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One size does not fit all… An economic development perspective on the asymmetric impact of Patents on R&D

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Abstract

Innovation is the building block of competitive advantages and thus economic policies are increasingly focused on creating stimulus to increase a country's innovative performance and growth potential, namely through knowledge accumulation in general and R&D in particular. In this context, current policy trend seems to support the strengthening of Intellectual Property Rights (IPR), in particular, patent protection, with the argument that positive effects will emerge and would be extensive to all countries regardless their level of development. In this paper we question this "one size fits all" policy and assess how patent thicket affects knowledge productive investment taking into account countries' development levels. Based on a panel of 95 countries over a ten-year period (1997-2006), our results show that patents have asymmetric impacts across countries development stages, evidencing pervious effects on technological leaders and positive ones on some laggards. Such evidence sustains that innovation policies be adjusted to countries development stages.

Keywords: R&D; patents; economic development

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1. Introduction

Innovation is the engine of economic growth and investment in R&D is its main input hence being the driving force of economic growth (Baudry and Dumont, 2006). Given this, policies aiming to promote economic development and growth are focussed nowadays on improving human capital and creating mechanisms to support innovation and stimulate R&D investment (Encaoua et al., 2006). One of the main policy instruments to increase the incentives to R&D, in particular, its expected return, is the intellectual property protection system. The insight provided by Romer's (1990) seminal work highlights knowledge's public good nature leading to the under rewarding of R&D investments due to its foreseeable spillovers and appropriability difficulties. The system of intellectual property rights aims at tackling the non-excludability characteristic of knowledge production function. The unrewarded social gains resulting from spillovers would justify public intervention (e.g. subsidizing or conducting public R&D).

Today's political tendency seems to be supportive of the strengthening of patent/IPR laws and enforcement under the argument of avoiding trade distortions and fostering innovation in the technological frontier, which through faster and more safe licensing and ordered diffusion, would also benefit catching-up and laggard countries (Maskus, 2000). Hence, some countries like the United States, backed by the World Trade Organization, strongly uphold the extension of Trade Related Intellectual Property Rights Agreements (TRIP). Nonetheless, like in Laffer's curve for the optimal tax rate, manipulating patent coverage and range of protection is not without its perks and trade-offs and the configuration of a global patent/IPR system must weigh different opposing dynamics that might influence R&D investment.

When patent rights granted are weak, the rents appropriable in the future from an innovation are minor and thus R&D investment may be under-supplied (Sakakibara and Branstetter, 2001; Varsakelis, 2001). The sub-optimal rewarding leads to sub-optimal R&D investment, sub-optimal technological progress rate, and consequently, results in a smaller economic growth rate. Shapiro (2001), Schneider (2005), Chen and Puttitanun (2005), and Hunt (2006), however, have conceptually challenged this linear view, arguing that excessive patent protection in rapidly innovating, strongly cumulative and path dependent industries may negatively impact on the returns to R&D investment and hence have a negative dynamic effect on economic growth. The first perspective is predominant (Almeida and Teixeira, 2007) whereas the latter is still scarcely explored.

In fact, not only it is a still barely addressed subject but most of the analyses on this subject neglect an economic development perspective. The academic absence of an economic development perspective is paired with the current design of Trade Related Intellectual Property Rights Agreements (TRIP) that aims to enforce and extend a common patent system regardless of countries' stages of development. Additionally, the few papers that undertake an economic development perspective concentrate on developing and least developed countries, almost ignoring the technological leaders.

The assessment of potential asymmetries in terms of stimulus to R&D simultaneously controlling for different levels of development and structural characteristics of countries is a gap that we aim to contribute to fill in. Thus, our goal in this paper is to contribute to empirically assess the potential for asymmetric impacts of the patent accumulation on R&D investment involving countries at different levels of development, allowing to evaluate whetherf there are reasons to differentiate patent systems among countries by creating a more complex but tailored patent system or whether, in the case we find only small asymmetric effects between patents and R&D, the simplest and common policy framework of "one size fits all" stands as suitable.

This paper is organized as follows. After introduction, in Section 2 we review the literature on economic development that analyses issues related with Patent and/or R&D. In Section 3, we devise our theoretical and econometric model, present the proxies for the variables used and provide a synthetic overview on the panel data estimation techniques. In Section 4, the results are presented and analyzed. Finally, we conclude this paper with some final notes and policy recommendations.

2. Economic Development, Patents and R&D: a literature review

Knowledge is recognized as the corner stone of productivity and ultimately, of economic growth (Encaoua et al., 2006). R&D aims at producing more knowledge and has become the driving force of economic growth being nowadays central in economic policy and a crucial factor for the economic development of countries (Maskus, 2000).

Economic policy is increasingly focussing on fostering R&D, promoting its efficiency and the capitalization of spillovers, ultimately enhancing its economic impact through innovation and diffusion. Notwithstanding the R&D/Patent importance, the vast literature on economic development has paid little attention to the subject (Maskus, 2000), lacking to assess the combination of patent-R&D relationship, and thus neglecting the potential asymmetry of effects across different economic development stages.

Table 1 provides a synthesis of economic development literature that focuses R&D and/or patents related topics and which, for the sake of organization, we grouped into the following categories: agricultural R&D; redirection of R&D; building technological capabilities, catching-up opportunities and technological transfer; science linkages; R&D - Foreign Direct Investment (FDI); R&D/IPR/economic development; and technological policy.

The set of papers grouped under 'Agricultural R&D' have in common the goal to assess how agriculture R&D could lead to an increase in productivity and lowering of food prices in underdeveloped countries, linking occasionally to patents when trying to understand how developed countries' R&D could be redirected to tropical agriculture specificities. Beintema et al.'s (1997) study presents a descriptive analysis of the evolution of R&D investment and number of R&D researchers, comparing the national agriculture systems in 21 sub-Saharan countries. Their conclusions point to an increase in the number of researchers however, not matched by R&D expenditures. Also Alston et al. (1998) perform a very comprehensive (comprising 153 countries) descriptive analysis on public policies supporting R&D. Their results corroborate Beintema et al.'s (1997) findings, concluding that Least Developed Countries (LDC) are still not investing enough and arguing that there are efficiency gains to be achieved from devising decentralised schemes of public financing rather than the common centralized coordination. The paper of Kremer and Zwane (2005) discusses the importance of implementing rewarding mechanisms that stimulated MNEs (Multinational Enterprises) to redirect their R&D's investment towards tropical agriculture. Though Kremer and Zwane (2005) do not focussed on patent systems as one possible instrument, their study reveals that technology push programs have resulted in low adoption rates whereas pull programs seem to have conducted to better results. German and Stroud's (2007) paper evaluates the integration of different learning processes, from formal R&D, empirical research and action research, to enhance knowledge building.

The redirection of North R&D to South needs is explicitly addressed by Lanjouw and Cockburn (2001).[1] Their empirical analysis of pharmaceutical MNEs finds no evidence of a patent stimulus effect on the redirection of pharmaceutical R&D to tropical diseases as a consequence of TRIP's increasing South coverage.

[1] North and South stand here as metaphor for, respectively, developed and developing/less developed countries.

A second group of studies analyses R&D in its role in 'knowledge building', bearing the vast majority of the studies an empirical microeconomic focus. Hobday (1995) analyses how electronic firms in Southeast Asia have overcome entry barriers and lack of capabilities and how they managed their learning from simple manufacturing to leaders, highlighting the key role played by imitation and reverse engineering in the accumulation of capabilities. Lee (1995) estimates the relationship between technology imports and R&D in Korean firms reinforcing Hobday's argument of technology transfer and imitation as key elements to technological capabilities accumulation. In the same line of reasoning, Choung et al. (2000) stresses the importance of initial OEM manufacturing, rather than R&D, to the deepening of capabilities and production skills. In fact, this group of papers highlights that R&D becomes a major input to capabilities building only upon firms' achievement of a minimum threshold level. However, in an attempt to asses the relevance of this threshold in terms of technology absorptive capacity, Katrak (1997) observes that importing technology actually stimulates R&D expenditures unlike what would be expected from the predominance of a substitution effect between technology import and R&D on initial technological levels. Vishwasrao and Bosshardt's (2001) results corroborate Katrak's, indicating a positive effect of technology imports on R&D investments. Niosi and Reid (2007) question the real opportunities to catch up presented by biotechnology or nanotechnology. According to them, these technologies given the demanding scale of financial and human resources for their development are only viable for the largest LDCs. Hence, the structural conditions might limit the potential of some technologies being developed at initial stages of development.

The distinction between embodied and disembodied technology raises the importance of introducing patent systems in order to promote a more efficient and complete diffusion. Disembodied or tacit technology is a barrier to imitation and learning, limiting the degree of technology transfer (Arora, 1996). Arora's (1996) empirical study comprising 144 Indian firms analyzes the importance of patents to the protection of leaders and the promotion of disembodied technology transfer. The econometric results support the argument of a positive relationship between IPR and the bundling of disembodied with embodied capital. Addressing technology transfer in a different perspective, Montobbio and Rampa (2005) conclude that developing countries tend to concentrate innovative activities in lower technological intensity industries, which are stagnating worldwide, creating therefore inertia to a structural evolution towards a more knowledge intensive structural specialization.

Innovation is increasingly understood as the result of a systemic process, combining Science Push and Demand Pull's perspectives and focussing on the efficiency of R&D. Here, a key role is devoted to networking, in particular 'science linkages', which can increase the economic return of public investment on human capital and also enhance firms' competitiveness and innovative performance, implying the bridging between the different sectors of an economy: firms, universities, government and nonprofits R&D institutions. Patent systems can provide the framework to regulate such relations, increasing the protection of each agent's interest, hence removing barriers to collaboration. Kodama and Suzuki's (2007) paper evaluates the significance of establishing effective science linkages and developing firm capabilities to make technology transfer viable. Describing the receiver-active Japanese paradigm, Kodama and Suzuki (2007) highlights the proactive role of firms in linking to universities. Analyzing science linkages, Mathews and Hu (2007) study the Taiwanese which presents a different model centred on university research. In Taiwan, patents have become the cornerstone of the technological market, being freely acquired from Universities by firms. This creates a signalling mechanism to the direction of public R&D, based on the direct commercialization of technologies in a market framework regulated by a patent/IPR system. Basant and Chandra (2007) presents a distinctive perspective on science linkages, focussing on their importance for cluster development in Bangalore, India, where the authors argue in favour of the need of Universities and Industry to co-evolve to maximize the cluster's performance and simultaneously providing a different funding alternative for Universities.

The patent system – R&D relationship is the focus of the economic development literature that addresses the attraction and importance of FDI in knowledge building and as a channel for embodied and disembodied technology transfer. Focusing on assessing which are the determinants of FDI R&D location, Kumar's (1996) results indicate that MNEs mostly externalize R&D of an adaptive type aimed at assisting market penetration in local and nearby markets being creative R&D kept in home countries. Hence, it is not surprising that the sensitivity of FDI R&D to IPR is not significant, even in industries particularly sensitive to IPR (Kumar, 1996). Reddy's (1997) conclusions, in the line of what Kumar (1996) states, point to local human capital as a "sine qua non" condition to attract FDI R&D. Glass and Saggi (1998) argue that the quality of FDI is dependent upon the rates of innovation and imitation where, given the need to accumulate a minimum threshold of capabilities, imitation can actually contribute to attracting quality FDI through its learning role. FDI seems to be much more responsive to cost differentials than to patent's protection (Glass and Saggi, 1998).

Finally, there is another set of articles (e.g., Helpman, 1993; Lai, 1998; Parello, 2008) that combine economic development, patent/IPR, and R&D, where the effectiveness of patent/IPR systems in stimulating innovation is addressed, arising also some discussion over the potential asymmetries of effects across different levels of economic development.

The debate regarding the adequacy of extending and strengthening patent/IPR protection worldwide is theoretically little explored (Helpman, 1993) and empirical demonstrations are even scarcer (Helpman, 1993, Maskus, 2000). Indeed, Helpman's (1993) paper constitutes one of the exceptions where stages of development are taken into consideration when analyzing the effects of patent/IPR systems on R&D. Helpman (1993) analyzes the effects of extending TRIP over terms of trade, interregional allocation of manufacturing, product availability and R&D investment patterns and across developed (North) and developing countries (South). By assessing the net benefits accruing to North and South from reinforcing IPRs in the South, Helpman concludes that if there are benefits from TRIP worldwide extension, there are not certainly for South. In spite of Helpman's (1993) analysis considers both developed and developing countries, it is clearly focussed on the South pointing to a negative impact on the South and an unclear net effect on the North. Likewise, Lai (1998) compares the effects of strengthening IPR in the South according to different possible channels for technology transfer. From a theoretical standpoint, Lai (1998) argues that stronger IPR in the South will foster North innovation whenever FDI is the main technology transfer channel and will have a negative effect when imitation is more relevant. Providing an empirical analysis, Gould and Gruben (1996) assess, for a sample of 79 countries, the impact of IPR on innovative performance and economic growth, finding evidence supporting a positive relationship between IPR strength and economic growth rates however distinctive for the different levels of openness in international trade, less relevant in trade protected countries. Connolly (2003) has studied the impact of technology imports on innovation and imitation across 51 countries. The estimates presented corroborate the positive relationship of technology imports on both imitation and innovation. Overall, the impact of reinforcing IPR on innovation is positive however, given that innovation is proxied by patents these results might be biased.

Also Schneider (2005) tries to assess the impact of IPR, high technology trade and FDI on innovation across developed and developing countries, considering high technology imports as a concurring channel for technology transfer. In a sample of 47 countries, Schneider's (2005) estimates reveal a significant impact of high technology trade on innovation and growth both in developed and developing countries, whereas the effect of IPR's strengthening is positive, being significantly higher in developed countries. Nonetheless, as in Connolly's (2003) study, innovation is again proxied by patents which may bias the estimators. Chen and Puttitanun (2005) also evaluate the impact of IPR in economic growth in developing countries, analyzing the trade-off between domestic innovation and imitation. In a quite novel fashion these authors assess the net potential opposing effects of imitation and domestic innovation instead of the usual balance between technology transfer and imitation. They argue that, despite usually being perceived that IPR will, in general, hurt developing countries (e.g. Helpman, 1993), IPR may actually have a positive, unaccounted for, effect over domestic innovation, which is usually disregarded in the North-South framework. Focussing on a South country, Léger (2005) studies the impact of IPR on the Mexican maize industry. He tries to evaluate, in a country that scores relatively well in IPR effectiveness, the relevance of IPR and its effects on the industry. His findings show that IPR had no impact on the innovative performance of the industry, contradicting the common argument that IPR would stimulate innovation. Furthermore, Léger (2005) argues that in order for a patent/IPR instrument to be effective, its framework should be adjusted to idiosyncrasies of different stages of development implicitly assuming the potential for asymmetric effects across different development stages. Furukawa (2007) demonstrates, using a variety expansion model, that reinforcing IPRs have different effects depending on the openness of economies, corroborating Gould and Gruben's (1996) results that stressed asymmetries of effects in terms of a country's trade openness. Furukawa's (2007) modelling indicates that for closed economies, loosening IPRs may actually enhance growth.

The question of which are the overall effects on the global economic growth rate and welfare from reinforcing South's patent protection is the focus of Parello's (2008) paper. He evaluates how IPR in the South affects R&D investment in the North and South, devising a model to analyse the different concurring effects. Overall, extending IPR coverage in South countries has a positive effect on global innovation but a negative on technology transfer through imitation. In the South, at a micro level, one observes a reduction on the number of researchers but a positive macro level effect taking into consideration externalities. Stating also that IPR may not be relevant to attract quality FDI, Parello (2008) falls short on not providing an analysis of the effects in the North.

