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Endogenous growth and intellectual property rights: A north–south modeling proposal

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ABSTRACT

In this paper, we develop a general equilibrium endogenous growth model that emphasizes the IPR enforcement effects on growth, in a scenario of north–south technological knowledge diffusion. The economy consists of three sectors, and firms are engaged in step-by-step innovation. In line with the literature, we introduce an IPR parameter that makes imitation more difficult. We find that, in steady state, the increases in IPR protection result in decreases in the growth rate. This result is in line with the literature, which argues that the enforcement of IPR does not always have a positive effect on economic growth. To sum up, we present some suggestions for future research which can help to clarify the relationship between IPR and endogenous growth.

1. Introduction

There is a broad consensus in the literature regarding the understanding of innovation as vital for economic growth (e.g., Aghion and Howitt, 1992; Barro and Sala-i-Martin, 2004; Acemoglu and Akcigit, 2012). Moreover, Intellectual Property Rights (hereafter referred to as IPR) are recognized as relevant for understanding innovation and thus emerge as a crucial determinant for economic growth analysis (e.g., Gould and Gruben, 1996; Glass and Saggi, 2002; Sener, 2006; Dinopoulos and Segerstrom, 2010).

According to Falvey et al. (2009) and Chu et al. (2012), we would expect a positive impact of stronger IPR on economic growth. Indeed, increasing patent protection raises the R&D incentives and improves technological progress, which in turn decreases economic growth volatility, proving that a superior patent breadth leads to a higher expected growth rate. Additionally, it is common among empirical studies to find a net positive effect between IPR protection (measured by a system of patents, for instance) and innovation. In fact, the empirical evidence suggests a positive relationship between this kind of protection and innovation, despite certain characteristics of the sample, such as the type of countries in the study (for instance, the above result is significant mostly for low and high income countries but not for middle income countries), may bring some bias into the analyses (for a detailed analysis of such differences see Azevedo et al., 2012).

Within the literature on economic growth, important contributions to the field of IPR have been made in juxtaposition with international trade. Several questions have emerged, such as: what is the optimal enforcement of IPR in a North (South) open economy? What are the effects of introducing IPR into a north–south endogenous growth model? These questions are in line with our research aims for this paper, as will be made clear below.

Several papers have used a north–south endogenous growth set up to deal with the above mentioned questions, specifically in terms of what is the optimal enforcement of IPR protection. Sá et al. (2009), for example, discuss this topic in relation to a small and developing open economy, analyzing whether there should be no enforcement on the one hand or complete enforcement on the other. Their results point to the dominance of a positive relationship between IPR enforcement and welfare, albeit showing that, when departing from weak protection choices, some exceptions may be found. Wu (2010) observes that there is no consensus in the literature on the relationship between IPR protection and economic growth, since this relationship relies on the development level of the country, which imposes different necessities of innovation and imitation that affect the impact of IPR protection. Mondal and Gupta (2009) also propose an endogenous growth model that analyses the effects of IPR protection on economic growth, concluding that a strategy of strengthening IPR in the South may lead to welfare gains in both the North and the South (although the marginal welfare gain is higher in the former than in the latter), which leads to a rise in the Northern innovation rate and a decrease in both the Southern rate of imitation and the south–north wage in the new steady state equilibrium. Thus, this strategy has a positive effect on the steady state equilibrium growth rate in both countries.

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In this paper, we aim to understand the effect of introducing IPR protection into a north–south endogenous growth model and it is important to stress that our goal is to study this effect only within endogenous growth models. Therefore, we don't take in consideration the other kind of models. Despite the important contributions that have been emerging to this research framework, the analysis is still in its infancy. In order to assess this latest evidence, we conducted a simple bibliometric exercise to gain a more quantitative picture of the research patterns concerned with IPR in the specific framework of Endogenous Growth Models (EGM). This exercise is based on two datasets gathered from the bibliographical database SciVerse Scopus.[2] Our first dataset was obtained using the terms "Endogenous Growth Model" (EGM) as search words (in all fields and choosing article and review as document type), whereas the second dataset was gathered from a similar search using the terms "Intellectual Property Rights" and "Endogenous Growth Model" simultaneously (EGM + IPR). The first set encompasses 2004 articles, while the second only comprises 71 articles.[3]

Fig. 1 represents the temporal evolution of the number of published articles broadly about EGM and specifically about EGM + IPR. Articles on EGM (alone) have been appearing since 1991, whereas the first year in which we find published articles concerning both IPR and EGM is 1998. This comprehensive search, whose first recorded entry is in 1998, sustains the argument that the analysis of IPR in the context of endogenous growth models is a rather new research field. Furthermore, despite the visible and sustained increase in EGM related research from 1995, the number of publications relating to EGM + IPR has remained almost stable over the years in focus.

As Fig. 1 shows, the relative weight of EGM + IPR in total EGM is small, with a peak occurring in 2012. However, there is no clear evidence of growth in relation to this weight in the analyzed time period. Faced with the fact that this line of research has only recently been undertaken, we argue that there are still important caveats that have to be dealt with, and in our paper we intend to contribute to limiting their scope, our original aim and main motivation being to explain the IPR enforcement effects on growth, in the presence of north–south technological knowledge diffusion.

As starting points for our modeling proposal, we consider Connolly and Valderrama's (2005) and Afonso's (2012) studies, both using a similar endogenous growth framework, which propose analogous building blocks in their models and achieve interesting results.

Nevertheless, these two articles report distinct results. Connolly and Valderrama (2005) focus on welfare and growth within a dynamic argument, arguing in favor of free trade, particularly from the point of view of developing countries. Afonso (2012) also focuses on technological knowledge diffusion issues, but in relation to the dynamics of wage inequality.

Thus our framework is based on Connolly and Valderrama (2005) and Afonso (2012), but we also draw on some studies specifically oriented towards IPR within EGM, such as those of Mondal and Gupta (2009), Sá et al. (2009) and Wu (2010). As in the first two studies, we also consider a model consisting of two economies (North and South) and three productive sectors in each economy: final goods, intermediate goods and designs (R&D sector). However, in comparison with Afonso (2012), we drop the hypothesis of distinct types of labor, and we do not consider transportation costs separately as in Connolly and Valderrama (2005). Moreover, we introduce a new parameter into the probability of imitation, in order to capture the effect of IPR protection, since it is an adequate procedure for showing that IPR enforcement aims at constraining imitation. Our main motivation is to contribute to overcoming the present gap in the literature on endogenous growth, given that most of the related literature, as it has been shown above with the bibliometric account, has treated IPR protection as a secondary issue or it has dealt with the relationship between IPR protection and other things, essentially between IPR protection and innovation (e.g., Helpman, 1993; Lai, 1998; Yang and Maskus, 2001; Akiyama and Furukawa, 2009).

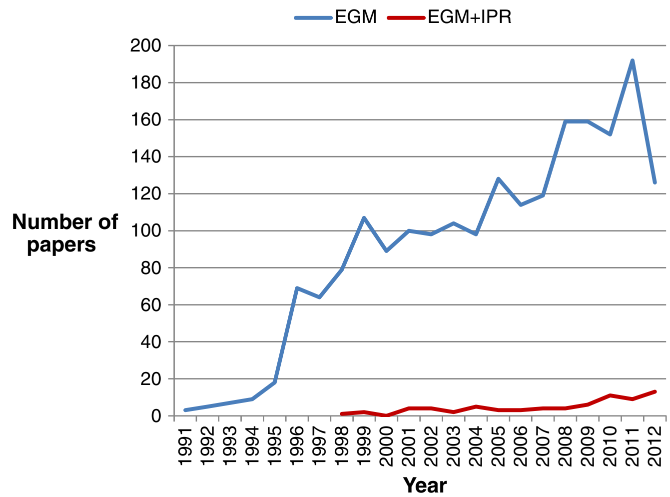

Fig. 1. Number of published papers by year.

Connolly and Valderrama (2005) make reference to IPR, but commence their analysis by assuming the absence of both domestic and international IPR enforcement. Afterwards, they introduce IPR, which force Southern imitators to pay a license fee to Northern innovators, and model them simultaneously as an increase in the imitative research fixed cost and a reduction in the fixed cost of innovative research. The authors show that the presence of IPR can positively affect both Northern and Southern welfare and argue that, in a world where growth is driven by technology and Southern research affects that developed in the North, Southern nations can benefit from some degree of IPR to foreign firms. Additionally, they state that the imposition of a low level of IPR leads to superior steady state growth rates compared with Southern trade liberalization alone. Moreover, they show that the gain associated with the increase in IPR is greater for both countries, as long as the South remains open to imports of Northern intermediate goods.

Afonso (2012) does not ignore IPR, but does not explicitly model them either. For instance, the author argues that the investment in a blueprint can only be claimed if profits are positive within a given period in the future and if this is guaranteed by both costly R&D and internal patents enforcement, that is, a national IPR system which protects the leader firm's monopoly of that quality good internally though not worldwide, while simultaneously spreading learned knowledge to other national firms in line with Connolly and Valderrama, (2005).

Connolly and Valderrama (2005) and Afonso (2012) introduce IPR enforcement, but deal with this issue in a simplified manner because their main purpose was not to discuss IPR. Hence, departing from modeling frames similar to these studies, we intend to focus our research on IPR. As mentioned above, we introduce a new parameter into the probability of imitation, which is treated by following the consensual position in the literature, that IPR protection makes imitation more difficult (e.g., Park and Lippoldt, 2005; Nair-Reichert and Duncan, 2008; Trommetter, 2010; Ivus, 2011). Nevertheless, it is important to stress that there is no agreement regarding the best way to introduce IPR into this type of model (see, for example, Mondal and Gupta, 2009; Sá et al., 2009; Wu, 2010).

[2] Scopus is the largest abstract and citation database of peer-reviewed literature and quality web sources, having been designed and developed for over 500 users and librarians internationally. This dataset includes the abstracts and references of 15,000 peer-reviewed journals from more than 4000 international publishers (http://www.elsevier.com/wps/find/bibliographicdatabasedescription.cws_home/705152/description#description, accessed on 22th October 2012).

[3] This search procedure is unrestricted and comprehensive in the sense that the engine searches in the whole text. Even so, it is important, bearing in mind that any bibliometric exercise bares a limitation concerning the impossibility of the chosen keyword being able to embrace the whole research in analysis (in our case, IPR and endogenous growth models related research).

Lastly, our results are related to the IPR literature (see Chu, 2009). This literature considers that the IPR effect on economic growth is unclear. That is to say, while some studies identify a positive relationship, others identify negative or inconclusive results. However, our results are in line with Helpman (1993), Taylor (1994), Datta and Mohtadi (2006), Furukawa (2007) and Eicher and García-Peñalosa (2008), who refute the idea that stronger IPR are always better.

Our work is not original neither in terms of model and mathematical formalization nor in terms of results, if we refer to each one of them separately. This work is not the only one examining the IPR in the context of product cycle model. For instance, Lai (1998), Yang and Maskus (2001) and Akiyama and Furukawa (2009) also use a north–south product cycle model but they employ a different mathematical formalization and they study, in particular, the effects of IPR on innovation while we use a mathematical formalization similar to Connolly and Valderrama (2005) and Afonso (2012) to observe the effect of IPR protection in economic growth. In addition, this is not the only paper which finds a given sign for the relationship between IPR and economic growth. According to the previous statements, there are works which find either a positive, a negative or an inconclusive relationship between IPR and economic growth, as we also conclude in Azevedo et al. (2012). In the quoted work, we verify that the great part of the papers about IPR does not study directly this relationship or this result is not their main goal. Then, our motivation is to study the mentioned relationship using a mathematical formalization similar to Connolly and Valderrama (2005) and Afonso (2012) to find a relationship between IPR and economic growth, though. Therefore, this work distances itself from the others because we use a different framework, a different mathematical formalization, which is not original but was not applied before with this aim. In this sense, our contribution to the literature, our novelty, is to develop an EGM with IPR protection and to try to check the sign of this relationship using a different approach from the ones which have had this purpose.

The present paper is structured as follows. After a brief introduction, Section 2 presents the set up of the model. Section 3 focuses in detail on the equilibrium and Section 4 concludes.

2. Set up of the model

We assume two economies with three sectors: intermediate goods, final goods and designs (R&D sector). The former sector operates in a monopolistic competition scenario, whereas the latter two operate under perfect competition. In particular, the R&D sector is closely associated with the intermediate goods sector: when successful, R&D activities result in innovations in the North and imitations in the South, and as in Romer (1990), provide inputs to the intermediate goods sector. In turn, quality adjusted intermediate goods and labor are inputs into the final goods sector. Thus, we use a standard quality ladder model, which, by considering two countries, also follows the contributions of authors such as Grossman and Helpman (1991b), and Barro and Sala-i-Martin (1997). The final good is consumed and the fraction that is not consumed is used in R&D activities or in the production of intermediate goods.

2.1. Final goods sector

In the production of the competitive final good, we have established some particular premises: (i) there is a fixed number of intermediate sectors, J; (ii) only the top quality good will be sold under limit pricing; (iii) the quality of each good rises with successful innovations; (iv) each quality upgrade can be considered as a step further up the ladder and the dimension of each step shows the dimension of quality upgrades. Technological knowledge is thus incorporated into intermediate goods and economic growth in each country is determined by technological developments in the quality of available inputs, independently of the country of origin. Final good can be produced both in North (country $i = N$) and in South (country $i = S$), by perfectly competitive firms, and the constant returns to scale production function at time t is:

$$Y_i(t) = A_i L_i^{\alpha} \sum_{j=1}^{J} (z_i(j,t))^{1-\alpha}, i \in \{N, S\}, \tag{1}$$

where:

$$z_i(j,t) = q^{k_N(j,t)} x_i(j,t). \tag{2}$$

The exogenous productivity level is given by a positive variable A_i, which depends on the country's institutions, related, for example, to government services, property rights and tax law; we assume $A_S < A_N$. The labor input used in the production of the final good is represented by L_i, $\alpha \in [0,1]$ being the labor share. $z_i(j,t)$ is the quality adjusted intermediate good j at time t. q, an exogenously fixed constant larger than 1, expressing the size of each quality improvement achieved by each success in R&D. The steps of the quality ladder are represented by k, with greater k indicating greater quality. The quality adjusted rank of j will increase from 1 ($q^0 = 1$) to q^1 with the first innovation, to q^2 with the second and to q^{kj} with the k_j^{th} innovation, which is used due to the profit maximizing limit pricing by the monopolist producers. The quantity $x_i(j,t)$ of j is used along with labor to create $Y_i(t)$. $(1-\alpha)$ is the aggregate intermediate goods input share.

In whichever country, for a given $p_i(t)$ and $p(j,t)$, the implicit demand for each j by the representative producer of ith final good is:

$$x_i(j,t) = L_i \left[A_i (1-\alpha) \frac{p_i(t)}{p(j,t)} \right]^{\frac{1}{\alpha}} q^{k_N(j,t)\left[\frac{1-\alpha}{\alpha}\right]}, \tag{3}$$

where $p_i(t)$ is the price of the final good i and $p(j,t)$ is the price of intermediate good j.

Replacing $x_i(j,t)$ in Eq. (2) with Eq. (3), using the resulting expression in Eq. (1), and substituting $p_i(t)$ by the MC_i and $p(j,t)$ by the limit price presented in the next subsection, the supply of final good in each country is:

$$Y_N(t) = A_N^{\frac{1}{\alpha}} \left(\frac{1-\alpha}{q} \right)^{\frac{1-\alpha}{\alpha}} L_N Q_N \left[n_{NN} + n_{NS} \left(1 + \tau_{x_S} \right)^{\frac{1-\alpha}{\alpha}} MC_S^{\frac{1-\alpha}{\alpha}} + n_S q^{\frac{1-\alpha}{\alpha}} \right], \tag{4}$$

$$Y_S(t) = A_S^{\frac{1}{\alpha}} \left(\frac{1-\alpha}{q} \right)^{\frac{1-\alpha}{\alpha}} L_S Q_N \left[n_{NN} \left(\frac{MC_S}{1+\tau_{x_S}} \right)^{\frac{1-\alpha}{\alpha}} + n_{NS} + n_S q^{\frac{1-\alpha}{\alpha}} \left(\frac{MC_S}{1+\tau_{x_S}} \right)^{\frac{1-\alpha}{\alpha}} \right], \tag{5}$$

$$Q_N = \sum_{j=1}^{J} q^{\frac{k_N(j,t)(1-\alpha)}{\alpha}}. \tag{6}$$

Q_N is the Northern aggregate quality index; thus, aggregate production in both countries depends on Q_N, since limit pricing with free trade guarantees that only the highest quality technology will be used. Consequently, even when an intermediate good is produced in the South, its quality level is the same as the prime Northern quality level.

In a scenario of perfect competition, the marginal cost, MC matches the price of the final good, p; i.e., $MC_i = p_i$. In this sense, the MC of producing an intermediate good is not dependent on its degree of quality and is similar across all domestic sectors. We normalize to one the Northern MC, $MC_N = 1$, and we assume that the arguments yield equilibrium marginal costs that are larger in the North than in the South, $MC_N > MC_S$.

2.2. Intermediate goods sector

What will the country producing the intermediate goods used in the production of final goods be? The answer depends not only on trade barriers, but also on each country's degree of technological sophistication. As the North is technologically more advanced, it is the innovator in pushing the world's technology frontier further. However, we consider that the South may improve its domestic technological knowledge by imitating Northern technology, at least until the gap is eliminated.

When the knowledge of how to produce an intermediate good is internally available, this intermediate good can be produced using the final goods production function. The *MC* of producing an intermediate good is the same as the *MC* of producing the final good, MC_i. We assume that $0 < MC_S < MC_N = 1$, which allows the South to produce the same quality level, k, at a price lower than its Northern competitor. This makes it possible for a successfully imitating Southern firm to capture the international market.

Additionally, we consider that within a country the knowledge of how to make a good is free.[4] Distinguishing between domestic IPR and international IPR, we suppose that the former are protected. That is, the innovator is domestically protected by a system of domestic IPR, and in a set of Schumpeterian creative destruction, continues as the best quality producer. However, our focus is on international IPR, which appear to protect the innovator Northern country from foreign copies. Hence, from now on, we mention IPR protection to refer to international IPR protection.[5]

Following the contributions of Barro and Sala-i-Martin (2004, Ch. 7) and Afonso (2012), according to the demand in Eq. (3), the monopolist intermediate goods firms maximize their profits throughout the optimal price, given by the following mark up:

$$p(k,j,t) = p(j,t) = p = \frac{1}{1-\alpha}, \tag{7}$$

which is constant over time, across firms and for all quality degrees. The nearer α is to zero, the lower is the mark up and thus the less room there is for monopoly pricing.

The kind of competition handled by the firm influences the expected profits. There are three types of firms: Northern firms facing Northern competition, n_{NN}; Northern firms facing Southern competition, n_{NS}; Southern imitating firms facing Northern competition, n_S. Thus, there are J sectors, $J = n_S + n_{NS} + n_{NN}$,[6] and bearing in mind I_N and I_S (the probability of successful innovation and imitation, respectively, which will be presented in Subsection 2.3), n_{NN}, n_{NS} and n_S depend on entry and exit:

$$\dot{n}_{NN} = I_N(1-I_S)n_{NS} - [I_N I_S + (1-I_N)I_S]n_{NN} \tag{8a}$$

$$\dot{n}_{NS} = I_N(I_S n_{NN} + n_S) - [(1-I_N)I_S + I_N(1-I_S)]n_{NS} \tag{8b}$$

$$\dot{n}_S = (1-I_N)I_S n_{NN}^f + n_{NS}^f - I_N n_S \tag{8c}$$

Thus, Northern firms challenging Northern rivalry select a limit price slightly below q times the lowest price at which the preceding innovator could sell, as the good is q times more productive than the precursor. $MC_N = 1$ is the lowest price at which the preceding innovator could sell in the North and $(1+\tau_{x_S})$ is the lowest price at which the good could be sold in the South, as it is subject to Southern tariffs on intermediates and *ad-valorem* transportation costs, τ_{x_S}. Thus, Northern firms facing Northern competition, n_{NN}, have two limit prices: $P_{NN} = qMC_N = q$ for national sales and $P_{NN}^f = q(1+\tau_{x_S})$ for sales to the South.[7] At these limit prices, world sales of all obsolete technologies will be wiped out. Similarly, Northern firms challenging Southern competition, n_{NS}, have limit prices $P_{NS} = qMC_S(1+\tau_{x_S})$ internally and $P_{NS}^f = qMC_S$ in a foreign country. Southern firms, n_S, always face Northern competition and impose limit prices $P_S^f = 1$ for sales abroad and $P_S = 1+\tau_{x_S}$ for home sales. In each intermediate good, the firm with the highest quality employs pricing to remove sales of lower quality. If $q(1-\alpha)$ is greater than $MC_N = 1$, the leader will use the monopoly pricing. However, if $q(1-\alpha)$ is less than $MC_N = 1$, the leader of each industry will use the limit pricing to capture the total market. In Connolly and Valderrama (2005), the leader in each industry uses limit pricing to remove sales of lower quality.[8] Innovations are drastic, so the dimension of quality upgrades is large enough for a firm in the North to control the international market with a unique quality level upgrade over a Southern imitation, $\left(q > \frac{(1+\tau_{x_S})}{MC_S}\right)$.[9] A firm in the South can win the worldwide market by imitating the leader in the North (and fixing a smaller price). Hence, there is a Vernon-type product cycle (e.g., Vernon, 1966) whereby production moves from the North to the South with successful imitation, and back to the North with new innovation.

2.3. R&D sector

Economic growth is boosted by R&D activities. Firms decide the amount of resources to apply, based on the expected present value of profits from successful research, which depends on the probabilities of innovation and imitation. In the North, R&D activities lead to the emergence of innovative blueprints for manufacturing intermediate goods, which improve their quality. In an intermediate goods sector j, currently at quality level $k_N(j,t)$, $I_N(j,t)$ represents the probability at time t that the $(k_N(j,t)+1)$th innovation will occur and will follow a Poisson process. Similarly, we also consider that these designs are internally protected through IPR and that the leader firm in each j (that is, the one holding the latest patent) uses limit pricing to guarantee monopoly. The probabilities of successful innovation and imitation are essential to R&D, as the profit yields accruing during each period t to the monopolist and the duration of the monopoly power contribute to the value of the top patent. These probabilities creatively extinguish either the extant top design (e.g., Aghion and Howitt, 1992) or the production in the North (e.g., Grossman and Helpman, 1991a, Ch. 12) influencing the monopoly duration. $I_N(j,t)$ is given by:

$$I_N(j,t) = y_N(j,t)\beta_N q^{k_N(j,t)} \zeta_N^{-1} q^{-\alpha^{-1}k_N(j,t)}, \tag{9}$$

where $y_N(j,t)$ is the flow of final good resources in the North allocated to R&D in j, which defines our set up as a lab equipment model (e.g., Rivera-Batiz and Romer, 1991); $\beta_N q^{k_N(j,t)}$ (with $\beta_N > 0$) denotes learning by previous domestic R&D, as a positive learning effect of accumulated public knowledge from earlier successful R&D (e.g., Grossman and Helpman, 1991a, Ch. 12; Connolly, 2003); $\zeta_N^{-1} q^{-\alpha^{-1}k_N(j,t)}$ (with $\zeta_N > 0$) is the adverse effect (cost of complexity) caused by the rising complexity of quality upgrades (e.g., Kortum, 1993, 1997; Dinopoulos and Segerstrom, 2007).[10]

Since the South is less developed, though not by too great a margin, we consider that there are intermediate goods for which $k_S < k_N$, implying that there are a number of top qualities produced in both countries even without international trade (i.e., for which $k_S = k_N$). The existence of international trade allows the South to gain access to all the best

[4] There are countries that simultaneously have enforced patents which protect the lead firm's national monopoly of a specific quality good and the associated knowledge. Hence, the other national firms cannot use this knowledge without any cost to themselves.

[5] Relatively to the articles that we quote in terms of IPR discussion, it is important to highlight that the great part of them make the analysis especially in terms of international protection. However, we also consider some articles which discuss IPR internally because we consider that some of their conclusions and analysis are important to our study and to understand some issues about the IPR protection.

[6] We fix $J = 1$, so that n's will be the share of the Southern market kept by each group (Connolly and Valderrama, 2005).

[7] "This holds if $q(1-\alpha) \le 1$. If instead, $q(1-\alpha) > 1$, then Northern firms will use monopoly pricing" (Connolly and Valderrama, 2005: 13).

[8] Even without internal IPR protection, the presence of any determined cost to mimic will successfully exclude domestic copy of a national product.

[9] There are different scenarios of drastic innovations in the literature (for example, the General Purpose Technologies, usually christened GPT) but, in the present work, we will not discuss these.

[10] As will become clear later on, the technical reason for the existence of the production function parameter α in Eq. (9) is the complexity cost, which along with the positive learning effect exactly balances the positive influence of the quality rung on the profits of each top intermediate good firm. In this sense, β_N reflects a positive spillover effect from past experience and ζ_N is a fixed cost of innovative research.

qualities so that it becomes an imitator, increasing the instantaneous probability of successful imitation of the top quality $k_N(j,t)$ in j, $I_S(j,t)$, given by

$$\begin{aligned} I_S(j,t) &= y_S(j,t)\beta_S q^{k_S(j,t)} \frac{e^{\varphi}}{\zeta_S \widetilde{Q}^{\sigma}} q^{-\frac{k_N(j,t)}{\alpha}} \frac{1}{\delta}\left(\frac{1}{\widetilde{Q}}\right)^{1-\delta} \\ &= y_S(j,t)\beta_S \frac{e^{\varphi}}{\zeta_S \delta} \widetilde{Q}^{\delta-\sigma} q^{k_N(j,t)\frac{(\alpha-1)}{\alpha}}, \end{aligned} \tag{10}$$

where $y_S(j,t)$ represents the flow of domestic final good resources allocated to R&D in intermediate good j, $\beta_S q^{k_S(j,t)}$ denotes the learning by past imitations (and we assume that $0 < \beta_S < \beta_N$ and $k_S < k_N$, i.e., we consider that the learning by past imitations is lower than the learning by past innovations). In a similar way, according to the empirical findings of Mansfield et al. (1981), the fixed cost of imitation ζ_S is supposed to be smaller than the innovation cost ζ_N. In line with Connolly and Valderrama (2005), the cost of imitation $\frac{\zeta_S \widetilde{Q}^{\sigma}}{e^{\varphi}}$ is affected by two new factors. Firstly, it depends positively on the sector j South/North technology ratio $\hat{q}_j$, and indicates the increasing cost of imitation as Southern technology approaches Northern technology. Therefore, there are decreasing returns to imitation since the group of goods that can be selected for imitation diminishes. In this context, σ influences the speed with which the cost of imitation increases as the technology gap drops.[11] Secondly, the cost depends negatively on the interaction between the two countries, φ. This is quantified by the South's openness to imports of intermediate goods, M, scaled by the aggregate North technology level, $Q_N = \sum_{j=1}^{J} q^{\frac{k_N(j,t)(1-\alpha)}{\alpha}}$. Once the imitation cost increases and the technology gap between North and South decreases, both the probability of imitation and the probability of innovation are modified during transition towards the steady state.

Also in Eq. (10), δ [0,1] measures the degree of IPR enforcement in the South,[12] $\varphi = \left(\frac{M}{Q_N}\right)^{\eta}$ and $\widetilde{Q} = \frac{q^{k_S(j,t)} * J}{q^{k_N(j,t)} * J} = \frac{QS}{QN} = \hat{q}_j$ (with $0<\widetilde{Q}<1$). Hence, we fix a negative relationship between δ and $I_S(j,t)$: the greater the parameter δ, the greater the degree of IPR enforcement in the South and the smaller the probability of successful imitation. Moreover, we consider that the smaller is the distance to the technological frontier (the higher $\widetilde{Q}$) the more these countries will implement IPR laws.

In general, developed countries have higher levels of IPR protection (e.g., Lai and Qiu, 2003; Grossman and Lai, 2004; Naghavi, 2007; Dinopoulos and Segerstrom, 2010). Nevertheless, it seems that in future research it will be necessary to verify whether the North has implemented IPR laws more or less rigorously compared with the South, since some other issues emerge from this discussion. For instance, it is interesting to analyze the causality effects that may here be involved: are developing economies less developed because they have weaker institutions, which also implies inability to apply stronger enforcement of IPR laws, or do these less developed countries fix a low level of protection, having also a low enforcement of IPR laws, because they intend to stimulate imitation in order to grow faster? We should bear in mind that some studies state that the relationship between the degree of IPR and innovation is not linear: it has an inverted U-shape (e.g., Furukawa, 2007, 2010; Panagopoulos, 2009).

Following this line of reasoning, Kim et al. (2012) empirically study not only the importance of the strength of IPR, but also the type of IPR suitable for distinct levels of economic development. The main conclusion of this study is that patent protection influences R&D intensity, and thus affects economic growth. Moreover, the results show that patent protection improves innovation (and hence economic growth) in countries where there is the capacity to develop innovative R&D. Thus, according to Kim et al. (2012), on the one hand R&D has a positive effect on economic growth in high income countries and in those middle income countries that use intellectual property protection to reward imitative and adaptive R&D, while on the other hand petty patents or utility models are positively linked with the R&D intensity of middle to low income countries.

The results of Xu and Chiang (2005) state that high income countries enjoy both internal technology and foreign technology, which is included in imported capital goods, whereas middle income countries benefit from technology spillovers from both foreign patents and imported capital goods. Finally, low income countries receive essential benefits from foreign patents. Moreover, they conclude that government policies regarding IPR protection and trade openness have significant effects on foreign technology spillovers in middle income and poor nations. In undertaking this study, the authors use the index of patent rights constructed by Ginarte and Park (1997), (whose value varies from zero to five, where zero is the weakest and five is the strongest value), as the measure of IPR and we can verify that, in the sample, the US – North – has the highest value of IPR (4.55), while Indonesia – South – has the lowest (0.64). If we place the values in ascending order, it is possible to confirm that in general Southern countries have lower levels of IPR protection, whereas Northern countries have higher levels.

