# Appropriate IPRs, Human Capital Composition and Economic Growth

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**Abstract**

We generalize a standard technology diffusion model by allowing for IPRs regimes to be endogenously defined by the development level of each country. Also we insert differences in in the compsition of human capital between North (leader) and South (followers)which shape the relative costs of innovation and imitation. Results show how an optimal growth trajectory is found for the follower country which initially imitates and that, once a "threshold development stage" is reached, optimally switches to innovation by fully enforcing IPRs achieving a higher proximity with the technology frontier in the long-run. Other scenarios, such as a premature increase in the enforcement of IPRs or a switch from imitation to innovation at early stages of development of the followers are found to be sub-optimal.

*JEL:* O31, O34, O43

*Keywords*: IPRs, Human capital, Technology transfer

# 1 Introduction

Recent empirical and theoretical works[1] point to institutions protecting property rights (and among of these of Intellectual Property Rights, IPRs) as essentials for long-run economic growth. Acemoglu, Johnson and Robinson (2001, 2005), Barro (2000), Hall and Jones (1999), Knack and Keefer (1997), Aghion and Howitt (2005) and Olsson (2007) are only some among the authors who claim property rights enforcement to be crucial for a country's economic performance. On a similar line of reasoning goes the recent endogenous growth model by Eicher and Garcia-Peñalosa (2008) studying the positive effect of endogenous IPRs.

Another recent strand of literature, on the other hand, argue how certain institutions which foster economic growth in developed countries may actually hinder the growth of least-developed ones. Acemoglu, Aghion and Zilibotti (2006), Aghion et al. (2001) or Aghion and Howitt (2005) develop the idea of Gerschenkron (1962) that 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].

Evidently, countries at different development stages are also endowed with different economic fundamentals. Hence, a country's technological progress may take the form of either innovation or that of imitation and adoption of technologies discovered elsewhere depending on its particular human capital level, skills or institutional quality.

At early stages of development, countries usually take advantage of their backwardness by imitating technologies discovered at the frontier. The process of technology adoption is not immediate however and it crucially depends on the recipient country's ability to implement and adopt/adapt these new technologies.

Previous studies such as those by Keefer and Knack (1997), Behnabib and Spiegel (1994, 2005) or Vandenbussche, Aghion and Meghir (2006) argue how both institutional factors and human capital accumulation play a fundamental role in the technology catching up process. Barro and Sala-i-Martin (1997), instead, emphasize how the convergence of backward economies towards higher

[1] An exception is the work of Boldrin and Levine (2005).

[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.

income and to the leader's technological level is basically driven by the relatively low-cost imitations performed by follower countries.

Crucially, 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 IPRs over countries which differ in their economic fundamentals (especially human capital levels), development stages and type of technological activities (imitation *vs* innovation).

With this paper we try to give some insights on these issues. We analyze the growth dynamics of two regions (North and South) which differ in their development stage, composition of human capital stocks, institutional quality and relative costs of innovation and imitation. We do so by merging some of the relevant features of the model by Helpman (1993) with those of the growth model by Barro and Sala-i-Martin (1997) and with the analysis of the impact of differences in human capital composition in the fashion of Vandenbussche, Aghion and Meghir (2006).

Since the seminal study of Helpman (1993) the analysis of the impact of IPRs on the growth and welfare of leaders and followers, *resp.* the technological innovators and the imitators, has provided ambiguous policy making insights. The reason is intuitive. As pointed out by Maskus (2000) IPRs may, on one hand, encourage new business development by stimulating technology innovation and compensating innovators for incurring in the fixed costs of R&D. On the other hand, however, tight IPRs enforcement may harm development prospects of follower countries by significantly raising the costs of imitation along with permitting monopolistic behaviors by owners of IPRs with consequent market distortions in all regions[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. (1987) 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 thirty percentage 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

[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.

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.

Interestingly, our results do not fully support neither the "Northern view" that LDCs' IPRs should be strengthened up to the levels of the North nor the "Southern view" that IPRs should be lax in order not to harm the growth prospect of technological follower countries. Our results lie in between these two views which, we show, are not mutually exclusive. Hence, the results of our model depart from previous theoretical literature by endogeneizing the optimal IPRs regime of the South as a simultaneous function of the costliness of imitation (itself linked to the human capital composition of each economy) and of the actual development stage and institutional quality of the followers.

In our model, the South (the follower region) is endowed with weak institutions, a relatively high fraction of unskilled workers (over the skilled ones) and it will initially perform imitation of the technologies discovered in the North. We will be assuming, moreover, that differences in the composition of human capital stocks shape the relative easiness by which both innovation and imitation are performed within an economy. In particular we will assume that countries endowed with a low skilled workforce will perform innovation at relatively higher costs w.r.t. the correspondent costs of performing imitation and *viceversa*. Crucially moreover, the ease of imitation will be assumed, similarly to Helpman (1993), to be a negative function of the extent by which IPRs are enforced as well as a negative function of the proximity to the technological frontier as in Barro and Sala-i-Martin (1997).

Given these assumptions we find an optimal IPRs regime for the follower country. This optimal regime is endogenous in the sense that is a function of the follower development stage, of its endowment of human capital, of its institutional quality and of its proximity to the technological frontier. We show how the optimal IPRs regime maximizes the growth of the follower while minimizing the technology gap with the frontier in the long-run.

Hence, on one hand, we show how, given the economic fundamentals of the follower and its capabilities of producing own-based R&D, an enforcement of IPRs above the optimal regime will decrease the growth in the follower country by excessively increasing the costs of copying a technology and therefore shifting resources from the more profitable imitative sector to the relatively high-cost innovation-R&D sector. The same happens if the South starts performing innovation rather than imitation at low development stage.

On the other hand, due to the fact that the adoption of new technologies is itself a costly activity, too weak IPRs will not give enough incentive to the imitators by decreasing the revenues coming from imitation. This might eventually lead to an equilibrium where the imitative effort will be suboptimal and actual growth less than the potential one with, instead, moderate IPRs protection.

Finally, we show that, once a "threshold development stage" is reached, the follower may optimally switch to innovation by fully enforcing IPRs and achieving a higher proximity with the technology frontier in the long-run. This result is in line with the theoretical model by Eicher and Garcia-Peñalosa (2001) or with the empirical results by Falvey et al. (2002) or Ginarte and Park (1997) who detect threshold levels in the enforcement of IPRs.

The remainder of the paper is as follows. In section 2 we will give the basic setup of the model focusing on the main variables which will be analyzed throughout the paper. In section 3 we will depict the behavior of the North economy (the leader) and set the conditions by which innovation is performed at the frontier. In section 4, instead, we will describe the South economy (the follower) and the setup for imitation by focusing particularly on the costliness of imitation and adoption of technologies discovered at the frontier and on the impact of IPRs protection, human capital composition and differences in institutional quality. Section 5 will be devoted to the study of the steady state growth and to the analysis of the transitional dynamics which lead the follower to theoretically converge towards the leader. Section 6, instead, shows our main theoretical results by analyzing the reaction of the follower economy to changes in the main variables of the model such as IPRs enforcement or the human capital composition of the southern workforce. At the end some conclusions.

# 2 Setup of the model

We assume, in the fashion of Grossman and Helpman (1981) or Barro and Sala-i-Martin (1997), that the world consists of 2 countries denoted by i=1,2 where country 1 represents the North and country 2 the South. The output in the two countries is expressed by means of a Spence (1976)/Dixit and Stiglitz (1977) production function as follows:

$$Y_i = A_i Z_i (L_{yi})^{1-\alpha} \sum_{j=1}^{N_i} (X_{ij})^{\alpha} \tag{1}$$

where $0 < \alpha < 1$, $Y_i$ is output and $X_{ji}$ is the quantity of the *jth* nondurable intermediate good used in the production by country $i$. $N_i$ is the number of types of intermediates available (known) in country $i$.

As in Barro and Sala-i-Martin (1997) we use the variable $N_i$ to proxy for the technological level of country $i$. The technology shown in eq. (1) can be accessed by all agents in country $i$ and production occurs under competitive conditions.

$A_i$ represents institutional quality while $Z_i$ captures specifically the enforcement of IPRs in country $i$. $L_{yi}$ is instead the fraction of the labor force employed in the production of output $Y_i$ . Trade is assumed to be balanced between the two countries such that the domestic output is equal to the total of domestic expenditures which go for consumption of goods, $C_i$, production of intermediates, $X_{ji}$, and R&D aimed at discovering new blueprints and varieties of intermediates.