Table 1: Synthesis of the economic development literature associated with Patents and/or R&D related issues

Theme	Author	Goals of the paper	Results	Method	Sample
Agricultural R&D	Beintema et al. (1997)	Present a comprehensive analysis of national agricultural systems in Africa	Number of agricultural researchers in Sub-Saharan African countries has increased significantly but R&D has evolved less positively.	Descriptive	19 to 21 Countries according to the variable and for a period of 30 years 81961-1991)
	Alston et al. (1998)	Survey of changes registered on public policies regarding agricultural R&D and its financing.	There is a global increase in agricultural R&D. However, LDCs still do not invest enough; There are efficiency gains to be achieved if instead of central coordination, financing schemes are devised under a perspective of competition.	Descriptive	Countries grouped according to levels of development (n=153)
	Fan et al. (2003)	Measure the impact of agricultural R&D on urban poverty by lowering food prices	In China, the effects on food prices have been large, as well as on urban poverty and on rural poverty.	Econometric estimation using simultaneous equations method	Case Study: China
	Kremer and Zwane (2005)	Analyses different schemes to stimulate private R&D to be directed towards tropical agriculture.	Technology push programs result in low adoption; Push programs are more appealing.	Descriptive	Theoretical
	German and Stroud (2007)	Provide a framework of integration of different learning processes	R&D, empirical research and action research should be combined because they convey different perspectives on learning.	Descriptive	Case Study (n=3)
MNEs Redirection of R&D	Lanjouw and Cockburn (2001)	Examine R&D stimulus provided by patents, focusing on directing R&D efforts to develop medicines for tropical diseases	There seems to be no evidence supporting a stimulus on Big Pharma's R&D decisions. Demand pull effect of patents is not evident but may be a long term process, identifiable in the future	Empirical	Firm level
Building technological capabilities, catching-up opportunities and technology transfer	Hobday (1995)	Analyze how latecomers firms in electronics overcame barriers to entry and their learning process	Firms progressed from simple manufacturing to innovative leaders, beginning from imitation and knowledge building until firms gathered enough knowledge to launch incremental innovations. Only in the more advanced stage, R&D became of significant relevance.	Empirical / Descriptive	Case Studies (n=4)
	Lee (1995)	Analysing the relationship between technology imports and R&D in Korean firms, using econometric techniques to suppress a literature gap.	Firms that import technology tend to have a strong commitment to R&D. Among these firms, the technology imported tends to be of non-complementary type.	Empirical / econometric analysis	Firm level (n=492)
	Arora (1996)	Aims to assess the importance of patent systems to the bundling of embodied and disembodied technology transfer	Positive relationship between IPR and the bundling of disembodied with embodied capital.	Empirical/ econometric analysis	Firm Level (N=144)
	Katrak (1997)	Examine the relationship between technology imports and firms' capabilities on two levels: 1) an initial level of capabilities is necessary to import technology? 2) does technology imports lead to a further investment in R&D?	Initial capabilities' relevance is reduced. Technology imports have a negative effect on the number of researchers but a positive one on R&D expenditures.	Empirical / econometric analysis	Firm level (n=82)
	Peretto (1999)	Develop the implications concerning the fact that R&D undertook in advanced countries firms cannot be undertaken on a less developed country	The evolution of industrial structure foes through different phases and steady-state is achieved when this structure stabilizes.	Theoretical	
	Choung et al. (2000)	Aims to describe the transition from latecomer firms to leaders	Concludes that initial OEM manufacturing, rather than R&D, to the deepening of capabilities and production skills	Data supported description	Firm level (N=4)
	Vishwasrao and Bosshardt (2001)	Focus on developing countries firms decisions related to technology transfer. The analysis addresses domestic as well as MNEs	Ownership (favouring foreign), size, market are the main determinants of technology adoption. The liberalization of 1991 had an overall positive effect on technology adoption, but far more significant on foreign owned companies.	Empirical / econometric analysis	Firm level (N=1400; T=5)
	Hasan (2002)	Analyze the impact of technological inputs (embodied and disembodied) on firms' productivity.	Results indicate a positive relationship (both on embodied and disembodied inputs), stronger in industries with more technological opportunities	Empirical / econometric analysis	Firm Level (N=286; T=12)
	Lorentzen (2005)	It tries to analyze the determinants of developing countries' manufacturing innovative capacity.	In advanced developing countries, firms investing in their own learning follow a different trajectory. Improving technical skills allows firms to close up on technological frontier and to adapt to technical changes. FDI's relevance may be diminished in these countries if we consider other external knowledge sources.	Empirical / descriptive	Case studies: South Africa (N=25)
	Montobbio and Rampa (2005)	Assessing the difficulties of technology transfer given the specialization of developing countries on stagnating low tech activities.	This specialization creates inertia and difficulties to structural change processes towards more knowledge intensive industries.	Empirical	Case studies (N=9)
	Niosi and Reid (2007)	Assessing the catching up opportunities presented to LDCs by biotechnology and nanotechnology	Concludes that only for large LDCs able to gather enough scale may these technologies lever technology upgrading and catching-up processes.	Empirical/Descriptive	Country level N=6