2.4. Consumers

We assume that the Northern consumer makes consumption and savings decisions so that he/she can maximize the present value lifetime utility:[13]

$$\max_{\{C_N, C_S^*, a\} t\to\infty} \int_0^{\infty} u\left(\overline{C}_N\right) e^{-\rho t} dt \tag{11}$$

$$u\left(\overline{C}_N\right) = \left(\frac{\overline{C}_N^{1-\theta} - 1}{1-\theta}\right) \tag{12}$$

$$\overline{C}_N = C_N^{k} {C_S^f}^{1-k} \tag{13}$$

$$\dot{a} = r_N a + w - E_N \tag{14}$$

$$E_N = P_N C_N + P_S^f C_S^f \tag{15}$$

$u\left(\overline{C}_N\right)$ is the instantaneous utility function with a constant intertemporal elasticity of substitution (CIES), where $\overline{C}_N$ is the Northern composite good, θ defines the inverse intertemporal elasticity of substitution and $\rho > 0$ is the homogeneous subjective discount rate.

Eq. (13) is a Cobb–Douglas aggregator that describes the Northern composite good, $\overline{C}_N$, in terms of Northern and Southern final goods, C_N and C_S^f, respectively, both consumed in the North (f means foreign or exports). In the same equation, parameter k corresponds to domestic expenditure-share.

The return to assets, a, in the North is r_N, and the wage rate is w. One unit of labor is supplied inelastically during every period. The path of the value of assets, $\dot{a}$, is represented in (14) as being the difference of labor and interest income minus Northern consumption expenditures, E_N (the budget constraint that is expressed as savings = income − consumption). The total Northern expenditures, E_N, are described in Eq. (15).

[11] Once the experience obtained from imitation rises one-to-one with $\hat{q}$, σ has to be greater than 1 for the probability of imitation to decrease as $\hat{q}$ rises. This assures a smooth transition.

[12] As stressed previously, we intend to understand in what form IPR should be treated in an endogenous growth model but there is no a consensus in the literature about the best way to introduce IPR in a model. However, the most part of literature argues that IPR make imitation harder and then, we establish a negative relation between IPR and imitation.

[13] Note that the model is not without drawbacks since we consider some assumptions, similarly to Afonso (2012), that simplify the model. However, we believe they do not affect significantly the conclusions because these issues are not in discussion in the present work. We can underline two of these unrealistic assumptions: infinitely-lively agents maximize lifetime utility and full employment of labor both in the North and in the South.

As in Connolly and Valderrama (2005), and Obstfeld and Rogoff (1996), the consumption-based price index, $\overline{P}_N$, is characterized as the minimum expenditure, E_N, so that the composite good index, $\overline{C}_N = 1$, for a given set of prices:

$$\overline{P}_N = \left(\frac{P_N}{k}\right)^{k}\left(\frac{P_S^f}{1-k}\right)^{1-k} \quad (16)$$

From standard calculations, we obtain two expressions for consumer demands:

$$C_N = k\frac{\overline{P}_N}{P_N}\overline{C}_N \quad (17)$$

$$C_S^f = (1-k)\frac{\overline{P}_N}{P_S^f}\overline{C}_N \quad (18)$$

If we transfer these expressions to the household utility maximization problem, we arrive at the usual expression for consumption growth (the standard Euler equation):

$$\frac{\dot{\overline{C}}_N}{\overline{C}_N} = \frac{1}{\theta}\left(r_N - \frac{\dot{\overline{P}}_N}{\overline{P}_N} - \rho\right) \quad (19)$$

The problem of the Southern consumer is absolutely symmetric:

$$\max_{\{C_N^*, C_S, a\}t\to\infty} \int_0^\infty u\left(\overline{C}_S\right)e^{-\rho t}dt \quad (20)$$

$$u\left(\overline{C}_S\right) = \left(\frac{\overline{C}_S^{1-\theta}-1}{1-\theta}\right) \quad (21)$$

$$\overline{C}_S = C_N^{f^{1-b}} C_S^{b} \quad (22)$$

$$\dot{a} = r_S a + w - E_S \quad (23)$$

$$E_S = P_S C_S + P_N^f C_N^f \quad (24)$$

Assuming that both countries spend the same income share on the goods produced in the North, $b = 1 - k$, the resulting expression for the Southern households' demand is:

$$\overline{P}_S = \left(\frac{P_N^f}{k}\right)^{(k)}\left(\frac{P_S}{1-k}\right)^{(1-k)} \quad (25)$$

$$C_N^f = k\frac{\overline{P}_S}{P_N^f}\overline{C}_S \quad (26)$$

$$C_S = (1-k)\frac{\overline{P}_S}{P_S}\overline{C}_S \quad (27)$$

Additionally, hypothetically, the relative price of the South's final good always adjusts to balance trade:

$$P_S = \frac{P_N\left(1+\tau_{Y_S}\right)C_N^f + P_{NS}^f n_{NS} X_{NS}^f + P_{NN}^f n_{NN} X_{NN}^f - P_{NS}^f n_{NS} X_S^f}{\left(1+\tau_{Y_N}\right)C_S^f} \quad (28)$$

3. General equilibrium

After describing the countries' structures in our modeling setup, we go on to compute the equilibrium dynamics of technological knowledge which is responsible for economic growth in cases where neither labor nor human capital accumulation exist. The effects caused by the interaction between the North and South, deriving from international trade of intermediate goods, occupy an important position in the dynamics general equilibrium.

The dynamic general equilibrium, and thus the particular case of the steady state, is defined by the path of resources allocation and prices, such that: (i) consumers and firms solve their problems; (ii) R&D free-entry conditions are met; and (iii) markets clear.

3.1. Equilibrium R&D

The expected current value of the flow of profits to the producer of j, $V(k,j,t)$,[14] relies on the profits at t, $\Pi_S(k,j,t)$, on the equilibrium interest rate and on the expected duration of the flow (i.e., expected duration of research leadership). $\Pi_S(k,j,t)$ depends on $MC_N = 1$, MC_S, $P_{NN}(j)$, $P_{NS}(j)$, $x_N(k,j,t)$ and $x_S(k,j,t)$ and thus on trade. For example, the expected duration of the imitator's leadership depends on $I_N(k,j,t)$, which is the potential challenger, since the Southern entrant competes with a Northern incumbent. Thus, $V_S(k,j,t)$ is:

$$V_S\left(k,\bar{j},t\right) = \int_t^\infty \Pi_S\left(k,\bar{j},t\right) exp\left[-\int_t^s \left(r_S(v) + I_N\left(k,\bar{j},v\right)\right)dv\right]ds \quad (29)$$

where $\Pi_S(k,j,t)$ using an imitation of the top quality k is:

$$\Pi_S\left(k,\bar{j},t\right) = (1-\alpha)^{\alpha^{-1}} q^{k_N(j,t)(1-\alpha)\alpha^{-1}}\left[(1-MC_S)L_N(t)A_N^{\alpha^{-1}} + \left(1+\tau_{x_S}-MC_S\right)L_S(t)\left(A_S\frac{MC_S}{1+\tau_{x_S}}\right)^{\alpha^{-1}}\right] \quad (30)$$

[14] I.e., $V(k, j, t)$ is the market value of the patent or the value of the monopolist firm, owned by consumers.

Differentiating Eq. (29) using Leibniz's rule, we obtain the dynamic arbitrage equation:

$$r_S(v)+I_N\left(k,\bar{j},v\right)=\frac{\dot{V}_S\left(k,\bar{j},t\right)}{V_S\left(k,\bar{j},t\right)}+\frac{\Pi_S\left(k,\bar{j},t\right)}{V_S\left(k,\bar{j},t\right)}-\dot{k}\left(\bar{j},t\right)\left(\frac{1-\alpha}{\alpha}\right)\ln q \tag{31}$$

Plugging Eq. (31) into the free entry R&D equilibrium condition, $I_S(j,t)V_S(j,t)=y_S(j,t)$, and solving it for I_N, we obtain the equilibrium probability of successful innovation. Since the probability of successful innovation drives the technological knowledge progress, equilibrium can be transferred to the path of Northern technological knowledge, from which free trade in intermediate goods also allows the South to benefit. The relationship turns out to yield the well known expression for the equilibrium growth rate of Q_N:

$$\hat{Q}_N=I_N\left(q^{(1-\alpha)\alpha^{-1}}-1\right). \tag{32}$$

3.2. Steady state

The steady state is characterized by constant growth, g^*, common to both countries, and is driven by available technological knowledge progress,

$$g^*=\hat{Q}_N^*=\hat{Y}_N^*=\hat{Y}_S^*=\hat{X}_N^*=\hat{X}_S^*=\hat{R}_N^*=\hat{R}_S^*=\hat{C}_N^*=\hat{C}_S^*=\hat{c}^*=\frac{1}{\theta}(r^*-\rho) \tag{33}$$

$\Rightarrow$ in particular $\hat{\widetilde{Q}}^*=0$ and sector shares n_{NN}, n_{NS} and n_S, will be constant.

Hence, the steady state growth rates of both countries depend exclusively on Northern technological progress, while the North remains the lead innovating country. Additionally, international trade and the succeeding risk of losing the market for a certain intermediate good to Southern imitation implies that the Northern rate of innovation depends on the Southern rate of imitation.

In steady state, $\frac{\dot{V}_S\left(k,\bar{j},t\right)}{V_S\left(k,\bar{j},t\right)}=\dot{k}\left(\bar{j},t\right)\left(\frac{1-\alpha}{\alpha}\right)\ln q$ and thus, bearing in mind Eq. (10), Eq. (31) becomes:

$$I_N^*=\beta_S\frac{e^{\varphi}}{\zeta_S\delta}\widetilde{Q}^{*\delta-\sigma}(1-\alpha)^{\alpha^{-1}}\left[(1-MC_S)L_N{}^*A_N{}^{\alpha^{-1}}+\left(1+\tau_{x_S}-MC_S\right)L_S{}^*\left(A_S\frac{MC_S}{1+\tau_{x_S}}\right)^{\alpha^{-1}}\right]-r^* \tag{34}$$

Eq. (34) shows that the available (or Northern) technological knowledge progress:

(i) hinges on the returns to innovation, which in turn rely on terms of I_S, $\beta_S\frac{e^{\varphi}}{\zeta_S\delta}\widetilde{Q}^{*\delta-\sigma}$, through inter country competition in intermediate goods. That is, the positive level effect from N to S (the access to the top quality intermediate goods increases production and thus the resources to imitative R&D) feeds back into N, affecting Q_N by creative destruction;
(ii) is independent of its scale, since it is not affected by the rung of quality k. Indeed, the positive influence of the quality rung on profits and on the learning effect is exactly offset by the negative influence on the complexity cost;[15]
(iii) is dependent on the market size effects.

Taking into account Eq. (32), Eq. (33) and Eq. (34), we can reach the steady state interest rate: firstly, we put Eq. (34) into Eq. (32) in replacing I_N, secondly we use Eq. (33) into the obtained equation replacing $\hat{Q}_N^*$ and finally we solve this in order to r^*. Indeed, since steady state prices of non-tradable and tradable goods are constant as well as the growth rate of available technological knowledge, see Eqs. (32) and (34), the common steady state interest rate, r^*, is obtained:

$$r^*=\frac{\left\{\beta_S\frac{e^{\varphi}}{\zeta_S\delta}\widetilde{Q}^{*\delta-\sigma}(1-\alpha)^{\alpha^{-1}}\left[(1-MC_S)L_N{}^*A_N{}^{\alpha^{-1}}+\left(1+\tau_{x_S}-MC_S\right)L_S{}^*\left(A_S\frac{MC_S}{1+\tau_{x_S}}\right)^{\alpha^{-1}}\right]\right\}\left(q^{(1-\alpha)\alpha^{-1}}-1\right)+\frac{1}{\theta}\rho}{q^{(1-\alpha)\alpha^{-1}}-1+\frac{1}{\theta}} \tag{35}$$

Now, we can easily achieve the steady state growth rate by using the previous expression in the Euler equation:

$$g^*=\frac{1}{\theta}\left[\left(\frac{\left\{\beta_S\frac{e^{\varphi}}{\zeta_S\delta}\widetilde{Q}^{*\delta-\sigma}(1-\alpha)^{\alpha^{-1}}\left[(1-MC_S)L_N{}^*A_N{}^{\alpha^{-1}}+\left(1+\tau_{x_S}-MC_S\right)L_S{}^*\left(A_S\frac{MC_S}{1+\tau_{x_S}}\right)^{\alpha^{-1}}\right]\right\}\left(q^{(1-\alpha)\alpha^{-1}}-1\right)+\frac{1}{\theta}\rho}{q^{(1-\alpha)\alpha^{-1}}-1+\frac{1}{\theta}}\right)-\rho\right] \tag{36}$$

The common steady state growth rates imply the persistence of a steady state north–south gap in technological knowledge. While total convergence in available technological knowledge is immediate with international trade (level effect), domestic levels may not converge totally; i.e., Q_N^* may stay below one.

[15] This is crucial for a symmetric equilibrium (on asymmetric equilibrium in quality ladder models and its growth consequences, see Cozzi et al., 2007).

While evaluation of Eq. (35) or Eq. (36) requires solving for transitional dynamics through calibration and simulation,[16] we can, however, emphasize six ways, in addition to the level effects, through which the trade influences, in opposite directions, steady state growth.

The first way in which trade influences steady state growth is the positive catching-up effect on the probability of successful imitation. The advantages of backwardness are only obtained in the presence of trade. Through the feedback effect, the probability of successful innovation is also affected and thus the steady state growth rate.

The second way is the positive spillovers from The North to the South. Each innovation in the North tends to lower the cost of imitation by the South because the backwardness advantage is strengthened with each improvement of the technological-knowledge frontier.

The third way is the positive effect arising from market enlargement, which encourages R&D activities by effecting the respective profitability.

The fourth (counteracting) channel is the monopolistic competition mark-up. The monopolist in The North loses profits with the entry into trade: the average mark-up is smaller under trade. The reason for this is that in pre-trade successful innovators are protected from international competition. Once engaged in trade and imitation becomes profitable, profit margins in the North are reduced, which discourages R&D activities.

The fifth way through which trade affects steady state growth, counteracting as well, is that firms in the South have to support the R&D cost of state-of-the-art intermediate goods, possibly several quality rungs above (and thus more complex) their own experience level in pre-trade.

The sixth way through which trade affects steady state growth, also counteracting, is by IPR; i.e., by increasing the IPR enforcement, the steady state growth rate decreases. In terms of steady state comparative static, and differentiating Eq. (36) with respect to IPR parameter (δ), we achieve $-\frac{e^{\varphi}\zeta_S}{(\zeta_S\delta)^2}+\frac{e^{\varphi}}{\zeta_S\delta}\ln\widetilde{Q}^*<0, \widetilde{Q}^{*\delta-\sigma}\left(-\frac{e^{\varphi}\zeta_S}{(\zeta_S\delta)^2}+\frac{e^{\varphi}}{\zeta_S\delta}\ln\widetilde{Q}^*\right)<0$ and thus $\frac{\partial g^*}{\partial\delta}<0$. The rise in IPR makes imitation costly in the South, and as a result the probability of successful imitation decreases. Through the feedback effect, this rise also has a negative effect on the steady state probability of innovation, which supports the literature that argues that the IPR effect on economic growth is not always positive.

Moreover, as we have discussed above, this effect can be ambiguous. On the one hand, there are studies that argue for a positive relationship between IPR enforcement and economic growth (see for instance Falvey et al., 2009, and Chu et al., 2012), while others present a negative one, a result dependent on certain features or even an inconclusive result (see, e.g., Datta and Mohtadi, 2006; Horii and Iwaisako, 2007; Furukawa, 2010). On the other hand, in general, empirical evidence suggests a positive effect of IPR on economic growth (see Azevedo et al., 2012). However, this evidence can be justified by the empirical measure of patent protection most commonly used (e.g., Chu, 2009).

In this sense, we can say that the result is still pending. In the next section we will present the main conclusions of the paper and discuss the possibility of following some research avenues in the future.

4. Conclusions

The relationship between IPR and economic growth (or innovation) has been increasingly analyzed in recent years, and IPR have become a common field of discussion in the literature relating to economic growth. However, the existing literature presents different results regarding the effect of IPR on economic growth, and some studies present distinct results under some constraints. Hence, we can conclude that this link is not clear.

In this paper, we have emphasized the importance of analyzing IPR within an endogenous growth theoretical framework. Using as our motivation a brief account of the development of IPR literature, we have analyzed the most commonly used mechanisms for introducing IPR into a model in an effort to better understand the connection between IPR and economic growth. Our general equilibrium endogenous growth model considers an IPR parameter in the function of the probability of imitation. We have also checked the sign of the effect of IPR enforcement on economic growth and have discussed the differences between our result and those reported in the related literature.

In particular, by introducing the IPR parameter into the probability of imitation function, we have made imitation more difficult; i.e., we have reduced the probability of imitation. Additionally, in the same function, we have introduced a negative relationship between the distance of each country from the technology frontier and IPR enforcement. This distance had a positive effect on the probability of successful imitation because the higher the distance of the country from the technology frontier (i.e., the lower is $\widetilde{Q}$), the higher the probability of imitation, I_S. In the end, we found that IPR enforcement impacted negatively on the steady state growth rate.

Our main result is not in line with the most common results concerning the empirical evidence on the topic (see Azevedo et al., 2012). However, the existing literature is not consensual as regards the IPR effect on economic growth.

In this context, it should be stressed that our aim in this paper is not to impose the true sign of the relationship between IPR and economic growth but to develop an endogenous growth model in which IPR are introduced and in which they play a central role in the analysis.

This analysis suggests that there is much more work to be done in this field. In future research, it would be interesting to analyze, for example, the nature of the sign found differentiating Eq. (36) with respect to IPR parameter (δ), because it can actually rely on countries' development level. Hence, it would also be useful to discuss the different degrees of IPR protection according to the countries' levels of development. The main argument supporting this idea is that each country, according to its stage of development, can have different necessities of innovation and imitation, so it will also have different needs in terms of IPR protection.

Another interesting study for future investigation is to verify whether, in countries where IPR laws do exist, they are strictly/effectively enforced, because afterwards it will be easier to understand the way in which the causality between IPR enforcement and economic development occurs. It will be easier to investigate whether these countries are less developed since they abide more strictly the IPR laws, or whether on the contrary these countries do not adhere to IPR laws (for instance, because their institutions are weaker) or arrange a low level of protection to imitate the others in order to achieve more development. However, the latter case may lead to the opposite result and may be a possible cause of sluggish development in those countries which lag behind. Hence, it would be useful to ascertain what kind of countries most respect IPR enforcement.

[16] Given the size of the paper, the transitional dynamics is not analyzed; however, it can easily show that the system of differential equations describing the saddle-path dynamic equilibrium comes from the individual utility maximization, equilibrium in labor and product markets, and R&D arbitrage conditions (innovation and imitation).

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