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# **Intellectual Property Rights and Innovation in Developing Countries: Evidence from Panel Data**

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**Contributed paper prepared for presentation at the International  
Association of Agricultural Economists Conference, Gold Coast,  
Australia, August 12-18, 2006**

## 1. Introduction

In industrialized countries, intellectual property rights (IPR) are part of the infrastructure supporting investments in research and development (R&D) leading to innovation. By granting temporary exclusive rights on inventions, IPR allow right-holders to price their products above marginal cost, and hence recoup their initial research investment. Such exclusive right creates incentives for the conduct of R&D. However, by granting monopoly rights on an invention, IPR impede its dissemination. The resulting underprovision of protected goods and monopoly distortions are usually considered acceptable costs for the creation of new knowledge and the increase in social welfare that it entails.

In general, IPR are perceived as contributing to the promotion of technological innovation and to the transfer and dissemination of technology, in a manner conducive to social and economic welfare (WTO-TRIPs Agreement, Art. 7). Still, growing numbers of experts question these affirmations for developing countries (LDCs) and argue that IPR “do little to stimulate innovation in developing countries” (CIPR, 2002: 1). IPR may provide an incentive for innovation but there is limited local capacity in LDCs to make use of it. Similarly, even if stronger IP protection supports an increase in technology transfer, limited local absorptive capability may limit the potential to use it. Finally, the environment in which IPR exist, for example the quality of the legal system and the importance of transaction costs, might severely constrain the incentive effect, as exemplified by a case study of the maize breeding industry in Mexico (Léger, 2005). In these countries, the balance between dynamic benefits and static costs might not be positive. Still, IPR is an important issue in bilateral, regional and multilateral trade negotiations. Pressure is put on LDCs to sign up for stronger standards of IP protection without having a clear picture of the impacts IPR have in these economies (Fink and Maskus, 2005).

This study hence investigates the role IPR play for innovation using a novel panel dataset of LDCs and industrialized countries. In doing so it contributes to the innovation literature by comparing the determinants of innovation in developing and industrialized countries and takes into account the cumulative nature of innovation by using dynamic panel estimation methods for samples with small N and small T.

The rest of the paper is organized as follows. Section 2 review the theoretical and empirical literature on IPR and innovation. Section 3 presents the methodology and the data used, and section 4 presents and discusses the results of the estimations. Section 5 concludes.

## **2. Innovation**

### **2.1. Nature and Determinants**

The result of the innovation process is a new product (or process) as well as new information, which has public good characteristics, i.e., non-rivalry and non-excludability. These two properties of information make the gains from innovation uncertain and difficult to appropriate, which implies that R&D opportunities that would be socially profitable are not exploited because they are privately unprofitable. In order for innovation to be undertaken, incentives need to be given. IPR is suggested as one possible government intervention to correct for this market failure<sup>1</sup>.

Three main reasons exist for innovation. First, the possibility of increased profits and market share, secured by IPR or other mechanisms (e.g. first-mover advantage, secrecy) motivates investments in innovative activity. Second, innovation would react to “demand-pull” factors (Schmookler, 1966), i.e., the perceived demand for new products and processes. Conversely, “technology-push” factors, that are related to advancements in technology and science, would also play an important role (Cohen and Klepper, 1996).

The environment in which a firm operates affects its innovative performance. At the macroeconomic level, economic and political stability (Lall, 1992) provides an environment supportive of innovation. Competition and openness to trade also affect incentives to innovate, however the impact is theoretically not clear (Grossman and Helpman, 1991). At the firm level, given that R&D is an expensive endeavor, cost of, and access to capital are important aspects. Finally, qualified scientists and workers are essential inputs into the innovation process, hence the level of human capital in the country is another important factor (Crespo *et al*, 2004).