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Theme	Author	Goals of the paper	Results	Method	Sample
Science Linkages	Bassant and Chandra (2007)	Explore the role of educational and R&D institutions on the development of city clusters in Bangalore and Pune.	Universities can create local linkages if they have significant capabilities. Co-evolution of industry and institutions is important to take full advantage of emerging opportunities. Science-industry linkages may be considerably extended because of universities financial distress.	Empirical / descriptive	Firm level (enquiry) (n=309)
	Kodama and Suzuki (2007)	Describe the receiver-end Japanese paradigm and its implications	Firms have become proactive in linking to universities and looking for solutions.		
	Mathews and Hu (2007)	Taiwan is upgrading the role of Universities as main fundamental research provider, enabling a system of IPR and commercialization of knowledge having firms per clients. The paper examines how these changes have impacted on the country's technological upgrading.	Universities are increasingly promoting programs to commercialize technology and stimulate technological spin-offs. Patenting has increased and R&D is focuses on technological fields of industrial interest.	Empirical / descriptive	Case studies (n=4)
FDI R&D	Kumar (1996)	Develop an analytic framework to explain the determinants of FDI R&D location	Larger penetration of FDI has no significant impact on attracting R&D (relevant only for developing) In attracting FDI R&D (MNEs externalize adaptive type only) FDI for export does not attract R&D. Local technological capabilities are important determinants to atractability, enhanced with cost advantage. Type of R&D undertaken in developing countries is not sensitive to IPR. Developed and full sample indicate positive impact of IPR in attracting FDI R&D. For Developing countries ipr have negative impact, almost significant at 10%. IPR relevant for creative but not adaptive R&D Testing in more sensitive industries, reveals that IPR are not of high relevant.	Empirical / econometric analysis	Country level N=84 Split according to industrialized (n=46) and LDC
	Reddy (1997)	Assessing R&D FDI in India and raising policy questions	Atractibility of India to FDi R&D lays on the availability of skilled human resources; IPR are relevant n attracting FDI;	Empirical / descriptive: enquiry	Firm level N=37
	Belderbos et al. (2001)	Analyzing the determinants of MNEs to establish backward vertical linkages on host countries	Size of local suppliers industry and the quality of infrastructure foster linkages. Restrictive trade policies have a negative impact. Linkages are more intense in low tech industries and towards other MNEs affiliates	Empirical / econometric analysis	Firm level N=272
	Glass and Saggi (1998)	Build a model to analyze the potential of FDI transferring state-of-the-art technology to LDCs with limited capabilities	The quality of FDI is linked to the rate of imitation to innovation. Larger North market, lower quality FDI. Larger need for resources or cost differential, higher quality FDI. Quality of FDI is constrained by local capabilities. Subsidizing imitation or taxing low quality FDI promote higher quality FDI. Contrasting to the common perception, imitation can enhance attraction of quality FDI by building capabilities.	Theoretical	

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Theme	Author	Goals of the paper	Results	Method	Sample
IPR/R&D	Helpman (1993)	Analyzing the effects of extending TRIP over terms of trade, interregional allocation of manufacturing, product availability and R&D investment patterns and across developed (North) and developing countries (South).	Concludes that if anyone stands to gain from TRIP's worldwide extension, it is certainly not the South.	Theoretical	
	Léger (2005)	suppress the lack of empirical studies concerning the impact of IPR on developing countries	IPR not relevant for maize industry. IPR framework should be revised and adapted to developing countries idiosyncrasies	Empirical / enquiries	Country level N=1 case study
	Connolly (2003)	Assess effects of technology imports on innovation and imitation.	Imitation and innovation positively associated to technology imports More important in developing than developed IPR have positive effects but innovation is proxied by patents – results are biased	Empirical / econometric analysis	Country level N=51, T=4
	Gould and Gruben (1996)	Assess the impact of IPR on innovation and thus on economic growth	Stronger IPR correspond to higher growth rates. Though relevant, the impact of IPR is smaller on trade protected countries because competition is less demanding.	Empirical / econometric analysis	Country level N=79, T=29
	Schneider (2005)	Assess the impact of IPR, high technology trade and FDI on innovation and	IPRs affect innovation more significantly in developed countries and this impact is positive. Human capital and r&d are more relevant to obtaining patents in developed countries FDi impact is statistically not significant	Empirical / econometric analysis	Country level N=47, T=21
	Chen and Puttitanun (2005)	Study IPR impact on economic growth in developing countries, analyzing the trade-off in terms of imitation and domestic innovation It is a different perspective on a relationship that usually accounts technology transfer vs imitation.	U-relationship between IPR and gdp; at low levels of gdp, countries lower ipr (signal is -) and at higher, countries increase ipr (+). Positive imp+act of ipr on patents applications in the USA. Domestic innovation increases with ipr	Empirical / Econometric analysis	Country level N=64, T=6
	Zigic (2000)	Analyze the optimal tariff between north and south with varying degrees of IPR	Tariffs besides shifting profits from South to North, may act as an additional instrument complementing IPR.	theoretical	Country level
	Lai (1998)	Compare and contrast the effects of strengthening IPR when the principal channel for technology transfer is FDI (multinationalization effect), imitation and the effects on long term innovation rates, international production transfer and income distribution between North and south.	Stronger IPR foster North innovation if FDI is the main channel of technology transfer Stronger IPR lower North innovation if imitation is the primary channel of technology transfer	theoretical	Country level
	Parello (2008)	Assess the impact of strengthening IPR in the South on R&D investment, technology transfer and skill accumulation	South IPR positively affect global innovation but permanent negative impact on tech transfer through imitation. North: decrease in skill accumulation and increase in wage inequality, no analysis is provided for north in terms of R&D impact. South: at the micro level, the effect is negative reducing R&D employment and at macro positive if externalities from skill accumulation are relevant. IPR may not be effective in attracting FDI.	Theoretical	
Technology Policy	Teubal (1996)	How policies can promote learning and R&D in NICs	Technology policy should be neutral in terms of sector. A bias towards high tech sectors is not adequate to NICs. The goal must be spreading R&D intensity across economic structures, stimulating high tech sectors, but not neglecting the others.	Empirical / descriptive	
	Diao et al. (1999)	Analyze the impact of government intervention to promote R&D	Trade liberalization has a negative impact on domestic R&D and economic growth. Subsidizing R&D costs may be effective and a more acceptable alternative to trade restrictive policies	Theoretical / empirical calibration and simulation for Japan	
	Zeng (2001)	Analyze interactions between innovation and imitation and the impact on economic growth and how policies may affect the results.	Subsidizing innovation speeds up economic growth but subsidizing imitation reduces it. Taxing imitation is not equivalent to subsidizing innovation.	Theoretical	

As reviewed in the present section and illustrated in Table 1, economic development literature has attributed a small amount of attention to the effects of IPR in technology transfer and innovation rates, failing to account its potential asymmetrical effects across different levels of development. Furthermore, although there are some studies that when analyzing the patent-R&D relationship address the question of asymmetries (e.g. Helpman, 1993), the impact on the leaders (up-North) is rarely assessed. In other words, the amount of research done in this subject, usually focuses on the effects for the South countries or in a framework North-South, where the South is at the centre of the analysis, neglecting the net effects on North.

It is, however, for North countries that the arguments of Shapiro (2001) and Hunt (2006) are more relevant. These authors have put forward a set of solid arguments that advice cautious in understanding the patent-R&D relationship in a linear, positive signaled way. In particular, Hunt's (2006) argument is that in rapid innovating industries such as semiconductors, innovation is a strongly path dependent process. Making patents easier to obtain and extending their protective range will contribute to the formation of a patent thicket where numerous intellectual property rights are entangled and through which innovative firms must cut through. In other words, if patent protection range is extensive then firms have to acquire several licenses and bear multiple patent burdens (Shapiro, 2001), thus increasing R&D investment's costs. The simple proliferation of patents and building up of a patent thicket is conducive of an increase on innovation costs creating a negative incentive to R&D spending and limiting knowledge use and diffusion. Rather than stimulate R&D, the medicine (that is patents) might actually have a negative impact on R&D investment when technologies are overlapping and follow a cumulative path due to excessive restrictions to their usage. Heller and Eisenberg (1998) refer to this problem as the "tragedy of gatekeepers" in reference to the fact that excessive protection on the use of a particular resource, ultimately leads to its under use, resulting in a poorer dynamic economic performance.

Although Hunt (2006) follows a microeconomic perspective, his intuition can easily be extended to a macroeconomic perspective considering the economic specialization pattern, with technological leaders presenting a high share of knowledge intensive industries and followers and laggards a more predominant pattern of low technology industries. In the North, the argument of Hunt (2006) stresses the negative impact of the formation of the patent thicket on its own R&D investment. In these countries, growth and innovative performance tends to rely on own R&D effort and clearly less on imitation (there is no catching-up margin). Furthermore, high technology industries face a rapid rhythm of innovation and a complexity level that enhances cumulativeness and path dependency. Thus, according to Hunt (2006) the expected signal of the relation between (accumulated) patents and R&D investment would be negative. However, IPRs' defenders would argue that the increase in returns through IPR extension to Southern countries and even in the North may compensate. Still, the creation of a 'patent thicket' seems a quite relevant aspect to be tested and to fit particularly in the North countries whose specialization pattern is characterized by more knowledge intensive industries, increasingly aggregating different types of knowledge and presenting a fast innovative rhythm and cumulative technological progress.

In follower countries, we find an acceptable level of capabilities that may allow them to explore the fruits of imitation and potentially take full advantage of their catching-up margin. The case for strengthening IPRs net effect has to weight the growth and capability building importance of FDI, imitation and stimulus to domestic R&D as we presented in the previous section.

Finally, for Least Developed Countries (LDCs), the low level of capabilities and human capital associated with the lack of scientific capabilities and infra-structures restricts severely the possibility for imitation (Maskus, 2000). Additionally, the economic structure characterized by low technology activities and exploitation of low-skilled labor cost advantages, reduces aspects of cumulativeness and rapid technology evolution. As Hunt (2006) recognizes, when referring the low technology industries, easing patents fosters innovation at no risk of forming a thicket.

In the next section, we model Hunt's (2006) argument in order to test for a sample of 95 countries whether there is econometric evidence supporting asymmetries of impacts of patents on R&D investment across countries different levels of development and if these differences are significant in order to argue against the current "one size fits all" IPR system and in favour of a more "tailored" patent system in accordance to countries stages of economic development.

3. Testing the potential asymmetric impact of patent on R&D across countries' development levels

Assessing the impacts of patent systems and Trade Related Intellectual Property Rights Agreements (TRIPs) on R&D is of utmost importance since R&D and innovation are the engine of economic growth. Existing empirical studies that bear an economic development perspective are rare and the few exceptions are focused on the South, overlooking the fact that

Northern technological leaders are an important part of the equation on global innovation dynamic performance.