## 2.1 Human capital composition

We assume labor in the 2 countries to be heterogeneous in human capital stocks. In both countries a fraction of population will be of the low skill type, namely $L_{yi}$, and employed in the production of the final good $Y_i$ .

The remaining fraction of the workforce, namely $L_{ri}$, represents the high skilled workers who will be employed in the innovation or imitation activities of country 1 and 2[4]. The following general condition is hence satisfied:

$$L_i = L_{yi} + L_{ri} \tag{2}$$

where $L_i$ is the total workforce and $L_{yi}$ and $L_{ri}$ represent respectively the low and high skilled shares of total workforce for country $i$.

Noticeably, North and South differ in the *composition* (and not only in the average levels) of their human capital stocks. The North, consistently with empirical evidence, is populated by a relatively larger share of high skilled workers (over its total population) than the South[5]. Conversely, the South, is largely populated by low skilled workers and only a relatively small fraction of its total workforce is high skill.

This condition can be restated more formally as follows:

$$L_{r1} > L_{r2} \tag{3}$$

and, conversely

$$L_{y1} < L_{y2} \tag{4}$$

[4] In practice, for country 2, we will see that $L_{r2}$ is employed in the imitation sector in the adoption/adaptation of the imitated blueprints.

[5] The share of the workforce achieving tertiary or secondary educational attainment levels is evidently higher in developed countries than in LDCs. This empirical observation motivates the theoretical assumption of our model.

## 2.2 Institutional Quality and IPRs enforcement

The variable $A_i$ proxies for the level of institutional quality of country $i$. Some authors such as Keefer and Knack (2002), Alesina et al. (1992) or Levine and Renelt (1991) point to the process of democratization and to the political stability of a country as the main features of a country's institutional quality. Others, such as Mauro (1995), or Barro (2000) also emphasize the role of corruption and criminality as distortions to the correct functioning of a country's institutional framework. We follow Hall and Jones (1999) and assume that the North owns more developed institutions than the South as follows[6]:

$$A_1 > A_2 \tag{5}$$

Importantly, the parameter $A_i$ proxies for all government and policy arrangements but it abstracts from IPRs protection which, due to the aim of our study, we explicitly insert into the model through the variable $Z_i$.

Higher values assigned to $Z_i$ imply tighter IPRs protection accorded to. both (i) goods and patents produced domestically, (ii) goods and patents produced externally from possible imitation by firms operating in country $i$. More precisely we assume full IPRs protection in country 1, the North. This corresponds to saying that $Z_1 = \max$[7]. More generally a high value of $Z_1$ implies a strong protection, *within the boundaries of country 1 only*, of the property rights of domestic firms which discover a new blueprint (in country 1) but also of the intellectual property rights belonging to foreign firms (those creating knowledge in country 2) against imitation by all agents operating in country 1. For simplicity, then, we assume that no imitation is possible in country 1 whatsoever.

On the other hand, a high value of $Z_1$ does not ensure firms based in country 1 against the possible imitation of their blueprints by agents in country 2 where the IPRs protection may be weaker. More formally we assume that protection of IPRs in country 2 is imperfect such that $0 < Z_2 < Z_1$. The imperfection of the IPRs system in the South makes it possible for agents in country 2 to imitate the blueprints discovered abroad, in country 1. As in Helpman (1993), the degree by which IPRs are enforced in the South ends up affecting the rate of imitation along with the number of imitated goods in country 2.[8] Imitation is then likely to occur in country 2 and it will be a negative function of the strength of the IPRs regime in the South.

[6] The intuition is that countries with better institutional quality are also those which *ceteris paribus* experience higher levels of GDP per capita. Robust empirical evidence justifies this assumption.

[7] The bottom line is that, developed countries (representing the North in our model) usually grant the maximum protection to IPRs while, conversely, protection in developing countries (the South) is usually imperfect and relatively low.

[8] In Helpman (1993) an increase of IPRs protection in the South negatively affects the rate of imitation in the South. In our formalization, as we will show in the next sections, we directly link the extent by which IPRs are enforced to the costs of imitation activities. Still, we obtain the same result that an increase in IPRs enforcement leads to a decrease of the rate of imitation and of the number of imitated goods.

## 2.3 Development stage and technological leadership

As it is usual in this kind of models we assume the North to be the technological leader. This is implied by the following:

$$N_1(0) > N_2(0) \tag{6}$$

where the pool of blueprints (or intermediates) that are known in country 1 is strictly higher than that in the technological follower country 2[9]. The relative technological proximity between country 2 and country 1 is expressed by the following ratio:

$$0 < \frac{N_2}{N_1} \leq 1 \tag{7}$$

Throughout all the paper we will be using the measure in eq.(7) to define the relative *development stage* of country 2 w.r.t. the leader.

# 3 The leader country

The basic setting we use in order to model innovation combines various features of the formalizations of Barro and Sala-i-Martin (1997), Romer (1990) and Helpman (1993). In principle, economic agents can increase their technology stock (the pool of available intermediates known for production, $N_i$) either by inventing a new blueprint or by imitating/adopting an existing one which is known in the other country. In practice, however, we will be assuming that the North is initially the only innovator and that the South imitates the discoveries made at the technological frontier. Later we will allow for this initial situation to change depending on the development stage of the follower.

## 3.1 Cost of innovation

One of the crucial assumptions of our formalization is that both innovation and imitation/adaptation are costly activities[10]. We define the cost of innovation by the parameter $\eta_i$.

Instead of assuming a fixed cost for innovation as in Barro and Sala-i-Martin (1997) we assume, somehow more realistically, that the cost of inventing a new blueprint is a decreasing function of the fraction of population endowed with high skills within each economy. This is like saying that the relative easiness of producing a unit of innovation increases with the fraction of highly talented/educated researchers which are employed in the R&D sector. It can be

[9] This is to say that there are no intermediates known in 2 that are unknown in 1 such that country 1 never has the reason to imitate country 2.

[10] This assumption is not new in the literature both empirical and theoretical. See for example Barro and Sala-i-Martin (1997), Eeckhout and Jovanovic (2002), Behnabib and Spiegel (2002), Mansfield, Schwartz, and Wagner (1981) and many others.

noticed that in our formalization the human capital "composition" effect enters directly into the model shaping the relative costs of innovation (and of imitation). More formally we assume the following cost function for innovation[11]:

$$\eta_i = \psi(L_{ri})^{-1} \tag{8}$$

where, as pointed out before, $\eta_i$ represents the cost of inventing a new blueprint and $L_{ri}$ is instead the share of high skilled workers employed in the R&D sector producing new knowledge.[12]

Notice that combination of eq. (8) with eq. (3) imply the following:

$$\eta_2 \geq \eta_1 \tag{9}$$

The cost of producing a unit of innovation in country 1 is lower than the corresponding cost in country 2 due to the higher share of high skilled workers employed in the North w.r.t. those employed in the South. The different composition of human capital stocks in the two countries shapes their relative innovation possibilities. The country endowed with the higher fraction of high skilled labor ends up being relatively more efficient in producing innovation due to the more educated and talented researchers employed in R&D. For simplicity of exposition we assume that the shares of high and low skilled workers in the two economies remain constant such that eq. (9) holds over time[13].

## 3.2 Innovation production in the leader country

Let us now assume a new intermediate good is introduced (invented) in country 1. The innovator retains monopoly power over the use of this good for production *within country 1*[14]. Since the intermediate good $j$ is priced in country 1 at $P_{1j}$ the flow of monopoly profit to the inventor is given by:

$$\pi_{1j} = (P_{1j} - 1)X_{1j} \tag{10}$$

where the 1 inside the brackets represents the marginal cost of producing the intermediate $X_{ij}$. The marginal product of the *jth* intermediate is instead given by:

[11] Our assumption is similar to that of Aghion and Howitt (2005), Behnabib and Spiegel (2005) who implicitly imply how the share of high skill workforce, and not the average quality of human capital, is a crucial determinant of the amount of innovation that an economy may produce.

[12] We assume here, for simplicity, that $\psi$ is a linear function. This may not be the case however and more complexity may be added to the model by assuming a non linear relation between the cost of innovation and the share of skilled workers employed in R&D. The results will not change qualitatively.

[13] Results would be the same if we allowed human capital composition to slowly change over time as in reality may happen. Mathematical tractability would be, however, more demanding not adding much to the results.

[14] As pointed out by Barro and Sala-i-Martin (1997), it is however simple to allow the good to become competitive with an exogenous probability $p$ per unit of time.

$$\partial Y_1/\partial X_{1j} = A_1 Z_1 \alpha L_{y1}^{1-\alpha}(X_{1j})^{\alpha-1} \quad (11)$$

This, in turns, leads to the demand function for the intermediate $j$ from all producers of goods in country 1:

$$X_{1j} = L_{y1}(A_1 Z_1 \alpha / P_{1j})^{1/1-\alpha} \quad (12)$$

Substituting eq.(12) into eq.(10) we get the monopoly price, which is the same for all types of intermediates:

$$P_{1j} = P_1 = 1/\alpha > 1 \quad (13)$$

which in turns implies that the total quantity of the *jth* intermediate that country $i$ will be producing amounts to the following:

$$X_{1j} = X_1 = L_{y1}(A_1 Z_1)^{1/(1-\alpha)}\alpha^{2/(1-\alpha)} \quad (14)$$

From this we finally get country's 1 total output by substituting eq.(14) into eq.(1) which gives:

$$Y_1 = (A_1 Z_1)^{1/(1-\alpha)}\alpha^{2/(1-\alpha)} L_{y1} N_1 \quad (15)$$

Two basic results can be directly seen from examination of eq. (15). On one hand, total output is a positive function of the country specific institutional quality and of the enforcement of property rights consistently with the recent empirical evidence (e.g. Hall and Jones (1999), Acemoglu et al. (2001) etc.).

On the other hand, holding constant country specific institutional quality, output per capita is going to increase as the technology level $N_i$, the number of intermediates available for production, increases[15].

By susbstituting eq.(13) and eq.(14) into eq.(10) one can get the flow of monopoly profit from sales to the owner of the rights of intermediate $j$ as follows:

$$\pi_{1j} = \pi_1 = (1-\alpha) L_{y1}(Z_1 A_1)^{1/(1-\alpha)}\alpha^{(1+\alpha)/(1-\alpha)} \quad (16)$$

As argued by Barro and Sala-i-Martin (1997) the present value of profits for the $j$th innovator is simply $\pi_{1j}/r_1$ where $r_1$ is the rate of return in country 1. When free entry is assumed in the R&D sector (and the quantity of R&D is nonzero) it must be that the present value of profits must equal the constant cost of invention $\eta_1$ at each point in time. Hence, rearrangement of the free-entry condition implies the following rate of return for economy 1:

[15] It is difficult to see from eq. (15) the partial effect of an increase of respectively the skilled or of the unskilled fraction of workforce on total output since $N$ is a function of human capital composition. We will show in the next sections how it is the increase of the high skill share of the workforce to be growth enhancing while an increase in the fraction of population endowed with low skills will result to be growth detrimental.

$$r_1 = (L_{y1}/\eta_1)\left(\frac{1-\alpha}{\alpha}\right)(Z_1 A_1)^{1/(1-\alpha)}\alpha^{2/(1-\alpha)} = \pi_1/\eta_1 \tag{17}$$

where the rate of return $r_1$ is the ratio of $\pi_1$, the flow of monopoly profit given in eq.(16), to the cost $\eta_1$ of obtaining this profit flow.

We assume that consumers maximize utility over infinite horizons through a standard Ramsey type utility function as follows:

$$U_1 = \int_0^\infty e^{-\rho t}\left[(C^{1-\theta}-1)/(1-\theta)\right]dt \tag{18}$$

where, as usual $\rho > 0$ represents the rate of time preference and $\theta > 0$ the magnitude of the elasticity of the marginal utility of consumption[16]. If we maximize the utility function subject to a standard budget constraint we obtain the usual expression for the consumption growth rate:

$$\dot{C}_1/C_1 = (1/\theta)(r_1 - \rho) \tag{19}$$

The growth rate of $C_1$ is constant due to the constancy of $r_1$ as in eq.(17). Hence, the growth rate of the economy in equilibrium is given by:

$$\gamma_1 = (1/\theta)(\pi_1/\eta_1 - \rho) = (1/\theta)\left[(1-\alpha)L_{y1}(Z_1 A_1)^{1/(1-\alpha)}\alpha^{(1+\alpha)/(1-\alpha)}\eta_1^{-1} - \rho\right] \tag{20}$$

where the parameters of the model are such that $\pi_1/\eta_1 \geq \rho$ ensures positive growth.

# 4 The follower country

## 4.1 The cost of imitation

Imitation and adaptation of leading-edge technologies imply a cost for the follower. The costliness of imitation is widely observed and acknowledged in theoretical and empirical literature. Maskus, Saggi and Puttitanun (2004), Mansfield, Schwartz and Wagner (1981), Coe and Helpman (1995) or Behnabib and Spiegel (2005) point out how the cost of both the adaptation and imitation of technologies discovered at the frontier (or in other technological sectors) is usually positive but relatively lower than the cost of innovation.

As argued by Maskus (2000), imitation usually takes the form of adaptations of existing technologies to new markets. Mansfield, Schwartz and Wagner (1981) point out for instance how, over 48 different products in chemical, drug, electronics and machinery U.S. industries, the costs of imitation lied between

[16] This implies the intertemporal elasticity of subsitution being equal to $1/\theta$.

40% and 90% of the costs of innovation. On the same line the empirical results of Teece (2008) who estimated the cost of technology transfer across countries to be equal, on average, to 19% of total project expenditure. Nelson and Phelps (1966) argue, moreover, how imitation and adoption imply an investment in human capital while Abramovitz (1986) emphasizes the role played by social and institutional resources in order for follower countries to adopt technologies discovered at the frontier.

We build on previous theoretical literature by expressing the cost function of imitation by the following:

$$\nu_2 = \eta_2 Z_2 \left(\frac{N_2}{N_1}\right)^{\sigma} \tag{21}$$

where $\nu_2$, the cost of imitation in country 2, is assumed to be a function of the strength of IPRs enforcement $Z_2$, and of $N_2/N_1$ the proximity to the frontier (the development stage of the follower).

Different aspects are here worth noticing. First of all, in the fashion of Connolly and Valderrama (2005) and Barro and Sala-i-Martin (1997) we assume the cost of imitation to be an increasing function of the proximity of the imitator to the technological frontier. The rationale goes as follows. When there exists a large pool of innovations (blueprints) from which an imitator can copy, the cost of imitation tends to be low. This happens when the ratio $N_2/N_1$ is small and the follower is relatively far from the frontier. However, when the pool of blueprints available for imitation shrinks, due to a higher proximity of the follower country w.r.t. the leader, the costs of imitation rise due to the fact that the remaining blueprints may be those more difficult to be imitated (or to be adjusted to production processes in country 2). This happens when the ratio $N_2/N_1$ gets closer to 1.

Hence, similarly to Barro and Sala-i-Martin (1997) when the blueprints available for imitation in the follower country are exhausted, the cost of imitation equals the cost of innovation, $\eta_2$, since imitation cannot be performed anymore.

The parameter $\sigma$ represents the elasticity of the cost of imitation to a decrease in the pool of available intermediates. It has been argued by Behnabib and Spiegel (2005) or Basu and Weil (1998), for instance, how the adoption of distant technologies may be more difficult for the follower. In particular, it is sometimes assumed how the technological frontier may not be immediately "appropriate" for the follower to be imitated due to the large technical differences between the leader and the recipient country. In our particular case, if $\sigma > 1$ an increase in the technological distance between the North and the South will imply a more than proportional increase in the cost of imitation reflecting the increasing difficulty faced by the follower in imitating distant technologies. The opposite applies when we assume $\sigma < 1$ while when $\sigma = 1$ an increase in the development gap $N_2/N_1$ will be *ceteris paribus* proportional to the increase in the imitation cost.

It is not only the relative proximity of the follower to the technological frontier to be important in defining the cost function for imitation. We depart from Barro and Sala-i-Martin (1997) formalization, by assuming the cost of imitation to be decreasing in the share of high skilled workforce employed in imitation activities in the economy, that is $L_{r2}$.

