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

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Evidence from Panel Data

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 the 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.

On the other hand, 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 (Gaisford *et al*, 2001). Overall, 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).

Given their lower innovative capabilities, IPR might not support local innovation in LDCs. Hence strong IP protection would not lead to higher domestic innovation levels, as exemplified by a case study of the maize breeding industry in Mexico (Léger, 2005). However, strong IPR would still impose the costs related to monopoly distortions on foreign inventions, leading to a net welfare loss. 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 (Fink and Maskus, 2005), without having a clear picture of the impacts IPR have in these economies.

More generally, the determinants of innovation in LDCs are still a relatively understudied research area, both theoretically and empirically. LDCs differ from industrialized countries in several respects - institutional, cultural and economic - which can affect innovation. Therefore their case deserves particular attention, especially given the importance innovation could have in supporting their process of economic development.

Given the little guidance offered by the theoretical literature and the scarcity of empirical evidence for LDCs, the study intends to identify the determinants of innovation, using a novel dataset of LDCs and industrialized countries.

The following section presents background information related to innovation, its determinants and IPR to define the theoretical concept. Section 3 presents the methodology and the data used, and section 4 presents the results of the estimations. Section 5 discusses the results obtained and section 6 concludes.

2. Theory

2.1. Innovation: Nature and determinants

Through the innovation process, a new product (or process) is created, 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[i].

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 the firm operates also affects its innovative performance. At the macroeconomic level, economic and political stability (Lall, 1992) provides an environment supportive of innovation. Market structure also affects incentives to innovate – either positively or negatively, depending on the situation – hence competition must also be taken into account (Grossman and Helpman, 1991). R&D being an expensive and risky endeavor, access to capital and diversification possibilities are essential for most firms. Finally, innovation cannot take place without qualified scientists and workers, hence the level of human capital in the country is another important factor (Crespo *et al*, 2004).

Even though innovation could play a crucial role for LDCs, most of the literature so far has focused on industrialized countries. However, LDC characteristics could differ enough from the usual models and call for another treatment. Demand-pull factors have a limited impact in LDCs, given the generally small purchasing power of their inhabitants. Markets are often incomplete, weak or non-existent (Lall, 1992), which, for certain areas such as risk, capital (financial and human) and information, has important implications for the conduct of innovative activities. 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

A few papers have been written about innovation and IPR in an international context. In a North-South setting, where only the North can innovate and the South has lower labor costs, Deardorff (1992) finds that strengthening IPR hurts the South and benefits 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). Using an endogenous growth model, including imitation and technology transfer, Helpman (1993) finds that strengthening of 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, a slowdown of innovation and the reallocation of production from the South (low-cost) to the North.

A few studies examined the link between IP protection and innovation for panels of countries (Alfranca and Huffman, 2003; Kanwar and Evenson, 2003; Lederman and Maloney, 2003). The former study uses a panel of EU countries to provide evidence quantifying the effects of economic incentives and institutions on private innovation in agriculture, while the other two papers use panels of industrialized and developing countries. They find the level of IP protection, institutional quality, economic openness, demand pull factors and availability of credit to be positive and significant factors explaining innovation. Conversely, risk and interest rate have negative impacts. These results are consistent with the literature, but LDCs are either not or underrepresented in these studies, and there is no explicit control for the level of development of the countries.

From this short overview of the literature, it is clear that the environment in which innovation takes place in LDCs supports investigating its determinants specifically for these countries. Furthermore, special attention is given to the role of IPR. It is disputed in the theoretical literature and more empirical evidence could guide the theory in the appropriate direction.

3. Methodology

3.1. Data

Based on the review of the literature presented in the preceding section, the factors most likely to influence innovation are presented in table 1, along with the expected signs of the parameters, the variables used in the estimation and their sources. Estimations are performed on two datasets: a sample of industrialized countries and a sample of developing countries[ii]. African countries are underrepresented in this dataset, which can bias the results in favor of more advanced LDCs, however data are simply not available for these countries. Table 2 presents the summary statistics.

Table 1. Description of data

	Expected Sign	Variable	Source
Dependent variable			
Innovation		Total R&D expenditures as a proportion of GDP (quinquennial average) (RDGDP)	UNESCO statistical yearbooks (various years), RICYT
Explanatory variables			
Demand-pull factors	+	Gross domestic product (GDP) per capita (constant 2000 US$) (GDPPC) Population (latest year) (POP)	World Development Indicators (WDI) (World Bank, 2005)
Technology-push factors	+	Lagged R&D expenditures as a proportion of GDP (L_RDGDP)	UNESCO statistical yearbooks, RICYT
Macroeconomic stability	+	GDP growth rate (GDPG)	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	-	Deposit interest rate (INTRATE)	WDI (2005)
Competition	+	Openness to trade (2001) (OPEN)	Penn World Table 6.1
Intellectual property protection	+	Index of IP protection (IP)	Park and Ginarte, (1997)
Human capital	+	Years of schooling, above 15 (EDU)	Barro-Lee data set (2000)

Innovation, the dependent variable, can be proxied using outputs, for example the number of patented inventions per year, or inputs, e.g. investments in innovation. Given the relatively recent introduction of IPR systems in LDCs, and the fact that not all innovations are patentable nor patented, the input-proxy is preferred.

Table 2 Summary Statistics

Variables	Developing countries			Industrialized Countries		
(in logs)	# Observations	Mean	Std. Dev.	# Observations	Mean	Std. Dev.
RDGDP	136	-4,9717	2,4861	128	0,2165	0,6572
GDPPC	211	7,4079	1,0788	131	9,6643	0,4191
POP	216	9,3663	1,6868	132	9,5112	1,4927
L_RDGDP	121	-5,3399	2,2945	106	0,1661	0,6773
GDPG	208	2,9089	0,3292	131	2,8633	0,1601
POL	216	0,3511	0,4787	132	0,0303	0,1721
SAV	202	2,7411	0,8265	125	3,1495	0,2256
INTRATE	136	2,9411	1,3387	128	1,9933	0,5085
OPEN	216	3,8973	0,7146	132	3,7517	0,5410
IP	216	0,6788	0,4376	132	1,1866	0,2100
EDU	203	1,4979	0,5256	132	2,0795	0,2732
Countries	36	-	-	22	-	-

IPR are expected to support private investments in R&D, therefore private R&D investments as a proportion of GDP would appear to be a more appropriate dependent variable. Still, given that the classification of R&D tends to be between productive and non-productive sectors, and that these series are not stable over time, I use aggregated R&D expenditures. Moreover, working with aggregated R&D expenditures allows including more LDCs in the sample.

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 of the type

$$y_{it} = \alpha y_{i,t-1} + \beta x_{it}^{'} + u_{it}, \quad i = 1, \ldots, N \text{ and } t = 2, \ldots, T$$

where α is a scalar, $x_{it}^{'}$ is 1 x K and β is K x 1. The error component is $u_{it} = \eta_i + v_{it}$ where $E[\eta_i] = 0, E[v_{it}], E[v_{it}\,\eta_i] = 0$ for $i = 1, \ldots, N$ and $t = 2, \ldots, T$. The v_{it} are assumed to be serially uncorrelated $E[v_{it}\, v_{is}] = 0$ for $i = 1, \ldots, N$ 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 η_i, $y_{i\,t-1}$ is also a function of η_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 η_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 α 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 $y_{i,\,t-1}$ 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 propose 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 (asymptotic properties). For finite samples, Windmeijer (2005) has developed a correction for the two-step covariance matrix that significantly increases the efficiency of these GMM estimators.

The availability of data is problematic: For none of the developing countries is the dependent variable available for all periods (5-year averages, 1970-1995), and there are also missing observations in the sample of industrialized countries. However, the GMM estimators are robust to missing observations. I therefore use these estimators (AB, BB, as well as OLS and FE,) to identify the determinants of innovation and the role of IPR, but also to identify the most appropriate estimator for datasets where both N and T are small. The equations are estimated using Stata 8, for the system GMM estimator a program created by Roodman (2005) is used. Tests for the presence of autocorrelation indicated that the hypothesis of no first-order autocorrelation could be rejected, as the hypothesis of homoskedasticity. The GMM regressions are hence performed using the two-step estimator

4. Results

4.1. Developing countries

Table 3 presents the estimation results for the different models, for the sample of developing countries. For all models, the F-tests show that the parameters are jointly significant (at the 1% level). For the two GMM estimators, the Hansen and Sargan tests result in the non-rejection of the null hypothesis, which implies that the over-identifying restrictions are valid. The tests for the presence of autocorrelation in the residuals, for the system GMM estimator (BB), show satisfactory results. However, the presence of first-order correlation in the residuals in the AB regressions is not rejected, as it should be, which indicates that the estimates are inconsistent (Arellano and Bond, 1991: 281). I will hence concentrate on the results from the system GMM (BB) regression, where the specification is appropriate.

Following expectations, $\alpha_{OLS} > \alpha_{FE}$, and α_{BB} and α_{AB} lie in the interval, even though α_{AB} is not significant. α has the expected sign in the BB regression, which supports the technology-push hypothesis. The IP variable is also positive and significant, as is the human capital. Even though it is not significant, the cost of capital (INTRATE) has the expected sign, but not population (POP) and GDP per capita (GDPPC), which contradicts the demand effect hypothesis.

Table 2. Estimation results for sample of developing countries

Variables	OLS	FE	AB	BB
L_RDGDP	**1,4375****	-0,0691	0,0504	**0,2369****
	(0,015)	(0,087)	(0,084)	(0,095)
IP	**0,2493****	1,8855	**4,0765*****	**4,1407*****
	(0,039)	(1,527)	(0,867)	(1,055)
EDU	**1,2132****	-0,6301	-2,2806	**1,8003***
	(0,467)	(1,652)	(1,722)	(1,031)
POP	0,2871	3,8348	4,1467	-0,2852
	(0,180)	(2,505)	(3,636)	(0,273)
OPEN	-0,5713	**2,0066****	-	-
	(0,577)	(0,901)		
SAV	0,1744	-0,8793	-0,9431	-
	(0,226)	(0,575)	(0,704)	
GDPPC	0,2049	-0,6863	-	-0,3041
	(0,237)	(1,015)		(0,645)
GDPG	**-1,4045*****	**-1,8928*****	**-2,2127*****	-
	(0,436)	(0,538)	(0,318)	
INTRATE	-0,2245	0,1296	-	-0,1509
	(0,425)	(0,208)		(0,256)
POL	0,2446	1,0099	**2,4159*****	0,5124
	(0,455)	(0,636)	(0,729)	(0,712)
CONSTANT	-4,2403	**-49,0581***	-	-
	(4,725)	(24,722)		

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

Variables	OLS	FE	AB	BB
R^2	0,6252	0,6186	-	-
F/ Wald-test	**14,93**	**5,51**	**8,36**	**40,38**
	(0,000)	(0,000)	(0,000)	(0,000)
Hansen/ Sargan test of over-id	-	-	**2,57**	**11,13**
			(1,000)	(1,00)
AB Test for AR(1)	-	-	-0,53	**-1,69**
			(0,594)	(0,091)
AB Test for AR(2)	-	-	**-1,12**	**-0,88**
			(0,265)	(0,380)
Countries	29	29	18	26
Observations	73	73	42	70

Note: P-values in parentheses

4.2. Industrialized countries

Table 4 presents the results of the estimations for the sample of industrialized countries. For all models, the F-tests show that the parameters are jointly significant (at the 1% level). Again, for the two GMM estimators, the Hansen and Sargan tests of over-identification, as well as the tests for the presence of autocorrelation in the residuals show satisfactory results for both GMM estimators. This time, α has the expected positive sign and is significant in all regressions, again supporting the technology-push hypothesis, and $\alpha_{OLS} > \alpha_{FE}$, with α_{BB} in the interval, but not α_{AB}. Again, I will concentrate on the results of the system GMM estimator, given that the Sargan/ Hansen and auto-correlation tests yield more satisfying results.

This time, the IP variable is negative, even though not significant, as is the human capital (EDU), contrary to expectations. However, population (POP) and GDP per capita (GDPPC), proxying the demand-pull effect, are now both positive and significant, at the 10% and 5% level, respectively. Furthermore, the variable openness to trade (OPEN), accounting for competition, is also positive and significant at the 10% level, which indicated that in more open countries, facing more competition, more resources are invested in innovative activity. The other variables are not significant, but the political failure (POL) and cost of capital (INTRATE) are negative, as expected, while the availability of capital (SAV) and the GDP growth rate, proxying the stability of the economy, are negative.

Table 4. Estimation results for sample of industrialized countries

Variables	OLS	FE	AB	BB
L_RDGDP	**0,7070*** **	**0,2842*** **	**0,7400*** **	**0,5882*** **
	(0,060)	(0,099)	(0,198)	(9,146)
IP	-0,0537	0,0903	**0,6014***	-0,2027
	(0,127)	(0,245)	(0,329)	(0,581)
EDU	0,0558	-0,3344	**-1,059****	-0,0456
	(0,092)	(0,286)	(0,449)	(0,138)
POP	0,0252	-1,1633	-0,8039	**0,0676***
	(0,025)	(0,553)	(1,824)	(0,038)
OPEN	0,0446	**0,5252*** **	0,2783	**0,1269***
	(0,039)	(0,192)	(0,297)	(0,072)
SAV	-0,0999	**-0,5902*** **	0,0734	-0,1837
	(0,098)	(0,175)	(0,191)	(0,359)
GDPPC	**0,3205*** **	**0,6032****	-0,1482	**0,5573****
	(0,090)	(0,238)	(0,418)	(0,207)
GDPG	0,0765	-0,1457	0,0571	-0,2823
	(0,138)	(0,151)	(0,139)	(0,255)
INTRATE	-0,0572	**-0,1355****	0,0551	-0,1332
	(0,053)	(0,066)	(0,071)	(0,191)
POL	0,0685	**0,3363****	0,0764	-0,0507
	(0,050)	(0,149)	(0,082)	(0,645)
CONSTANT	**-3,2308****	6,6121	0,0252	**-4,3937****
	(1,298)	(4,855)	(0,082)	(1,829)

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

R^2	0,9248	0,6728	-	-
F/ Wald-test	**1439,16**	**14,80**	**70,34**	**389,58**
	(0,000)	(0,000)	(0,000)	(0,000)
Hansen/ Sargan test of over-id	-	-	13,11	10,46
			(0,7288)	(1,000)
AB Test for AR(1)	-	-	-2,79	-2,37
			(0,0053)	(0,018)
AB Test for AR(2)	-	-	-0,88	-0,11
			(0,3788)	(0,910)
Countries	22	22	21	22
Observations	104	104	81	104

Countries included in each regression listed in appendix

5. Discussion

5.1. Analysis of the results

These results suggest that innovation, in both developing and industrialized countries, strongly depends on past R&D investments, the so-called "technology-push" factor, 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. This is however the only factor for which the (significant) effect is the same in both samples.

The importance of the level of human capital (EDU) in LDCs could reflect the general scarcity of this resource among the countries of the sample, and the comparatively high level of R&D investments in countries with more human capital (South Korea, Israel). Conversely, the relatively homogeneous level of human capital amongst industrialized countries, and the generally high-level character of the science performed in these countries could explain the lack of significance of this variable in that sample. IPR is a positive and significant factor explaining domestic R&D investments in LDCs, but not in industrialized countries. This outcome could result from the omission of a measure of institutional capacity[iii], that IPR would capture in LDCs, and that would not play such an important role in industrialized countries.

Finally, in industrialized countries the demand-pull factors (POP, GDPPC) play an important role, but not in LDCs. In the same line of though 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 4. 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.

5.2. Econometric issues

From the econometric perspective, several points need to be addressed. The small size of the datasets and the problem of missing observations can induce biased in the estimations performed, and hence affect the quality and reliability of the results obtained. In cases where few observations are missing, the benefits of replacing them with imputation and interpolation methods are higher than the costs (reduced reliability of the estimations) but in situation with several missing observations, the costs might be too high. The system GMM estimator developed by Blundell and Bond, along with the finite sample correction developed by Windmeijer, seems to be the most appropriate for the estimation of panel datasets with small T and relatively small N, based on the specification tests (Hansen test of over-identification, tests for the presence of first- and second-order autocorrelation in the residuals) and on the theory.

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.

6. 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 relatively 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 intellectual property protection and human capital would be important factors supporting innovation in LDCs, and openness to trade and demand-pull factors such as GDP per capita and population would be instrumental in industrialized countries. The GMM system estimator is found to be the most appropriate estimator for datasets with rather small N and small T, in this case with missing observations and heteroskedasticity.

The results indicate that demand-pull factors become more important for countries that have attained a certain level of development. In LDCs, the importance of IPR as a determinant of innovation, especially in regressions where no other variable accounts for the quality of institutions, indicates the significance of institutions for the process. Similarly, investments in research and development, but also in human capital, are instrumental to support innovation in LDCs, and thus supporting economic development.

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[i] Other can include tax breaks on the performance of R&D, contests, R&D, or public performance of R&D.

[ii] None of the former socialist states is included, since no intellectual property protection was awarded during the study period. The developing countries included in the different regressions are: AB: Argentina, Brazil, Chile, Colombia, El Salvador, Guatemala, India, Indonesia, Israel, Korea, Mauritius, Mexico, Pakistan, Peru, Philippines, Singapore, Thailand, Venezuela; BB: AB + Costa Rica, Egypt, Guyana, Jamaica, Jordan, Niger, Panama, Sri Lanka; OLS, FE: BB + Iran, Panama, Turkey. The industrialized countries are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, USA (New Zealand is not part of the AB estimation).

[iii] Such measure was available only for a small subset of the samples and hence was not used.