Intentionally taking the neglected North economic development perspective, in the present section we aim at empirically test whether there is enough evidence supporting asymmetric effects of patent systems on R&D investment across different stages of development. This enables us to analyze the adequacy of "one size fits all" patent system in opposition to the need of conceiving a more "tailored" solution.

To model and test our hypothesis, we use Hunt's (2006) argument and estimate, using panel data techniques, the effects of the patent thicket over R&D investment for a sample of 95 (developed and developing) countries comprised over a 10 year period (1997 to 2006). For assessing the (potential asymmetric) effects of patents on R&D across we propose the following reduced model specification:

$$RD_{it} = \theta + \delta_1 AccumPat_{it} + \boldsymbol{\varphi}\mathbf{X} + v_{it}$$

Where *i* and *t* stands for, respectively the country and year indexes.

RD stands for R&D expenditures in percentage of GDP and is our dependent variable which was obtained from the UN Statistics Division online database. To model Hunt's patent thicket, we use USPTO data on patents granted per million of inhabitants and sum each year's granted patents to the previous years' accumulated sum starting in 1997. This gives us the accumulated patents for each country, proxying for the patent thicket.

In accordance to our literature review (Section 2), a vector X is added to the model specification in order to control the estimation using variables proxying countries structural characteristics and governance performance.

For structural characteristics we include FDI, High Technology Exports, Science Links, GDP per capita in Purchasing Power Parity and denominated in USD. FDI can be a determinant of R&D expenditures directly through MNE's R&D location as well as acting as an (indirect) technology transfer channel.[2] The inclusion of High Technology Exports aims to reflect the specialization pattern of each country's economic structure, namely, in terms of technology intensity.[3] Science links variable was constructed subtracting R&D executed by firms to R&D funded by firms, divided by total R&D expenditures. In the absence of quantitative measures

[2] To proxy FDI, we use FDI inflows in percentage of Fixed Capital Formation, data retrieved from UN Statistics Division online database.
[3] This variable reports on the percentage of high technology imports in percentage of total manufactured exports and was also retrieved from UN Statistics Division.

of science links between firms and universities, our reasoning was that this difference would indicate whether or not R&D funded by enterprises exceeded their internal execution, thus indicating whether they are financing other entities from the National Scientific System (Universities and Public R&D institutions), and thus linking to them. Thus, if the coefficient associated to this variable is positive it would mean that firms' funding exceed their execution, and thus we infer that firms use Universities to obtain technology. Finally, despite one of the sampling methods uses income as a key variable, we include the log of GDP per capita in Purchasing Power Parity to account for potential differences among each group of countries in terms of income.

To account for governance quality, we use law enforcement and political stability indicators retrieved from Kaufman et al. (2008). Law enforcement proxies the enforceability of patents whereas political stability is a determinant of long term investment decisions, thus highly likely to influence R&D investments.[4]

The assessment of the existence of asymmetric effects across countries different stages of development advices that we estimate the above-mentioned model for a set of countries sub-samples. We use two decomposition methods. The first one is based on the fact that Hunt's argument is essentially applied to technological leaders, that is, countries with relatively high innovative dynamics. Thus, we use RD and split up countries using a threshold of 2.5%, with countries with RD>2,5% standing as the technology frontier ones. The two resulting subsamples, one with 10 countries, comprising the technology frontier countries, which have a very high investment in R&D, and the other remaining 85 countries, which R&D intensity is below 2,5%. However, testing asymmetries according to the levels of development advices that we also use a more stratified framework based on GDP. This leads to our second splitting method. Using World Bank's Atlas method, countries are split according to their level of per capita GDP in comparison to a set of thresholds. Here we obtained four subsamples separating low, medium-low, medium-high and high income per capita countries.

The next table provides a brief statistical summary regarding each of the variables used in our estimation.

[4] These indicators are defined in an interval of -2,5 to 2,5. In order to ease the interpretation of coefficients we use added 2,5 to every observation so that the interval is now defined between 0 and 5. Kaufman et al. (2008) present cases where the minimum or the maximum is actually outside the predefined values, fact that justifies why after adding 2.5, negative values are still present in the data.

4. Cross country evidence on the asymmetric impact of patent systems

Somewhat surprising results arise from the empirical analysis which is summarized in Table 2. In general, the results support the existence of differentiated impact of patents across countries.

When considering the threshold of 2,5% expenditures in R&D, we observe a negative and significant effect of the proxy for the patent thicket on R&D investment, which corroborates Hunt's argument. Although the countries which are included in the group below the 2,5% threshold are quite heterogeneous, on the overall, this group presents a significant positive relationship of (accumulated) patent on R&D investment. This would be expectable from Hunt's argument since patent thickets are more relevant for countries with a very high R&D intensity.

Analysing the results obtained using the disaggregation of countries based on the Atlas Method, we find evidence that not only supports the asymmetric effects of patents on R&D investment across different stages of countries development levels but also provides evidence of a pattern of asymmetries that is not linear along the "development ladder". High income countries sample (31 countries) lead to a non significant estimate probably due to heterogeneity in the group. In fact, we find asymmetries not only regarding the elite of R&D>2,5%, but also on different levels of development,[5] namely obtaining a negative and significant sign in medium-low income countries. In contrast, a positive effect of patents on R&D investment is found on low income level and medium-high income level countries.

The positive signal on medium-high income countries tends to reflect the relevance of domestic R&D and innovative activities on the capabilities of signalling by these countries whereas for low income countries the predominance of low technology intensive industries actually benefit from easing the granting of patents and thus stimulating R&D. The negative signal in medium-low income countries is more surprising revealing that perhaps for these countries accessing to knowledge and imitation is more relevant than domestic R&D or that the patent thicket creates a higher cost of entry in innovation which firms still far from the frontier have difficulties to bear.

Apart from the case of medium-high income countries FDI emerges not statistically significant as an R&D determinant. In fact, the impact is even negative suggesting that FDI

[5] In addition to these two disaggregation methods, we also tested the model using Castelacci's (2006) technological convergence clubs and also simpler model specifications. The estimates corroborate the main results obtained and presented here and certify the robustness of our results.

may replace the need for domestic R&D as a concurrent channel for capability building or, in a worst case scenario, act like in the natural resources curse.

High technology exports are overall not significant throughout different levels of economic development with the exception of R&D<=2,5% where the heterogeneity of included countries is such that this variable contributes in a barely significant way to distinguish countries structural characteristics.

Science linkages are crucial to increase R&D cost efficiency as well as stimulating the economy through Universities research results. Our econometric results allow to infer that science linkages are relevant to R&D bearing an effect several times higher, in absolute value, on high income and above the 2,5% threshold in comparison to lower income levels or less R&D intensive countries. The direction of effect is nevertheless common and negative indicating that the execution of R&D by firms is a strong determinant of R&D investment and the relevance of firms in participating is higher in developed countries. Being that the execution of R&D by firms emerged as a major determinant of R&D investment, this indicates that public policy may need to redirect from a science push perspective towards a more demand pull approach, bridging public R&D to the economy.

GDP per capita (logGDP) captures relevant information in terms of determinants of R&D investment being overall significant at 1%. The effects on the first two sub samples are positive with a higher absolute impact on technological leaders. Using the Atlas method, results are still significant but more at odds. There arises a negative impact of GDP upon R&D investment on low and high income countries. If on the former case the explanation may lay on the heterogeneity of the sub sample, for high income levels the particular cases of oil producing countries characterized by high income levels but low R&D commitment may explain these distortions.

Finally, governance indicators appear only to be relevant for technological leaders (RD>2,5%), both presenting a negative signal. Nevertheless, among these countries the performance levels in terms of governance are generally very high and small differences among these countries may distort results despite their statistical significance.

Table 2: Panel Data Estimation Results

Variables	*Mean*	*Min*	*Max*	*St.deviation*	**R&D/GDP threshold 2,5%**		**Level of Income according to World Bank's Atlas Method**			
					RD/GDP *>2,5%*	***RD/GDP*** *<=2,5%*	***1*** *(Low)*	***2*** *(Med-Low)*	***3*** *(Med-High)*	***4*** *(High)*
AccumPat	*4,77*	*0,01*	*0,88*	*0,92*	-.00028**	.00028***	.09125**	-.05285**	.00785 ***	.000083
FDI	3209,14	0,00	145,36	364,86	-.000982	-.00042	-.00044	-.000345	-.00139*	-.00046
HighTech	386,19	-70,47	20,49	24,33	-.01167	.00207*	-.00196	.00209	-.00131	-.00730
ScienceL	74,96	0,01	13,55	14,87	-2.28048*	-.33708***	.03355	-.54036***	-.16652	-1.34902**
PolStab	0,43	-0,60	-0,06	0,12	-.25772*	.02052	-.01928	.05935	.02052	.06656
Law	4,84	2,83	3,92	0,45	-.71481**	-.06492	-.09503	-.03003	-.01819	-.03593
LogGDP	4,15	-0,32	2,64	0,90	2.90849***	.14014***	-.83039***	.32588***	.01896	-1.13946**
Constant					-24.35351***			-2.37902***	.38802	13.32792***
N*T					10*10=100	85*10=850	6*10=60			31*10=310
Adj R^2					0.90154	.97236	.80099			.96934
FEM/REM					REM	FEM	FEM	REM	REM	FEM
G&T					G&T	G	G	G	G	G&T

5. Conclusions

The main goal of the present paper was to assess the patent-R&D relationship from an economic development standpoint, seeking to bring at the forefront of the analysis the effect of (accumulated) patents on R&D Investment not only on South countries or North-South framework but above all re-directing the analysis towards a rather overlooked perspective, that of the North. In particular, we aimed at empirically explore the hypothesis of asymmetric impacts of patents on R&D investment across different stages of countries economic development and provide insights on fostering R&D investment.

The econometric modeling followed an extension of Hunt's (2006) microeconomic argument to a macroeconomic perspective, using the patent thicket as the main independent variable. Using panel data estimation techniques for a sample of 95 countries over a ten years period, we estimate the effects of patent thicket formation on R&D investment controlling for the country's stage of development.

Our results support the hypothesis of asymmetric effects for different stages of development, bearing a negative impact on R&D strongly committed countries (that is, those that present a R&D intensity above 2,5%) as well as on medium low income countries, whereas for medium high and low income countries the effect is significant and positive. Hence, we find evidence that support asymmetric impacts that do even change signal along the climbing of the "development ladder".

In the light of these results we ought to argue against the "one size fits all" approach to IPRs, concluding that a more flexible patent system that changed the protective range of patents across stages of development would be more R&D supportive and also lead to a superior innovative performance.

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