More formally combining eq. (21) with eq. (8) we can restate the cost function for imitation as follows:

$$\nu_2 = \psi(L_{r2})^{-1} Z_2 \left(\frac{N_2}{N_1}\right)^{\sigma} \tag{22}$$

As argued by Nelson and Phelps (1966), the speed of technology catch-up is a positive and increasing function of human capital levels. The higher the human capital of a lagging economy and the faster will be the technological catch-up. In fact, Nelson and Phelps (1966) argue how "*it is clear that the farmer with a relatively high level of education has tended to adopt productive innovations earlier than the farmer with relatively little education [...] for he is better able to discriminate between promising and unpromising ideas [...] The less educated farmer, for whom the information in technical journals means less, is prudent to delay the introduction of a new technique until he has concrete evidence of its profitability*".[17]

We insert into this same line of reasoning by arguing how reverse engineering, on which a considerable part of the imitation activities is based, is more likely to be performed by engineers than by low skilled workers. Instead, it is the physical production of the "replicas", used for production of the final good, to be carried out by unskilled workers. Following this rationale, our formalization implies that the cost of imitation will be lower the higher the share of skilled workforce in the South.

Finally, consistently with previous theoretical literature, we assume the cost of imitation to be increasing in the enforcement of IPRs within the follower's boundaries, that is, to be an increasing function of $Z_2$. From a general point of view intellectual property rights 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*

[17] Our assumption is somehow alternative to the one of Vandenbussche, Aghion and Meghir (2004) in which a low skilled worforce is assumed to be better suited for imitation tasks than a more skilled one. In Vandenbussche, Aghion and Meghir (2004) an increase of the share of unskilled workforce (when the South performs imitation) results to be growth enhancing since the elasticity of unskilled labor is higher in imitation than in innovation. We believe, instead, that imitation requires a consistent amount of skills at any development stage.

*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 a new blueprint.

Helpman (1993), among the others, argues how "*we may interpret a tightening of intellectual property rights as a decline in the rate of imitation; the stronger legal and administrative actions taken by the Southern government to protect Northern IPRs, the slower the pace of imitation*". In our formalization, hence, IPRs enter the cost function of imitation by increasing the cost of adopting and copying leader's technologies and therefore reducing the speed and pace of the imitation performed by the follower.[18]

To summarize, the way we formalize the cost function of imitation merges at least three basic assumptions recently independently seen in theoretical models. As in Aghion and Howitt (2005), Acemoglu et al. (2006) or Basu and Weil, we link the cost of imitation on the actual development stage of the follower ($N_2/N_1$). Also, as in Behnabib and Spiegel (1994, 2005) and Nelson and Phelps (1966) the cost of imitation will decrease as the skills of the workforce (education) increase. Finally, an increase in the IPRs enforcement of the South, as in Helpman (1993) or Maskus (2000) will imply a reduction in the possibilities of imitation and a rise in its cost. All these features, when analyzed jointly, will determine the optimal growth path for the follower economy.

## 4.2 Imitation in the follower economy

Now that we have set the conditions for the cost function of imitation we can move to the dynamic behavior of the South economy. We assume that country 2 starts in a situation where the cost of *innovation* is strictly higher than the cost of *imitation* such that:

$$\eta_2 > \nu_2(0) \tag{23}$$

Once a blueprint is discovered in the North this will be imitated by an agent in the South. Similarly to what happens in the North, the imitator in the South will retain monopoly power over the use of the imitated good for production within country 2. The intuition, again, goes as follows. Imitation/adaptation of a new technology is a costly activity; the outcome of imitation results in a new intermediate good, $X_{2j}$, which will be similar to the initial one $X_{1j}$ discovered in the leader country but "ready-to-use" for production in country 2.[19]

[18] One may think of an increase of IPRs enforcement as corresponding to a decrease of the pool of available blueprints for imitation. This, consistently to what we argued up to now would ultimately increase the cost of imitation.

[19] We may think of the imitated good as one of lower quality but that still own the basic characteristics of the leader's innovation. Many example may be reported for this situation. Counterfited CDs, MP3 players, clothings and so on. All these goods are similar to the original

The computation of the rate of return in country 2 is slightly more complex than that for country 1. This is because the cost of imitation is increasing over time being a positive function of the ratio $N_2/N_1$. We follow the simpler formalization proposed by Barro and Sala-i-Martin (1995)[20] by assuming that the follower country is far from the technological frontier and that the pool of available innovations to be imitated is large so that the rate of return will be nearly constant and given by the following:

$$r_2 = (L_{y2}/\nu_2)\left(\frac{1-\alpha}{\alpha}\right)(Z_2A_2)^{1/(1-\alpha)}\alpha^{2/(1-\alpha)} \tag{24}$$

Interestingly, a gap in rate of returns arises between the North and the South since the cost of imitation in the South is initially lower if compared to the cost of innovation in the North. This gap is such that $r_2 > r_1$ during the transitional dynamics[21].

Also we are able to compute the growth rate for the whole economy in country 2 as a function of model parameters:

$$\gamma_2 = (1/\theta)(\pi_2/\nu_2 - \rho) = (1/\theta)\left[(1-\alpha)L_{y2}(Z_2A_2)^{1/(1-\alpha)}\alpha^{(1+\alpha)/(1-\alpha)}\nu_2^{-1} - \rho\right] \tag{25}$$

# 5 Steady state and growth dynamics

In order to be more specific about the dynamic behavior of the economies it is convenient to start with the analysis of the growth in steady state and then move to the analysis of the transitional dynamics.

## 5.1 Steady state

In steady state the two economies are expected to grow at the rate of expansion of the technology frontier, that is at $\gamma_1$. By definition, therefore, in steady state $N_2$ grows at the same rate as $N_1$ so that $\nu_2$ remains constant in accordance with eq. (21). Also, $C_1$ grows at the same rate as $C_2$ which corresponds to $\gamma_1$ in the long run.

ones in the sense that own their basic characteristics and features but, at the same time, are usually of lower quality and sold at a cheaper price.

[20] A slightly more complex formalization is given in Barro and Sala-i-Martin (1997) where the rate of return for country 2 is expressed by $r_2 = \pi_2/\nu_2 + \dot{\nu}_2/\nu_2$where $r_2$ includes the capital gain term $\dot{\nu}_2/\nu_2$ which adds to the dividend rate $\pi_2/\nu_2$. We refer the interested reader to Barro and Sala-i-Martin (1997), p.8.

[21] For now it is convenient to notice simply that under the general assumptions given from eq.(3) to eq. (8), for $N_2/N_1 < (N_2/N_1)^* < 1$ it will always hold that $r_2 > r_1$. The asterisk superscript represents the technology proximity of the follower w.r.t. leader in steady state. We will discuss this situation in the next section.

As in Barro and Sala-i-Martin (1997), even if the two countries do not share a common capital market, the process of technology diffusion will end up equalizing the rate of returns in the two economies. The steady state value of the rate of return expressed in eq. (24) for economy 2 will be equal to that of the leader economy 1 as follows:

$$r_2^* = r_1 = \pi_1/\eta_1 \tag{26}$$

where the asterisk superscript denotes values in steady state for country 2. Hence, since $r_2^* = r_1$, eq. (17) and eq.(24) imply:

$$\pi_2/\nu_2^* = \pi_1/\eta_1 \tag{27}$$

where $\nu_2^*$ represents the correspondent steady state value for the cost of imitation $\nu_2$. Combining eq.(16) with eq.(**??**) we can express the steady state value for the cost of imitation as a function of the other variables of the model. This is as follows:

$$\nu_2^* = \eta_1 (Z_2 A_2 / Z_1 A_1)^{1/(1-\alpha)} (L_{y2}/L_{y1}) \tag{28}$$

## 5.2 Transitional dynamics

From what argued up to now it is easy to understand that for any given value of $\nu_2(t) < \nu_2^*$ the follower economy will be found below its steady state. Hence, during the transitional path, the South will be growing faster than the North due to the relative gap in rate of returns between the imitation performed by the South (which is highly profitable at initial stages of development) and the innovation performed by the North.

One may think of this situation as the South having a cost "*comparative advantage*" w.r.t. the leader which makes it able to grow relatively faster. Nonetheless, *ceteris paribus*, as country 2 converges towards the technological level of the leader ($N_2/N_1$ gets bigger) the cost of imitation in country 2 rises up to a point where country 2 completely exhausts its "*growth comparative advantage*" and starts growing at the rate of the technological frontier. That is, $\gamma_2$ goes from being initially higher than $\gamma_1$ to a situation where $\gamma_2^* = \gamma_1$ in steady state[22].More formally we have the following:

$$\nu_2(t) = \nu_2^* \Longleftrightarrow \gamma_2^* = \gamma_1 \tag{29}$$

while, during the transition dynamics it will be that

$$\nu_2(t) < \nu_2^* \Longleftrightarrow \gamma_2 > \gamma_1 \tag{30}$$

[22] This also implies a technology gap between country 1 and country 2 equal to $(N_2/N_1)^*$.

# 6 Appropriate IPRs, H and Development Stage

Different IPRs regimes are likely to affect the growth dynamics and especially the optimal decision of imitation in the South. On the other hand, the relative composition of human capital (skilled over unskilled workers) and the level of institutional quality enter the cost function of imitation and innovation and therefore they also define under what conditions imitation may (or may not) be optimal in the long run.

Up to now we have been analyzing the situation for which the South grows faster than the North by profitably imitating the technologies discovered in the leader country. Two general assumptions are at the basis of this result.

First, we assumed that the cost of imitation in the South, $\nu_2(0)$, is lower than the cost of innovation in the North, $\eta_1$, (condition for which the South tends to converge to the North). Second, we assumed that in the South imitation is initially cheaper than innovation, that is, the cost of imitation $\nu_2(0)$ is lower than the correspondent cost of innovation $\eta_2$ (condition for which imitation is performed rather than innovation)[23]. The choice of the South of performing imitation *during the transitional dynamics* (rather than innovation) is therefore based on the gap between $\nu_2(t)$ and $\eta_2$. More formally we have been assuming the following:

$$\nu_2(t) < \eta_1 < \eta_2 \tag{31}$$

We are now interested in defining under what general conditions imitation, rather than innovation, results to be an optimal activity for the follower *in the long run*. This reduces to finding for what parameter values the cost of imitation, in the long run, is lower than the cost of innovation, that is when $\nu_2^* < \eta_2$ is satisfied.We give the results in Proposition 1 here below:

**Proposition 1** *As long as differences in IPRs enforcement between leader and follower are large, the follower country finds optimal to imitate in the long run.*

Putting together eq.(31) with eq.(28) we can restate the condition for which imitation is optimal (w.r.t. innovation) in the long run as follows:

$$\nu_2^* < \eta_2 \Leftrightarrow (Z_2 A_2 / Z_1 A_1)^{1/(1-\alpha)} L_{y2} / L_{y1} < \eta_2 / \eta_1 \tag{32}$$

Rearranging eq. (32) yields to the following, more general, optimal condition for imitation in the long run expressed as a function of the IPRs ratio $Z_2/Z_1$:

$$\phi < (\kappa/\xi)^{1-\alpha} \theta^{-1} \tag{33}$$

[23] Recall, also, that $\eta_2 > \eta_1$ strictly holds, that is, the cost of innovation in country 2 is strictly higher than the cost of innovation in country 1 due to the relative difference in human capital stocks composition across countries.

where we redefined the variables as follows[24]:

$$\phi = Z_2/Z_1 \tag{34}$$

$$\kappa = \eta_2/\eta_1 \tag{35}$$

$$\xi = (L_{y2}/L_{y1}) \tag{36}$$

$$\theta = A_2/A_1 \tag{37}$$

The intuition behind this result goes as follows. For large enough differences in IPRs enforcement between the North and the South (small values of $\phi$) the steady state cost of imitation in the South will be always lower than the correspondent cost of innovation in the South, that is $\nu_2^* < \eta_2$ will be satisfied. This is to say that, when IPRs are weakly enforced in the South, imitation will result to be an *easier* and more profitable activity for the follower if compared to innovation.

Formally, as long as the inequality in eq.(33) holds, also the steady state cost of imitation for country 2 $\nu_2^*$ will be strictly less than the correspondent cost of innovation $\eta_2$. As argued before, this condition is satisfied for relatively low values of $Z_2/Z_1$ such that, in that case, the follower will always choose to imitate. .

The analysis of IPRs regimes is of particular interest since developing countries have been pushed to comply with very restrictive IPRs regimes by developed countries. The rationale for this argument is based on the belief that strengthening IPRs protection in the South may play the crucial role of incentivizing innovative effort and R&D and consequently may promote economic growth.

Developing countries, on the other hand, claim how given their "actual" development stage, an increase in the IPRs enforcement may end up harming their development prospects by rising the costs of imitation and inhibiting their *quasi*-free access to new technologies.

In Proposition 2 we show how the "Southern" belief that strengthening IPRs is detrimental for the follower country (when this performs *imitation*) does not always hold and that instead some degree of IPRs is optimal in the South as well. Instead in Proposition 3 we show that the "Northern" belief that innovation should be preferred to imitation *"no matter what"* does not hold for a broad set of scenarios where the development stage, the human capital level or

[24]Notice that the new variables in eq.(33) are all expressed as the ratio of the follower's quantities over the leader's in order to make the analysis more readable.

institutional quality of the follower are too distant from that of the technological frontier.

**Proposition 2** *For large enough differences in economic fundamentals between leader and follower a moderate increase of IPRs enforcement is beneficial for the follower country* ***even if this preforms only imitation****. Higher proximity to the technological frontier is achieved by the follower when IPRs are moderately strengthened.*

From a first examination of eq.(33) it is possible to notice how a moderate increase of $Z_2$ (that is, a relative strengthening of IPRs in the South) will not result to be harmful to the growth of the follower even in a situation where this country *only performs imitation*. In fact, it is easy to see how there exists a set of parameter values for which the IPRs regime of the South $Z_2$ could increase without violating the optimality condition for imitation in the long run, $\nu_2^* < \eta_2$. Rearranging eq. (33) as $\frac{Z_1 A_1}{A_2}(\kappa/\xi)^{1-\alpha} > Z_2 \Rightarrow \nu_2^* < \eta_2$ it can be shown that there exists a wide set of values for $A_1, A_2$ and $Z_2$ for which an increase in $Z_2$ will not violate the optimality condition for imitation in the long run.

From an economic point of view, the intuition behind this result goes as follows and it crucially relies on the observed costliness of imitation. In order to perform imitation a firm in the South must incur in some non negligible costs. These costs must be repaid by a profit stream to the imitator as it happens to the innovator in the leader economy when this discovers a new blueprint.

On one hand, a weak enforcement of IPRs in country 2 allows more free imitation of the blueprints (intermediates) discovered in country 1 by decreasing the relative cost of imitation as shown in eq.(21). On the other hand, however, a weak IPRs regime decreases the flow of monopoly profits to the imitator in country 2 as shown in eqs.(**??**) and (24) by granting the imitator with a weaker monopoly power and reducing his/her possibilities to fully recoup the costs of imitation.[25]

Crucially, as long as $\nu_2^* < \eta_2$ applies, that is as long as the steady state cost of imitation is lower than the cost of innovation in the South, an increase of IPRs results to be beneficial for the growth of the follower in imitation.

The implications of this result can be seen clearer if we derive the expression for the steady state value of the technology gap $(N_2/N_1)^*$ between country 1 and 2. Combining eq.(21) with eq.(28) we derive a unique value for $N_2/N_1$ which satisfies the steady state condition $\nu_2(t) = \nu_2^*$. This is given by the following:

[25] A case for our argument is the high competition among the imitators of the original iPhone by Apple. At least a dozen different clones (official and unofficial) of the original mobile device exist in the market (which are accessible from all over the world) and which are simultaneously competing one another and against the original device.

$$(N_2/N_1)^* = \left[\xi\,(\phi\theta)^{1/(1-\alpha)}\,/\,(Z_2\kappa)\right]^{1/\sigma} \tag{38}$$

We are interested in the relation between the long run technological proximity of the South w.r.t. the leader, $(N_2/N_1)^*$, and the effect of an increase in the strength of the IPRs regime in the South. In particular, we are interested in studying under what conditions an increase in the enforcement of IPRs leads to an increase (if any) in the proximity of the follower w.r.t. the technological frontier.

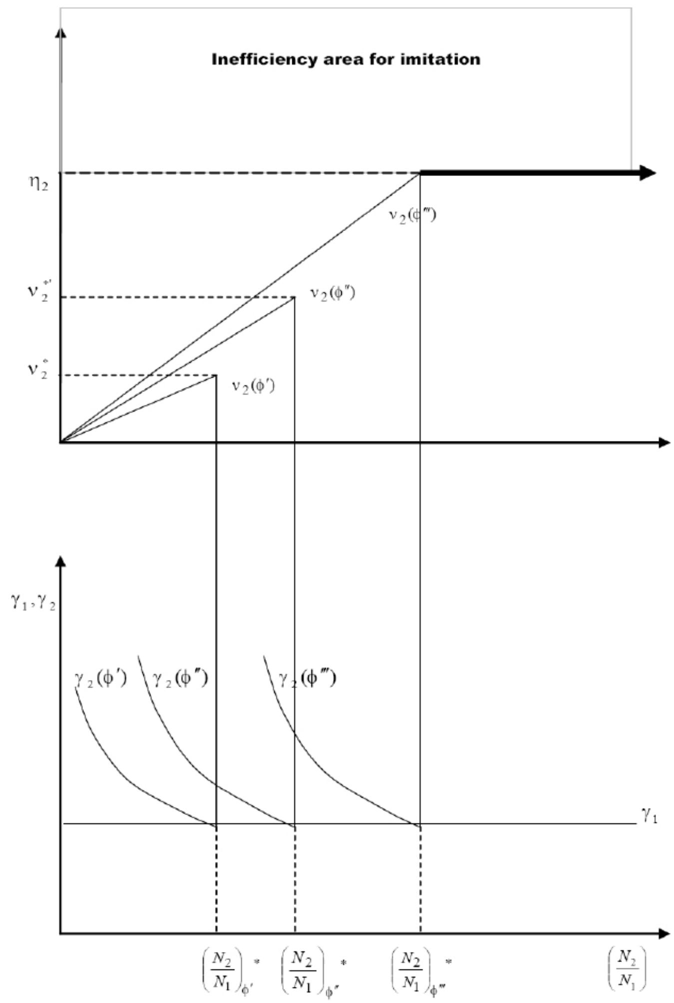
The assumptions made on the model parameters ensure that the steady state technology gap "in imitation" is reached before country 2 reaches the technology level of the leader, that is $0 < (N_2/N_1)^* < 1$.

It is possible to see how he steady state gap in eq.(38) is a positive function of $Z_2$ through the parameter $\phi$[26]. We show the main implications of propositions 1 and 2 in Figure 1.

Both the cost function of imitation as given in eq.(21) and its correspondent value in steady state as in eq.(28) increase as $Z_2$ rises. In particular, the function depicting the current cost of imitation, $\nu_2(t)$, becomes steeper at higher values of $Z_2$ and intercepts the function representing the steady state cost function at higher values where higher proximity with the technological frontier in the long-run is increasingly achieved.

It is here assumed that $\phi^{'} < \phi^{''} < (\phi^{'''} = \tilde{\phi})$. A tightening of IPRs in the South leads to increasingly higher values of technology proximity with the frontier in the long run which are achieved by corresponding shifts of the transitional path $\gamma_2$ to the right in our graph. Crucially, once $\nu_2^* = \eta_2$ the South becomes indifferent on whether performing imitation or innovation. Hence, when $\phi^{'''} = \tilde{\phi}$ holds we find a unique value of $(N_2/N_1)^*_{\phi^{'''}}$ which represents the maximum proximity w.r.t. technological frontier attainable in imitation given the specific economic fundamentals of the South. Hence, $\tilde{\phi}$ is the optimal IPRs regime given the institutional given the institutional quality and human capital endowment of the South.

[26]Notice that an increase in $L_{r2}$ in the denominator implies a more than proportional increase in the numerator of eq.(38) due to $\phi^{1/(1-\alpha)}$ and $\alpha < 1$.




Transitional dynamics

**Corollary:** *Given the follower's particular human capital composition, institutional quality and development stage a threshold IPRs regime is found such that the follower is indifferent on whether performing imitation or innovation;* $\tilde{\phi} = (\kappa/\xi)^{1-\alpha}\theta^{-1}$*.The optimal IPRs regime depends on the institutional quality and human capital endowment of the South.*

The long run proximity of the South w.r.t. technological frontier does not only depend on the IPRs regime but it is also an increasing function of the institutional quality endowment of the follower, through $\theta$ and of its human capital composition, through $\kappa/\xi$.

The positive impact of better institutional quality ($A_2$) in the South is somehow straightforward and it can be seen by examination of eq.(28) and eq.(38).This result is consistent with previous empirical literature such as Hall and Jones (1999) or Acemoglu et al. (2001). Better institutions in the South are associated with higher technology levels in the long run.

The result of **proposition 2** is of particular interest due to the way we inserted IPRs enforcement into the model; that is on the "cost-of-imitation" side. Previous theoretical literature, such as Grossman and Helpman (1991), Helpman (1993) or Lai (1997) points out how an increase in IPRs enforcement leads to a welfare loss for the South. From our formalization it is evident how these results are somehow alternative. In fact, when we take into account differences in the development stage, human capital levels and institutional quality across countries, we can show how a moderate increase in IPRs enforcement raises the welfare of the South and its proximity to the technological frontier.

It is worth noticing, however, how our result applies as long as the inequality in eq.(33) is satisfied. Instead, an excessive protection of IPRs may end up harming the follower economies when these are at their initial stages of economic and institutional development. In fact, for values of $\phi > \tilde{\phi}$, such IPRs regime does not imply any welfare improvement while it only reduces the growth rate of the follower country under imitation. Then, what happens if, instead of imitating, the follower decides to innovate?

**Proposition 3** *Switching from imitation to innovation before an appropriate development stage is achieved (the steady state technology proximity w.r.t. the frontier) is not an optimal choice for the follower country.*

Developed countries (especially the U.S. and Japan) have been pushing least developed ones to enforce stronger IPRs regimes within their boundaries. Their argument is that stronger IPRs would foster own based R&D and eventually economic growth. Clearly, the request of stronger IPRs in the South is also based on economic calculations by developed countries which are net exporters of new technologies and that every years are hurt from imitation and patent infringements in southern countries.

It is often argued how developing countries are poor due to their low technological level and that, therefore, they should boost their R&D sector. This result may be achieved, within this line of reasoning, by tightening IPRs and by giving stronger incentives to innovators in the South.

If indeed one may agree on the empirical evidence that developing countries are poor because of their low technical and technological level, it is not clear whether the solution to this problem should be to directly incentivize own based research and R&D regardless of the development stage of these countries and of their actual capabilities of producing innovation.

We show how a shift from imitation to innovation too early in the development of the South may not be welfare-improving leading, instead, to a decrease, rather than an increase, of the follower's growth rate.

Let us define a scenario such that the South decides to switch from imitation to innovation before its steady state technology gap $(N_2/N_1)^*$ is actually reached. We are here depicting the initial stages of development of the South when this economy is still far from the technological frontier and it is found within the transitional dynamics below its steady state. Notice that this happens under weak conditions such that $(N_2/N_1)^*$ may (or may not) be lower than the optimal $(\tilde{N}_2/\tilde{N}_1)^*$ and that $\phi \leq \tilde{\phi}$ does not have to hold with equality.

Thus, given these assumptions, when $[N_2(t)/N_1(t)] < (N_2/N_1)^*$ it also applies that $\nu_2(t) < \nu_2^*$ and therefore that $\nu_2(t) \ll \eta_2$. More formally, it can be seen that if:

$$[N_2(t)/N_1(t)] < (N_2/N_1)^*$$

then

$$\frac{(1/\theta)\left[(1-\alpha)L_{y2}(Z_2A_2)^{1/(1-\alpha)}\alpha^{(1+\alpha)/(1-\alpha)}v_2(t)^{-1}-\rho\right]}{(1/\theta)\left[(1-\alpha)L_{y2}(Z_2A_2)^{1/(1-\alpha)}\alpha^{(1+\alpha)/(1-\alpha)}\eta_2^{-1}-\rho\right]} = \frac{\gamma_2^{imit.}f(\nu_2(t))}{\gamma_2^{innov.}f(\eta_2)} \gg 1 \tag{39}$$

This is to say that before an appropriate development stage is reached, any attempt to shut down the imitative sector in favour of the innovative one will result to be growth diminishing for the follower.

Crucially, again, this result depends on the human capital composition in the South.[27] It is worth to notice here how not only the enforcement of property rights but also the relative gap in the endowment of high skilled workers between the North and the South and the relative gap in institutional quality affect the decision of whether imitation is chosen over innovation by the South.

**Proposition 4** *Improvements in the economic fundamentals of the South (human capital and institutional quality) make imitation increasingly less attractive w.r.t. innovation. However, the effect of an increase in the ratio of high skilled workers on the decision on whether to perform imitation or innovation (and ultimately on economic performance) depends upon the South development stage.*

[27] This can be explained by the fact that both imitation and innovation are better performed (they come at a lower cost) when the fraction of high skilled workers is higher. This is in the spirit of the Nelson and Phelps (1966) hypothesis. This said, however, $L_{r2}$ enters into eq.(39) affecting $v_2$ less than proportionally while affecting $\eta_2$ linearly. *Ceteris paribus* an increase in the share of high skilled workers employed will affect the ratio in eq.(39) by increasing the denominator and making innovation increasingly more profitable w.r.t. imitation.

Institutional quality differences between the North and the South, as expected, play a role in the definition of the conditions for which imitation rather than innovation results to be optimal in the long run. In particular we find how an increase in the quality of institutions in the South reduces the profitability of imitation w.r.t innovation with the inequality in eq.(33) being less likely to hold for high values of $A_2$.

From a more general point of view even if it is difficult to determine the causality between institutional improvements and economic development[28], it is clear how the two phenomena evolve on parallel paths and usually coexists. As a country develops from an economic point of view it is more likely to start obeying international rules as well as to pursue a better control of diversion within its boundaries. Our result show how, consistently with these assumptions, as a country improves on its institutional quality it is also more likely to shift from imitation to innovation activities in the long run and how this choice results to be an optimal one.[29]

On the other hand, an increase in the share of the high skilled workforce in the South implies a reduction of the costs of imitation (as shown in eq. (22)) but also a reduction of the cost of producing potential innovation (as shown in eq.(8)). Hence, an increase in the high skilled share of the total workforce results to be generally growth enhancing. However, the positive impact of an increase of skilled workers over imitation and innovation activities is uneven. While an increase of $L_{r2}$ implies a proportional decrease in the cost of producing innovation, its impact on the imitation cost depends on the actual proximity to the technological frontier, $N_2/N_1$ , that is on the follower's development stage as shown in eq.(22).

*Ceteris paribus*, increasing the high skilled content of the follower's workforce leads to a decrease of both $\kappa$ and $\xi$. This implies, on the other hand, that the inequality in eq. (33) is gradually less likely to hold for any given value of IPRs enforcement in the South when the fraction of workforce with high skills increases. To put it in other words, imitation becomes less attractive in the long run when the economic fundamentals of the follower improve, namely when the share of high skilled human capital in the South increases. Here below we analyze the composition growth effect of an increase in human capital.

**Proposition 5** *A rise in the fraction of population with a higher level of education is growth enhancing under broad conditions. Conversely, a rise in the fraction of population with a lower degree of education is growth diminishing. The result applies in imitation or innovation for both North and South economies.*

[28] See Hall and Jones (1999) for an example of this analysis.

[29] As in Acemoglu, Aghion and Zilibotti (2006), it is here evident how some "poor institutional arrangements" (imitation and lax IPRs) may optimally arise at initial stages of development of a country but that these will be abandoned as a country catches up with the frontier.

This result can be seen by the inspection of the growth rate in eq. (20) for the leader or from its correspondent in eq.(25) for the follower. Everything else equal, the growth rate of the economy is a function of the level of educated (skilled) over uneducated (unskilled) workers in the economy. Taking the partial derivative of the growth rate w.r.t. $L_{ri}$ and imposing this to be greater than zero yields to the following:

$$\frac{\partial \gamma_i}{\partial L_{ri}} = (1/\theta)\left[(1-\alpha)(Z_i A_i)^{1/(1-\alpha)}\alpha^{(1+\alpha)/(1-\alpha)}\eta_i^{-1} - \rho\right][1-2L_{ri}] \tag{40}$$

Due to the assumptions made on the model parameters in order to ensure positive growth, the term $(1/\theta)\left[(1-\alpha)(Z_1 A_1)^{1/(1-\alpha)}\alpha^{(1+\alpha)/(1-\alpha)}\eta_1^{-1} - \rho\right]$ will be always greater than zero. This leads to the following:

$$\frac{\partial \gamma_i}{\partial L_{ri}} > 0 \Leftrightarrow L_{ri} < 1/2 \tag{41}$$

The derivative in eq.(40) shows how an increase in the skilled fraction of workforce is growth enhancing for plausible values of $L_{ri}$, that is for values of $L_{ri}$ below the half of the total population. Instead, the opposite is true for the unskilled population. That is, when $L_{y1}$ is below 1/2 an increase in the fraction of population with a higher degree (which decreases the fraction of those with a lower one) will be growth beneficial.[30]

**Proposition 6** *Once the steady state technology proximity with the leader has been reached, a tightening of IPRs above the threshold level $\tilde{\phi}$ is condition necessary but not sufficient to achieve absolute convergence and higher income levels. "Appropriate" human capital levels, skills and institutions are needed for the follower in order to perform innovation profitably and to catch up with the frontier. In any other case a tightening of IPRs (when institutional and human capital quality remain poor) leads to suboptimal equilibria and to conditional convergence.*

From the analysis of the propositions above we know that *when imitation is performed* the optimal IPRs regime is $\tilde{\phi}$. Southern growth is maximized by the particular path that satisfies $\phi = \tilde{\phi}$ up to the point where $N_2/N_1 = (\tilde{N}_2/\tilde{N}_1)^*$.

We showed how within the transitional dynamics imitation rather than innovation proves to be more profitable. This result holds also when the costs of imitation rise moderately[31] due to a slight increase in the strength of IPRs. Higher returns are paid to imitation (w.r.t innovation) before the steady state technology, $(\tilde{N}_2/\tilde{N}_1)^*$, has been reached.

[30] In both cases the relation between the increase in the share of high skilled human capital and the growth rate of the economy is not linear and it encounters diminishing returns pointing to possible duplication effects as argued by Romer (1990).

[31] As shown in proposition 2.

This said, the crucial question is whether $(\tilde{N}_2/\tilde{N}_1)^* < 1$ represents the best outcome that the follower can achieve in the long run once we assume also that innovation is possible for the follower. We analyze this case here below.

First of all, it is straightforward to show how, for any value of the technological gap such that $N_2/N_1 > (\tilde{N}_2/\tilde{N}_1)^*$, it will also be true that:

$$\nu_2^* > \eta_2$$

and hence

$$\gamma_2^{innov.} > \gamma_2^{imit.} \Longleftrightarrow \frac{(1/\theta)\left[(1-\alpha)L_{y2}(Z_2A_2)^{1/(1-\alpha)}\alpha^{(1+\alpha)/(1-\alpha)}\eta_2^{-1} - \rho\right]}{(1/\theta)\left[(1-\alpha)L_{y2}(Z_2A_2)^{1/(1-\alpha)}\alpha^{(1+\alpha)/(1-\alpha)}\left[\nu_2^*\right]^{-1} - \rho\right]} > 1 \tag{42}$$

Above the steady state value $(\tilde{N}_2/\tilde{N}_1)^*$ the South grows faster performing innovation than it does performing imitation due to the small residual technology gap w.r.t. the frontier which was before the reason of its growth comparative advantage. Hence, as a first general remark, a higher proximity w.r.t. the technological frontier could be theoretically achieved only by switching to innovation once $(\tilde{N}_2/\tilde{N}_1)^*$ has been reached. Innovation, in fact, is performed more efficiently than imitation at relatively high development stages when the follower is close to the technological frontier and the number of blueprints to be imitated scarce.

Crucially, therefore, if the South starts innovating *above* $(\tilde{N}_2/\tilde{N}_1)^*$ it becomes immediately optimal to fully enforce IPRs within its boundaries such that R&D will receive the maximum incentive and the new blueprints discovered in the South will be fully ensured against imitation.

At the same time, we showed in previous propositions that if the South starts innovating *below* $(\tilde{N}_2/\tilde{N}_1)^*$ its welfare will decrease. In fact, $(\tilde{N}_2/\tilde{N}_1)^*$ may be thought as a growth turning point which must be reached by performing imitation but overtaken by innovation.

Hence, the new steady state value for technology proximity of the South w.r.t. the North (when the South performs innovation) will be now given by the following:

$$\left(\hat{N}_2/\hat{N}_1\right)^* = \left[\xi\theta^{1/(1-\alpha)}/\kappa\right]^{1/\sigma} \tag{43}$$

where

$$\left(\hat{N}_2/\hat{N}_1\right)^* > (\tilde{N}_2/\tilde{N}_1)^*$$

Crucially, the South still represents the technological follower due to the fact that the $\left(\hat{N}_2/\hat{N}_1\right)^* < 1$.

Let us express the attainable income ratio between South and North in the long run by combining eq.(15) and its correspondent for the South with eq.(43). This is as follows:

$$(Y_2/Y_1)^* = \left[\theta^{1/(1-\alpha)}\left(L_{y2}/L_{y1}\right)\left(\hat{N}_2/\hat{N}_1\right)^*\right] \tag{44}$$

The income ratio between the two economies in eq.(44) will not remain constant due to the relative differences between the economic fundamentals of the South w.r.t. those of the North. The North, in fact, is still more efficient in producing innovation.

Hence, fully enforcing IPRs is a *necessary* but *not sufficient* condition to achieve absolute convergence with the leader. In fact, as expected, unless the South improves on its economic fundamentals (skills, human capital of institutions) it will be "trapped" in a high development stage, between the attainable $\left(\hat{N}_2/\hat{N}_1\right)^*$ and the lower $(\tilde{N}_2/\tilde{N}_1)^*$.[32]

This scenario captures the situation of those countries at the frontier which are technologically developed but still fail in reaching the same income standards of the leaders due to small but persistent differences in R&D or institutional quality w.r.t. the leader country. Convergence in technological levels is therefore *conditional* in the sense that it depends on the economic fundamentals of the two economies.[33]

*Absolute* convergence may be achieved, therefore, only by rising the high skilled fraction of total workforce and the overall institutional quality of the economy. In fact, from eq.(8), eq.(35) and the correspondent for economy 2 of eq.(40) it may be seen how an increase in $L_{r2}$ will imply a decrease in $\kappa$, the ratio $\eta_2/\eta_1$ which represents the inverse of the efficiency of the R&D sectors in the two economies. In a similar way, also an increase of institutional quality of the South ends up leading to an increase in the ratio $(Y_2/Y_1)^*$ by rising the parameter $\theta$.

[32] In other words, due to the differences in economic fundamentals between North and South it will be true that, above $(\tilde{N}_2/\tilde{N}_1)^*$, also $(\gamma_2^{inn.} > \gamma_2^{imit}) < \gamma_1$. Hence, even if slower, the South will diverge from the North and go back to $(\tilde{N}_2/\tilde{N}_1)^*$.

[33] If institutional quality or human capital levels do not contextually improve as the follower moves from imitation to innovation by tightening its IPRs regime it is simple to show how the growth of the follower will be reduced both if this innovates or imitates. In the first case, innovation will be poorly performed (making use of a relatively less skilled workforce w.r.t. the leader). The number of new blueprint discovered by the South will be less than that discovered in the North implying an increasing technological gap North-South. In the second case, imitation also will be performed inefficiently due to the higher costs imposed by the fully enforced IPRs regime w.r.t. the situation where $\phi = \tilde{\phi}$ that is when the IPRs regime is optimal in imitation.

Leapfrogging of the South w.r.t. the North is also possible when the North becomes intrinsically inferior w.r.t. the South in its economic fundamentals, institutional quality and human capital as standard neoclassical theory would suggest. When the analysis is the same but reversed with the North being the follower.

# 7 Conclusions

The debate over the enforcement of IPRs in developing countries has still not led to an agreement. In particular, the effects of the TRIPs agreement which forces LDCs to adopt the IPRs regime of developed countries is object of lively discussion.

One major line of disagreement over the adoption of stronger IPRs in developing countries is that they may harm LDCs' growth by prohibitively rising the costs of imitation. One of the arguments used by developed countries in favour of strong IPRs protection standards in developing countries is based on the fact that these are expected to promote own based research and innovation (discouraging imitation). Even if this may be actually the case, it is not clear whether shifting resources from imitation to innovation *ex abrupto* may be regarded as an optimal policy regardless of the development stage of the economy under consideration. The usual concern about the implementation of strong IPRs regimes relates to the fact that follower countries, endowed with low levels of institutions and human capital, may not be able to compete with the leaders in product innovation when IPRs are strongly enforced and imitation is reduced drastically.[34]

A trade-off exists in the enforcement of IPRs in developing countries which do not apply to developed ones. Imitation, on one hand, represents probably the major technological activity for least developed countries. This is so due to the relative lower costs of imitation w.r.t. those of innovation. On the other hand, stronger IPRs regimes, it is argued, may set the right economic incentives conductive to higher growth in the long run through own based R&D and technology development. Hence, the decision of whether enforcing IPRs in developing countries, and of how much, should be based on these cost calculations.

With this paper we show how, inserting differences in IPRs enforcement and in the composition of human capital stocks into a standard innovation-imitation

[34] It has been argued by several commentators how the Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS), which concluded the Uruguay Round of negotiations at the WTO in 1994, basically set uniform intellectual property protection standards (which are those of the developed nations) on all members without leaving any flexibility to developing nations if not in the date of full enforcement of the treaty itself. The date for full adoption and implementation of TRIPS by LDCs, the 1st of January 2006, has recently passed but Least Developed Countries may apply for an extention with regards to pharmaceutical products only to the year 2016.

growth model leads to interesting policy making insights. One of the novelties of our contribution stands in the joint analysis of IPRs, of human capital and institutional differences along with that of the role played by each economy's development stage.

We are able to depict how much the South can increase its IPRs regime before harming its own growth. This depends heavily on the joint behaviors of the other variables in the model, that is, on the relative quality of human capital and general institutions in the South.

Our results show how the switch to innovation cannot be made regardless of the economic fundamentals and development stage of the follower. If the switch from imitation to innovation happens to early in the development of the follower it will result to be growth diminishing. The follower will not be able to produce innovation profitably before a certain development is reached. This also requires a consistent increase in the human capital endowment of the follower and an improvement of its institutional quality.

We then find an optimal IPRs regime such that growth is maximized in the long run when imitation is performed by the South. Differently from previous theoretical literature, a moderate increase in the IPRs enforcement (when we start below the optimal IPRs regime) results to be growth enhancing for the follower even if this performs only imitation at initial stages of development. This is due to the fact that imitation, as argued by Levin et al. (1987), Mansfield, Schwartz, and Wagner (1981) or Gallini (1992) is a costly activity and, as innovation, needs some degree of monopoly power in order for the associated fixed cost to be recouped by the imitator as well.

We studied these issues by building a North-South theoretical model where innovation and imitation are performed. Here, the leader country, representing the North, produces innovation at the frontier more efficiently than the South due to its more skilled workforce. The South, however, may transitively grow faster than the North by imitating the technologies discovered at the frontier due to imperfect IPRs protection. Imitation results to be cheaper at initial stages of development.

We merged features from different previous contributions such as Barro and Sala-i-Martin (1997), Helpman (1993) or Grossman and Helpman (1991), Nelson and Phelps (1966) and Behnabib and Spiegel (2005) in order to formalize the cost function and dynamics of the follower country.

The relative easiness of imitation, its cost, has been assumed to be a function of the proximity to the technological frontier, of the IPRs regime and of the quality of human capital devoted to imitation in the South. All these variables have been shown to be crucial in the definition of the optimal growth path for the follower country. Similarly to Vandenbussche, Aghion and Meghir (2006) or Acemoglu, Aghion and Zilibotti (2006) we find how some poor institutional arrangements arise at initial stages of development and that these are growth maximizing until a threshold development stage is reached. In particular the South finds optimal to keep its IPRs regime low *enough* in order to maximize its growth until a critical development stage is reached.

The predictions of our model therefore are consistent with the idea that "*one size (XL) IPRs may not fit all*". This is to say that a complete harmonization of IPRs regimes may be growth detrimental when it does not take into account the specific economic and institutional development of the follower countries, that is their human capital and institutional levels. In this sense IPRs regimes can be considered "appropriate" to the development stage of an economy.

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