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NON-LINEAR EFFECTS OF INTELLECTUAL PROPERTY RIGHTS ON TECHNOLOGICAL INNOVATION: EVIDENCE FROM EMERGING AND DEVELOPING COUNTRIES

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ABSTRACT

The protection of Intellectual Property Rights (IPR) is a key determinant of innovation. Following the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), all member states of the World Trade Organization are called upon to introduce high intellectual property rights standards. Hence the importance of the issue relative to IPR. Recent studies suggest that IPR protection stimulates innovation only under certain conditions. In this study, we suppose that IPR have a positive impact on technological innovation only in countries with high levels of economic development. The objective of this study is to examine the relationship between intellectual property rights, economic development and technological innovation in the context of emerging and developing countries. To measure innovation, we use patent applications filed by residents of a given country with the United States Patent and Trademark Office. IPR is measured by the Ginarte and Park index. Panel Threshold Regression is applied to data of 55 emerging and developing countries for the period 1980-2009. The estimation results provide evidence for the existence of nonlinear relationship depending on economic development level. We conclude that « one size does not fit all ».

Contribution/Originality: This study is one of very few studies which have investigated the threshold effects in the relationship between intellectual property rights and technological innovation in emerging and developing countries.

1. INTRODUCTION

Technological innovation is the main driver of economic growth. However, from a social point of view, the industrial sector under invests in Research and Development (R&D) because of the problems relative to appropriation of the benefits of research efforts. The protection of Intellectual Property Rights (IPR) is one way, among others, to cope with these problems.

According to the *Organisation Mondiale de la Propriété Intellectuelle*, intellectual property rights allow the creator or owner of a patent, trademark or copyrighted work to benefit from his or her work or investment. Patents are arguably the most robust form of IPR. The patent confers the exclusive right to an invention. It guarantees to its holder the protection of the invention against any kind of exploitation (by manufacturing it, using it, selling it, etc.) for a limited duration (usually 20 years).

The protection of ideas through robust IPR prevents imitation. Therefore, it ensures return on investment. IPR system promotes the generation of new knowledge in this case. However, it is not clear that stronger protection always increases the motivation to innovate. Recent theoretical works suggest that IPR protection stimulates innovation only under certain conditions. Datta and Mohtadi (2006) showed that the early stages of development that are associated with low levels of human capital are associated with great confidence to technological imitation. Whereas at later stages of development, skills allow the emergence of innovations.

The objective of this study is to investigate the effect of intellectual property rights on innovation. It aims to highlight non-linear effects in the relationship between IPR and innovation according to the level of economic development. This problem is becoming increasingly important especially in the context of developing countries. In fact, following the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), all member states of the World Trade Organization (WTO) are called upon to introduce high IPR standards.

The purpose of this study is to highlight a possible non-linear relationship between IPR and innovation. Therefore, it is necessary to consider an econometric approach that takes into account the non-linearity. Hansen (1999) threshold regression approach is able to meet these requirements. We estimate a threshold model applied to panel data for 55 countries in six five-year periods. Findings confirm that the protection of intellectual property rights affects technological innovation of emerging and developing countries depending on their level of economic development.

Our empirical analysis differs from the existing literature in several ways. First, previous empirical works on the relationship between IPR and innovation have focused on developed countries or on a combination of developed and developing countries (Ginarte & Park, 1997; Kanwar, 2007; Lach, 1995; Maskus & McDaniel, 1999; Schneider, 2005). Our analysis offers new evidence about emerging and developing countries. Second, unlike several studies, we assume a non-linear relationship between IPR protection and innovation. To the best of our knowledge, this is the first study to use panel threshold regression to analyse the possible non linear effects that may exist in the relation IPR / innovation.

This paper is structured as follows: in the second section, we will review some previous studies relative to the effect of IPR on innovation. The third section will focus on the research methodology. The fourth section will be devoted to the presentation and interpretation of the results. Finally, the fifth section will deal with the conclusion.

2. LITERATURE REVIEW

2.1. Theoretical Literature

Theoretical literature points to either monotonous or non-monotonous relation between IPR and innovation. We present the following theoretical arguments to describe the nature of the IPR / innovation relationship.

The patent affects innovation mainly through its effects on the imitation rate. According to Arrow (1962) the innovator's profits decrease because of the competition which is due to the imitation process. Thus, the imitation delay achieved through patent protection represents a stimulus for firms to invest in R&D. The protection of ideas through robust IPR ensures the return on investment and therefore encourages the generation of new knowledge.

However, it is not certain that stronger protection always increases the motivation to innovate. Recent theoretical works suggest that IPR protection stimulates innovation only under certain conditions. Maskus (2005) (cited in Mohtadi and Ruediger, (2014)) points out that high levels of IPR should be introduced in markets where certain factors such as low barriers to entry, labor market flexibility and an international trading system are already present and developed at a certain level. Introduced differently, high levels of IPR protection may not have effects or even be associated with negative effects on the economy. Such prerequisites are not reachable in some developing countries. Siebeck, Evenson, Lesser, and Primo (1990) noted that robust IPR do not promote R&D in developing countries because of several barriers such as low human capital, lack of physical capital, weak institutional systems and high economic uncertainty. Datta and Mohtadi (2006) have shown that the early stages of development that are associated with low levels of human capital are associated with great confidence in technological imitation. While at more advanced stages of development, skills enable the emergence of innovations.

2.2. Empirical Literature

Several empirical studies have attempted to analyze the impact of the level of IPR protection on innovation. They consider either a linear or a non-linear relationship between these two variables.

Studies assuming a linear relationship found mixed results, confirming a positive effect in some cases and a negative effect in others. For example, Varsakelis (2001) conducted a study of 50 countries to analyze the factors that influence research and development activity. He found that the most important factor affecting R&D intensity is patent protection. Kanwar (2007) exploited data for 44 developing and developed countries for the period 1981-2000. He found that robustness of protection has a big positive influence on R&D spending. In contrast to these studies, Lerner (2002) examined 177 patent reform events in 51 countries over a period of 150 years. The reforms cover the promulgation of patent laws, changes in the term of rights and fees, and limitations of patent rights (e.g. compulsory licenses). He found that, on average, the number of patents filed by residents prior to the reforms was not significantly different from the number of patents filed after reforms.

These mixed results may be explained by the existence of non linearities in the relationship between IPR protection and innovation. That's why some authors try to explain in their empirical works how the impact of IPR protection on innovation varies according to the level of economic development. These studies can be classified into three categories. The first includes works that estimated innovation / IPR elasticity in groups of countries using an ex-ante classification. Schneider (2005) examined the role of IPR in innovation and economic growth in 19 developed countries and 28 developing countries during the period 1970-1990. He found that IPR positively affect innovation, but this effect is more significant in developed countries. Allred and Park (2007) found a U-shaped curve tracing the relationship between IPR protection and innovation. However, papers using this method can be criticized (i) for the use of an ex-ante distinction between developed and developing countries and (ii) for not allowing a direct role of the level of economic development in the innovation / IPR elasticity.

A second group of papers tries to solve the first problem (i) mentioned above. Ginarte and Park (1997) analyzed the link between IPR and growth in a range of countries. They calculated an IPR protection index. The authors found that the distinction between developed and developing countries shows that IPR and economic growth are positively related in developed countries, but this is not the case for developing countries. They highlighted these effects for countries above and below the median value of the level of GDP, respectively. The robustness of these thresholds is not however shown. These are rather determined exogenously.

Finally, a third group of papers aims to illustrate the direct effect of the level of economic development on the link between IPR and innovation (the criticism (ii) mentioned above). Among these works, we can mention that of Chen and Puttitanun (2005) who conducted a study of 64 developing countries during the period 1975-2000. They found that the positive impact of IPR on innovation increases with the level of economic development. However, the authors use a simple first-order polynomial of the interaction term (between the IPR index and the GDP level) to account for the non-linear influence of GDP. This method has important limitations such as the ex-ante specification of the form of the relation and the absence of tests for higher order polynomials.

From the theoretical and empirical literature cited above, we will assume that intellectual property rights affect innovation in a non-monotonic way. To test non-linear effects in the IPR protection /innovation relationship and to overcome the limits of previous studies, we will opt for Hansen (1999) threshold-effect model.

Threshold regression models state that individual observations can be divided into classes based on the value of an unobserved variable. As part of this work, we use the level of economic development as a threshold variable. The choice of this variable aims to allow a certain comparability of our results with those of Chen and Puttitanun (2005) and also reflects our ambition to test the hypothesis that economies, which are differentiated by their level of economic development may not converge and thus find themselves on different innovation paths.

2.3. Other Determinants of Technological Innovation

Aside from intellectual property rights and economic development, innovation literature highlights other factors affecting its level in the context of emerging and developing countries. In the present study, we use three variables: human capital, size of country and foreign direct investments (FDI).

In idea-driven models, the level of human capital represented by the level of education and skills of the population is considered as a key determinant of economic growth (Lucas Jr, 1988). The empirical literature highlights the positive role of human capital in shaping innovation (Furman, Porter, & Stern, 2002; Hall & Jones, 1999; Jaumotte & Pain, 2005a, 2005b, 2005c).

Pritchett (1996) recognizes four reasons explaining why a large population could be useful. First, the pressure of the large population can induce changes that lead to greater productivity. Second, theories of economic growth assume that knowledge is a non-rival good. This implies that once the innovation is created, a number of people can use it and exploit it to create others. More important is this number, wider will be the use and exploitation, and therefore the creation of innovations. Third, a larger population can lead to greater production through economies of scale. Finally, even in the absence of economies of scale, a larger population can lead to agglomeration economies. The latter imply that the density of economic activity is at the origin of greater productivity. Agglomeration economies may have several sources: Reduced transaction costs, increased specialization, easier benefits of innovations within the industry, or fixed costs of financing economic and social infrastructure.

Lerner (2002); Furman et al. (2002) and Chen and Puttitanun (2005) found a positive impact of the size of the country on technological innovation.

Recognized for a long time as a source of wealth creation, growth and poverty reduction, foreign direct investment contributes significantly to technology transfer. