*	*6.57* *(.09)*	*5.56* *(.13)*
n. Obs	*50*	*50*	*35*	*35*

****, **,* Significant at 1%, 5% and 10% confidence intervals*
Instruments: Engfrac, Eurfrac, Latitude, Years open to Trade
Followers are defined as all countries with a distance from the leader as 10% or more in the level of productivity in the initial year. Standard errors are corrected for heteroskedasticity

Table 7: Threshold analysis

	TFP growth 1970-2000		TFP growth Differentials
	All	**Followers**	**All**
Constant	-.006 (.002)***	-.006 (.002)***	.012 (.001)***
Distance from model implied Institutional Threshold	.005 (.001)***	.007 (.000)***	-.005 (.001)***
R2	*.28*	*.37*	*.28*
Obs.	*50*	*35*	*50*

****, **,* Significant at 1%, 5% and 10% confidence intervals*
Standard errors are corrected for heteroskedasticity.
OLS estimates

References

[1] Abramovitz, M. (1986). “Catching Up, Forging Ahead, and Falling. Behind”. Journal of Economic History 46, 385-406.

[2] Acemoglu D., S. Johnson and J. Robinson (2001). "The Colonial Origins of Comparative Development: An Empirical Investigation", American Economic Review 91, 1369-1401.

[3] Acemoglu D., S. Johnson and J. Robinson (2005). "Institutions as the Fundamental Cause of Long-Run Growth", in Aghion P. and S. Durlauf (eds), Handbook of Economic Growth, Elsevier.

[4] Acemoglu D., P. Aghion and F. Zilibotti (2006). "Distance to Frontier, Selection, and Economic Growth", Journal of the European Economic Association 4 (1), 37-74

[5] Alcalà, F. and A. Ciccone (2004). “Trade and Productivity”. Quarterly Journal of Economics 119, 613-646.

[6] Aghion P. et al. (2005). "The Unequal Effects of Liberalization: Evidence from Dismantling the License Raj in India". NBER working paper.

[7] Aghion P., Harris C. and Vickers J. (1997) "Competition and Growth with Step-by-Step Innovation; An Example", European Economic Review 41, 771-782.

[8] Aghion, P. and P. Howitt, (1992). “A Model of Growth Through Creative Destruction” Econometrica 60 (2), 323-351.

[9] Aghion, P. and P. Howitt (2005) "Appropriate Growth Policy,". Forthcoming in the Journal of the European Economic Association.

[10] Baier S. L., Dwyer G. P. and Tamura R. (2006). “How Important are Capital and Total Factor Productivity for Economic Growth?”, Economic Enquiry 44(1), 23-49.

[11] Bailey, M. and H. Gersbach (1995). "Efficiency in manufacturing and the need for global competition", Brookings Papers on Economic Activity, 307-347

[12] Barro, R. and X. Sala-i-Martin. (1995). "Economic Growth", McGraw-Hill.

[13] Barro, R. and X. Sala-i-Martin. (1997). “Technological Diffusion,Convergence and Growth,” Journal of Economic Growth 1, 1-26

[14] Barro R. and J. Lee. (1993). "International comparisons of educational attainment," Journal of Monetary Economics 32(3), 363-394

[15] Basu, S. and J. Fernald. (1997). "Returns to scale in U.S. Production. Estimates and Implications". Journal of Political Economy 105, 249-283.

[16] Basu, S. and M. Kimball. (1997). “Cyclical Productivity with Unobserved Input Variation.” NBER Working Paper 5915.

[17] Basu, S., J. Fernald and M. Kimball. (1998). “Are technology improvements contractionary?”. International Finance Discussion Paper 625, Board of Governors of the Federal Reserve System

[18] Basu, Susanto, and David N. Weil, (1998), “Appropriate Technology and Growth,” Quarterly Journal of Economics, November, 113(4), 1025-54.

[19] Benhabib, J. and M. Spiegel. (1994). “The Role of Human Capital in Economic Development: Evidence from Aggregate Cross-Country Data,” Journal of Monetary Economics 34, 143-173.

[20] Benhabib, J. and M. Spiegel. (2005). "Human Capital and Technology Diffusion", in Aghion P. and S. Durlauf (eds), Handbook of Economic Growth, Elsevier

[21] Bils, M. and P. Klenow. (2000)- “Does Schooling Cause Growth?,” American Economic Review 90(5), 1160-83.

[22] Boldrin, M. and Levine, D. (2005) "Against Intellectual Monopoly", Cambridge University Press

[23] Caselli F. (2005). "Accounting for Cross-Country Income Differences," in Aghion P. and S. Durlauf (eds), Handbook of Economic Growth, Elsevier.

[24] Connolly M. and D. Valderrama. (2005). "North-South technological diffusion and dynamic gains from trade," Working Papers in Applied Economic Theory, Federal Reserve Bank of San Francisco.

[25] Cherchye L. and W. Moesen. (2002). "Institutional Infrastructure and Economic Performance: Levels versus Catching Up and Frontier Shifts," Public Economics Working Paper Series, Katholieke Universiteit Leuven, Centrum voor Economische Studiën, Working Group Public Economics.

[26] Coe, D. and E. Helpman. (1995). "International R&D Spillovers," European Economic Review 39(5), 859-87

[27] de la Fuente A, Doménech R. (2006), "Human capital in growth regression. How much difference does data quality make?". Journal of the European Economic Association 4(1), 1-36.

[28] Dollar, D. and A. Kraay (2003). "Institutions, trade, and growth" Journal of Monetary Economics 50(1), 133-162

[29] Easterly W. and R. Levine. (2001). "It's Not Factor Accumulation: Stylized Facts and Growth Models"- World Bank Economic Review, 15, 177-219.

[30] Economic Freedom of the World index, http://www.fraserinstitute.ca.

[31] Falvey, R., Greenaway, D. and Foster, N. (2002) "North-south trade knowledge spillovers and growth". Journal of Economic Integration, Vol. 17, pp.650-670.

[32] Fischer S. (1993). "The Role of Macroeconomic Factors in Growth," Journal of Monetary Economics 32, 485-511

[33] Frankel J. and D. Romer, (1999), "Does Trade cause Growth? ". American Economic Review 89(3), 379-99.

[34] Gallini, N. (1992) "Patent Policy and Costly Imitation", The RAND Journal of Economics 23, 52-63

[35] Gerschenkron A. (1962). Economic backwardness in historical perspective: Cambridge, Belknap Press of Harvard University Press.

[36] Ginarte J.C. and Park W.C. (1997) "Determinants of patent rights: A cross-national study". Research Policy, 26, 283-301.

[37] Grossman G. and E. Lai (2004) "International Protection of Intellectual Property". American Economic Review 94, 1635-1653.

[38] Hall, R. and C. Jones. (1999). "Why Do Some Countries Produce So Much More Output Per Worker Than Others?," Quarterly Journal of Economics 114(1), 83-116

[39] Helpman, E. (1993). “Innovation, Imitation, and Intellectual Property Rights,” Econometrica 61, 1247-80.

[40] Jones C. (1995), “R&D-Based Models of Economic Growth” Journal of Political Economy 103, 759–784

[41] Levin, R., et al. (1988), "Appropriating the returns from Industrial R&D", Working paper, Cowles foundation, Yale University

[42] Levine, R. and D. Renelt. (1992). "A Sensitivity Analysis of Cross-Country Growth Regressions," American Economic Review, American Economic Association. 82(4), 942-63

[43] Kaufmann D., andKraay A., (2002) "Growth without governance," Policy Research Working Paper Series 2928, The World Bank

[44] Kaufmann D., Kraay A. and P. Zoido-Lobatòn. (1999) “Aggregating Governance Indicators”, World Bank Working Paper

[45] Klenow, P., and A. Rodriguez-Clare. (1997). “The Neoclassical Revival in Growth Economics: Has It Gone Too Far?,” N.B.E.R. Macroeconomics Annual, 73-103.

[46] Keefer P. and S. Knack. (1997). "Why Don’t Poor Countries Catch Up? A Cross-National Test of an Institutional Explanation". Economic Inquiry 35, 590-602.

[47] Keefer P. and S. Knack (2002). " Polarization, Politics and Property Rights: Links Between Inequality and Growth", Public Choice 111, 127-154.

[48] Kwan Y. and E. Lai (2003). " Intellectual Property Rights Protection and Endogenous Economic Growth".Journal of Economic Dynamics and Control 27, 853-873.

[49] Kumar S. and R. Russell (2002), “Technological Change, Technological Catch-up, and Capital Deepening: Relative contributions to Growth and Convergence.” American Economic Review 92, 527-548.

[50] Maskus, K. (2000). "Intellectual Property Rights and Economic Development," Case Western Reserve Journal of International Law special Supplement 32(2), 471-500.

[51] Nelson, R. and E. Phelps. (1966). “Investment in Humans, Technological Diffusion, and Economic Growth,” American Economic Review 56, 69-75.

[52] Olson M., N. Sarna and A. Swamy. (2000).“Governance and Growth: A Simple Hypothesis Explaining Cross Country Differences in Productivity Growth”, Public Choice, 102, 341-364

[53] Parente, S., and E. Prescott. (2000). Barriers to Riches, Cambridge, MA: MIT Press.

[54] Prescott, E. (1998). "Needed: A Theory of Total Factor Productivity," International Economic Review, 39(3), 525-551.

[55] Rogoff K. and C. Reinhart. (2003). "FDI to Africa: The Role of Price Stability and Currency Instability," IMF Working Papers

[56] Romer, P. (1990). "Endogenous Technical Change," Journal of Political Economy 98, 71-102.

[57] Sachs, J. and A. Warner. (1997). "Fundamental Sources of Long-Run Growth,". American Economic Review 87(2), 184-188.

[58] Solow, R.M., (1956) "A contribution to the theory of economic growth, Quarterly Journal of Economics, Vol. 70(1): 65-94.

[59] Staiger, D. and J. Stock. (1997). "Instrumental variables regression with weak instruments." Econometrica 65(3), 557-86.