Though innovation could play a crucial role for economic development in LDCs, most of the literature so far has focused on industrialized countries. However, a different treatment could be warranted given that LDC characteristics differ from the usual models. Demand-pull factors could have a limited impact in LDCs, given

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<sup>1</sup> Others can include tax breaks on the performance of R&D, contests, R&D, or public performance of R&D.

the generally lower purchasing power of inhabitants. Markets are often incomplete, weak or non-existent (Lall, 1992), which has important implications for the conduct of innovative activities, especially in areas such as capital (financial and human) and information,. The institutional environment is characterized by the presence of high transaction costs, which often include corruption (Collier, 1998), and by weak institutions. These could affect the functioning of the market and the transmission of signals – e.g. demand for certain goods – to the innovators. Furthermore, the performance of IPR, a market-based tool, in malfunctioning markets, still has to be investigated.

## 2.2. IPR in a North-South setting

In a North-South setting, where only the North can innovate and the South has lower labor costs, Deardorff (1992) finds that stronger IPR hurt the South and benefit the North. Another study (Chin and Grossman, 1990) reaches similar conclusions, except for the case of highly productive R&D, for which international IP protection increases global welfare. There is however always a conflict of interest between the North and the South. Zigic (1998) extends this model to allow for different levels of IP protection and finds that this conflict holds when R&D efficiency is low, but that the interests could be in congruence for higher R&D efficiency levels. Similarly, in a model assuming different preferences in the North and the South, strong IP protection in the South provides incentives for Northern innovation addressing Southern needs, hence benefiting both regions (Diwan and Rodrik, 1991). However purchasing power is not taken into account: Anecdotic evidence from the case of essential medicines in least-developed countries shows that strong IPR might not be enough for Northern R&D to take place.

In a dynamic general equilibrium framework including imitation and technology transfer, Helpman (1993) finds that strengthening IPR spurs innovation in the North in the short-run but slows it in the long run. The South also loses from stronger IPR, through a deterioration of its terms of trade, reallocation of production and a global slowdown of innovation. Conversely, a dynamic endogenous growth model (Saint-Paul, 2004) reveals that the South might lose more than the North from weak IPR, depending on the relative comparative advantages and the growth potential of the goods concerned. In general, the impact of stronger IPR on innovation is still unclear theoretically and heavily depends on the models used and their underlying assumptions.

### 2.3. Empirical Evidence

A few studies examined the link between IP protection and innovation for panels of countries. Alfranca and Huffman (2003) use a panel of EU countries to estimate the effects of economic incentives and institutions on private innovation in agriculture, and find the level of IP protection, institutional quality, economic openness and the lagged value of agricultural production to be positive and significant factors. Conversely, interest rate and the lagged value of crop production have (significant) negative impacts.

Kanwar and Evenson (2003) investigate the determinants of innovation and technological change, proxied by total R&D investments as a proportion of GNP. They obtain similar results: IP protection, credit availability, demand-pull factors, trade openness and human capital positively affect innovation, while political instability and interest rate would have a negative effect. They however do not consider the impact of past innovative activity, which is done by Lederman and Maloney (2003), who use a dynamic GMM estimator. They find that interest rate and risk negatively affect aggregate private and public R&D investments, while past R&D investments, credit market depth, IP protection, complementary institutions and the quality of research institutions are positive and significant explanatory factors. However, GMM estimators rely on asymptotic properties, hence estimates can be biased for small samples like their. Furthermore, they do not control explicitly for the level of development of the countries.

A recent article (Higino Schneider, 2005) investigates the role of trade, FDI and IPR on innovation and finds that, while IPR play a significant and positive role in industrialized countries, it is negative and not significant for LDCs, and is positive and significant for the whole sample. Contrary to the other studies, she uses the number of patent applications in the USA as a proxy for innovation. Since IP protection systems are relatively recent in LDCs, and that not all innovations qualify for patent protection, this measure might be imperfect for the study of innovation in LDCs. Furthermore, patenting activity might be closely related to the structure of the economy, that is not controlled for. Finally, past innovative activity is not taken into account.

The impact of IPR on innovation in LDCs is theoretically not clear, and the empirical evidence available indicates that it might be different for industrialized and developing countries. This paper hence investigates the role of IPR and other determinants of innovation using a new dataset of industrialized and developing coun-

tries. It also compares different econometric estimators to find out which one is appropriate for small panel datasets.

### 3. Methodology

#### 3.1. Data

I constructed a new panel dataset comprising 22 industrialized and 44 developing countries. I use average annual data for seven 5-year sub-periods (1970-1995). Table 1 presents the variables used in the estimations, along with the expected signs of the parameters, and their sources.

**Table 1. Description of variables**

	<b>Expected Sign</b>	<b>Variable</b>	<b>Source</b>
<b>Dependent variable</b>			
Innovation		Total R&D expenditures as a proportion of GDP (5-year average) (RDGDP)	UNESCO statistical yearbooks (various years), RICYT
<b>Explanatory variables</b>			
Demand-pull factors	+	Gross domestic product (GDP) per capita (constant 2000 US\$) (GDPPC)	World Development Indicators (WDI) (World Bank, 2005)
	+	Population (latest year) (POP)	
Technology-push factors	+	Lagged R&D expenditures as a proportion of GDP (L_RDGDP)	UNESCO statistical yearbooks, RICYT
Macroeconomic instability	-	Inflation (INF)	WDI 2005
Political instability	-	State failure events dummy (POL)	Constructed from State failure task force
Access to capital	+	Saving as a proportion of GDP (SAV)	WDI (2005)
Cost of capital	-	Real interest rate (INTRATE)	WDI (2005)
Competition	+/-	Openness to trade (OPEN)	Penn World Table 6.1
Intellectual property protection	+/-	Index of IP protection (IP)	Park and Ginarte (1997), Park (2002)
Human capital	+	Years of schooling, above 15 (EDU)	Barro-Lee data set (2000)

Innovation is proxied by total R&D expenditures as a proportion of GDP. IPR are expected to provide incentives for private R&D, but the classification of R&D tends to be between productive and non-productive sectors and these series are not stable over time and working with aggregate R&D expenditures allows including more LDCs in the sample. Intellectual property protection is proxied by a time-varying index of IP protection that covers 5 categories of patent law: extent of coverage, membership in international agreements, provisions for loss of protection, enforcement mechanisms and the duration of protection.

Estimations are performed on three sub-samples: industrialized countries, developing countries and the whole sample (see table 2). Least-developed countries are underrepresented in this dataset: data are not available for the periods covered, which could bias the results. Table 3 presents the summary statistics.

**Table 2. Countries**

Developing Countries	Industrialized Countries
Argentina, Bolivia, Brazil, Central African Republic, Chile, Columbia, Costa Rica, Cyprus, Ecuador, Egypt, El Salvador, Guatemala, Guyana, India, Indonesia, Iran, Jamaica, Jordan, Mauritius, Mexico, Nicaragua, Niger, Pakistan, Panama, Peru, Philippines, Singapore, Sri Lanka, Sudan, Thailand, Trinidad & Tobago, Turkey, Uruguay, Venezuela, Zambia	Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, USA

**Table 3. Summary Statistics**

Variables	Developing Countries (44)		Industrialized Countries (22)		Total Sample (66)	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
RDGDP	0,104	0,347	1,451	0,749	0,666	0,865
GDPPC	2450,12	2815,74	15 291	6 865	4 585,63	6 744,68
POP	38 715	108 934	33 338	50 611	35 912	09 567
INF	74,79	391,03	7,611	6,631	48,260	305,639
POL	0,291	0,455	0,028	0,166	0,203	0,403
SAV	17,546	10,411	24,259	5,253	19,898	10,237
INTRATE	5,816	22,151	3,932	4,113	5,023	16,053
OPEN	65,84	59,31	44,338	24,165	58,873	49,937
MANUF	17,646	9,331	21,671	5,298	18,218	8,823
IP	2,159	0,727	3,201	0,659	2,523	0,844
EDU	4,347	2,035	7,897	2,104	4,617	2,776

### 3.2. Estimation

Given the theoretical importance of technology-push factors, the past investments in R&D as a proportion of GDP, i.e., the lagged dependent variable, is used as a regressor. This introduction generates a dynamic relationship for countries ( $i$ ) over time ( $t$ ) of the type

$$y_{it} = \alpha y_{i,t-1} + \beta x'_{it} + u_{it}, \quad i = 1, \dots, N \text{ and } t = 2, \dots, T$$

where  $\alpha$  is a scalar,  $x'_{it}$  is  $1 \times K$  and  $\beta$  is  $K \times 1$ . The error component is  $u_{it} = \eta_i + v_{it}$  where

$E[\eta_i] = 0$ ,  $E[v_{it}] = 0$ ,  $E[v_{it}\eta_i] = 0$  for  $i = 1, \dots, N$  and  $t = 2, \dots, T$ . The  $v_{it}$  are assumed to be serially uncorrelated  $E[v_{it}v_{is}] = 0$  for  $i = 1, \dots, N$  and  $s \neq t$ .

Some problems arise from the introduction of the lagged variable on the right-hand-side. Since  $y_{it}$  is a function of  $\eta_i$ ,  $y_{i,t-1}$  is also a function of  $\eta_i$ , causing a correlation between a regressor and the error term. This renders



the OLS estimator inconsistent and biased (upwards). Estimation using fixed effects (FE) eliminates the inconsistency by eliminating  $\eta_i$ . However, for panels with small T, this induces a correlation between the transformed lagged dependent variable and the transformed error term, which causes the fixed effects estimator to be biased (downwards). The estimates of  $\alpha$  obtained with these two methods can however be used as boundaries to control for misspecification or inconsistency in other models.

Arellano and Bond (1991, hereafter AB) proposed a generalized method of moments (GMM) procedure where they use orthogonality conditions between  $y_{it, t-1}$  and the disturbance  $v_{it}$  to obtain supplementary instruments, which yields a consistent estimator. Other authors (eg. Blundell and Bond, 1998, hereafter BB) have since found that weak instruments could cause large finite sample biases, especially when time series are persistent and the number of series observations is small. They proposed a system GMM estimator using equations in differences and in levels to bring additional moment conditions and increase efficiency. Such estimation procedure is adequate for panels with large N and small T since it relies on asymptotic properties. Windmeijer (2005) hence developed a correction for the two-step covariance matrix that significantly increases the efficiency of these GMM estimators, that is used here.

Comparing these different estimators, Judson and Owen (1999) and Adolph *et al* (2005) found the Least-Squares Dummy Variable Corrected estimator (LSDVC), originally proposed by Kiviet (1995) and recently extended by Bruno (2005a, 2005b) to the case of unbalanced panels, to be the most efficient and less biased. However, while taking care of the endogeneity of the lagged dependent variable, the LSDVC estimator assumes strict exogeneity of the other regressors. The results for all estimations are presented but, given the qualities of the LSDVC estimator, only these results will be discussed. Estimations are performed using Stata8, and all variables are estimated in logs. For the system GMM estimator a program created by Roodman (2005) is used, while for the LSDVC estimation the program of Bruno (2005b) is used.

Tests for the presence of autocorrelation indicate that the hypothesis of no first-order autocorrelation can be rejected, as the hypothesis of homoskedasticity. The GMM regressions are hence performed using the two-step estimator.

Table 4. Estimation results

Variables	Developing Countries					Industrialized Countries					Total Sample				
	OLS	FE	LSDVC	AB	BB	OLS	FE	LSDVC	AB	BB	OLS	FE	LSDVC	AB	BB
L_RDGDP	<b>0,563***</b> (0,019)	<b>0,571***</b> (0,021)	<b>0,596***</b> (0,021)	<b>0,471***</b> (0,003)	<b>0,887***</b> (0,166)	<b>0,713***</b> (0,050)	<b>0,596***</b> (0,027)	<b>0,629***</b> (0,024)	<b>0,606***</b> (0,016)	<b>0,915***</b> (0,056)	<b>0,598***</b> (0,017)	<b>0,577***</b> (0,021)	<b>0,602***</b> (0,017)	<b>0,474***</b> (0,001)	<b>0,880***</b> (0,173)
IP	0,172 (0,248)	0,528 (0,571)	0,617 (0,768)	<b>0,464***</b> (0,166)	0,241 (0,243)	<b>0,428**</b> (0,151)	0,070 (0,207)	0,043 (0,218)	-0,158 (0,145)	0,038 (0,159)	<b>0,671***</b> (0,227)	0,299 (0,562)	0,564 (0,464)	<b>0,877***</b> (0,066)	0,239 (0,328)
EDU	<b>0,697**</b> (0,258)	-0,239 (0,822)	-0,150 (0,868)	-0,230 (0,291)	-0,359 (0,222)	<b>0,325**</b> (0,149)	0,008 (0,210)	-0,013 (0,192)	<b>-0,559*</b> (0,309)	0,213 (0,154)	<b>0,888***</b> (0,229)	<b>1,222***</b> (0,461)	<b>1,104***</b> (0,226)	-0,093 (0,156)	-0,522 (0,512)
POP	0,018 (0,066)	<b>1,701*</b> (0,955)	1,502 (1,342)	<b>1,347**</b> (0,535)	0,063 (0,056)	<b>-0,054**</b> (0,025)	-0,217 (0,376)	-0,397 (0,499)	-0,976 (0,729)	<b>-0,043*</b> (0,025)	- (0,229)	- (0,461)	- (0,226)	<b>0,515**</b> (0,242)	-0,053 (0,069)
OPEN	- (0,066)	- (0,955)	- (1,342)	- (0,535)	<b>-0,902**</b> (0,433)	-0,088 (0,054)	0,097 (0,138)	0,104 (0,130)	<b>0,541*</b> (0,272)	-0,053 (0,055)	<b>-0,808***</b> (0,099)	<b>-0,719*</b> (0,402)	0,328 (0,520)	- (0,381)	-0,626 (0,381)
MANUF	<b>-0,607*</b> (0,334)	<b>-0,937*</b> (0,477)	<b>-0,863**</b> (0,404)	<b>-1,231***</b> (0,218)	- (0,433)	- (0,054)	- (0,138)	- (0,130)	- (0,272)	- (0,055)	<b>-0,669***</b> (0,218)	-0,578 (0,457)	<b>-0,602*</b> (0,324)	<b>-0,780***</b> (0,098)	0,650 (0,657)
GDPPC	<b>-0,224**</b> (0,111)	0,141 (0,440)	0,084 (0,807)	<b>1,173***</b> (0,383)	<b>0,429***</b> (0,115)	-0,022 (0,056)	<b>0,322**</b> (9,147)	<b>0,361***</b> (0,104)	0,074 (0,135)	0,023 (0,054)	<b>0,259***</b> (0,093)	-0,100 (0,532)	-0,156 (0,448)	<b>0,774***</b> (0,173)	0,144 (0,222)
CONSTANT	- (0,111)	<b>-16,463*</b> (8,377)	- (0,807)	- (0,383)	- (0,115)	- (0,056)	-1,382 (3,107)	- (0,104)	- (0,135)	- (0,054)	- (0,093)	-3,827 (3,707)	- (0,448)	- (0,173)	- (0,222)
R <sup>2</sup>	0,842	0,829	-	-	-	0,936	0,853	-	-	-	0,937	0,819	-	-	-
F/ Chi <sup>2</sup> test	<b>211,25</b> (0,000)	<b>138,02</b> (0,000)	<b>58,88</b> (0,000)	-	<b>7276,75</b> (0,000)	<b>305,21</b> (0,000)	<b>120,20</b> (0,000)	<b>592,86</b> (0,000)	-	<b>1950,67</b> (0,000)	<b>562,13</b> (0,000)	<b>129,98</b> (0,000)	<b>104,52</b> (0,000)	-	<b>1965,84</b> (0,000)
Test for AR(1)	-	-	-	-1,88 (0,060)	-1,00 (0,319)	-	-	-	-2,05 (0,040)	-1,89 (0,059)	-	-	-	-1,89 (0,058)	-1,02 (0,309)
Test for AR(2)	-	-	-	-2,09 (0,036)	-1,48 (0,139)	-	-	-	-1,42 (0,156)	-0,34 (0,731)	-	-	-	-2,02 (0,043)	-1,47 (0,143)
Countries	35	35	35	33	35	22	22	22	22	22	55	55	55	43	54
Observations	211	211	211	155	160	152	152	152	128	107	272	263	263	180	200

Note: significant at the 1% level:\*\*\*, 5%: \*\*, 10%: \*. Standard errors in parentheses.

## 4. Results and Analysis

### 4.1. Estimation Results

Table 4 presents the estimation results for the different models and sub-samples. For all models, the F-tests show that the parameters are jointly significant. As already mentioned, given that GMM estimators rely on asymptotic properties, and given that the test for the presence of autocorrelation in the residuals are not satisfactory, these estimates will not be discussed. OLS and FE estimators are presented for comparison purposes.

As was already mentioned, OLS produces an estimate of  $\alpha$  that is biased upwards, and  $\alpha_{FE}$  is biased downwards. Following expectations,  $\alpha_{OLS} > \alpha_{FE}$  for the full sample as well as for the sub-sample of industrialized countries, but for the developing countries sub-sample  $\alpha_{FE} > \alpha_{OLS}$ . Even though  $\alpha_{LSDVC}$  is not located in the interval for full sample and the developing countries sub-samples, it is slightly above the upper-bound ( $\alpha_{OLS}$ ) which could indicate an upward bias. For all samples  $\alpha$  is positive and strongly significant, which supports the hypothesis of the cumulative nature of innovation. Furthermore, the magnitude of the coefficient is higher for the industrialized countries sub-sample, which could indicate that this effect is stronger for these countries. We are especially interested in the IP index, however it is not significant in any of the LSDVC regressions, but is significant in the OLS regressions for the total sample and the industrialized countries sub-sample. This could be explained by the high level of correlation between the IPR index and other variables in the estimations, see table 5 for some of the correlations. The correlation between IPR and lagged R&D is high and significant for industrialized countries and the full sample, however it is low and insignificant for the LDCs sub-sample. Looking at the correlation between IPR and openness to trade, that is significant for LDCs but not for the two other samples helps explaining the strengthening of IPR in these different groups. In industrialized countries, IPR were strengthened to protect inventions, while in LDCs strengthening took place to comply with international trade agreements, as was observed in Latin American countries (Jaffé and van Wijk, 1995). This however raises the question of the possible endogeneity of the IPR variable.

**Table 5. Correlations for IPR**

IPR and..	LDC	DC	Total sample
<b>L_RD</b>	0,0619	0,6419 *	0,6048 *
<b>EDU</b>	0,3263 *	0,4052 *	0,5904 *
<b>GDPCAP</b>	0,3161 *	0,5473 *	0,6500 *
<b>POP</b>	-0,1837 *	0,4500 *	-0,0633
<b>OPEN</b>	0,2010 *	0,1390	0,0187
<b>MANUF</b>	-0,1099	-0,0032	0,0466

Note: \* significant at the 5% level

Education appears to play an important and positive role in explaining innovation for the full sample, however the coefficient (even though positive) is not significant in the two sub-samples. Manufacturing, which is used to account for the structure of the economy, is negative and significant for the full sample as well as for the LDCs sub-sample, however given the availability of data it was not included in the estimations for industrialized countries. Finally, the demand pull hypothesis, reflected by the variables GDP per capita and population, is supported only in the sub-sample of industrialized countries where GDP per capita has a positive and significant coefficient. The lower levels of R&D in developing countries appear not to respond to the purchasing power of the local market. Given that we are working with aggregate R&D expenditures, it could also be that most of the R&D expenditures come from the government and hence do not react to perceived market demand but rather to strategic priorities.

#### 4.2. Analysis

These results suggest that innovation, in both developing and industrialized countries, strongly depends on past R&D investments, the so-called technology push factors, and more importantly so in industrialized countries. This could be due to the fact that in most industrialized countries, firms and research institutes have a high level of technological capabilities and hence benefit from advances in science pushing further the technological frontier, i.e., domestic investments and investments from other industrialized countries. Conversely, the level of technological capabilities amongst firms and research institutes in LDCs is in general lower (or more heterogeneous), and these have access to spillovers from the R&D activities in industrialized countries, and the role of domestic investments would hence not be as important. This is supported by empirical evidence in

Coe, Helpman and Hoffmaister (1997) who found that R&D spillovers are especially important when countries are trading with countries with higher technological capabilities.

Similarly, in industrialized countries the demand-pull factors (GDPPC) play an important role, but not in LDCs. In the same line of thought as the discussion on the technology-push factors, demand for innovation in LDCs can be satisfied from several sources – domestic and foreign – while the demand for a variety of differentiated products, adapted to the local conditions, more important in industrialized countries might explain this situation. Another explanation would be that the characteristics of the markets in LDCs (high transaction costs) impair the transmission, and hence the impact, of demand for innovation.

These results are consistent with those of previous studies discussed in section 2. However, the number of significant parameters is a lot higher in these other studies, and the estimation methods differ: Kanwar and Evenson use OLS on the equation in logarithmic form, in a static model (not including past R&D investments), ignoring the potential role of technology-push factors on innovation, which are here found to be important. On the other hand, Lederman and Maloney use the GMM system estimator, which is expected to yield consistent estimators for panels with large N and small T, without correcting for the small sample bias, which causes the standard errors to be underestimated (Windmeijer, 2005). Furthermore, they chose to estimate certain variables in logarithmic form where the interpretation of the results becomes problematic and contrary to standard procedures, e.g., estimating most variables in levels but the IP index in logarithmic form. Even though Kanwar and Evenson (2003) look at the determinants of private R&D and Lederman and Maloney (2003) use aggregate R&D, they obtain similar results.

There might also be a selection bias in the DC dataset since the countries for which data are available possess a certain level of institutional capacity. This *de facto* eliminates countries with lower levels of institutional capacity and takes away some of the variability, and hence representativity of the sample. However, data for these countries are not available, and the results derived for LDCs, especially when compared with the ones of industrialized countries, also provide useful information for policy-making in countries at lower levels of development.

## 5. Conclusion

This paper identifies the determinants of innovation using a panel of developing and industrialized countries, applying different panel estimation methods to the case of panels with small N and T. Previous investments in R&D are found to be an important factor explaining private R&D investments, in both samples, while demand-pull factors (GDP per capita) play a role in industrialized countries but not in developing countries, human capital is positive and significant only in the full sample.

Even though the LSDVC estimator has been found to be most efficient and less biased in Monte Carlo simulations, it is appropriate only when dealing with strictly exogenous regressors.. This could explained the possible bias observed in the above estimations. Further work should attempt to combine this estimator with instrumental variable methods to deal with the endogeneity of regressors. Another econometric issue related to the high correlation among regressors, which makes the interpretation of the coefficients difficult and potentially affects the significance of the variables. Finally, the availability of data is problematic, and further efforts will be put on the development of sample selection models to take the potential bias of the sample into account in the estimations of the parameters.

Given the importance of innovation for economic growth and development, the study of the innovation process in developing countries warrants more attention, and the results presented here underline the need to control for the level of development of look more specifically at the case of developing countries, as determinants of innovation could differ according to the level of development.

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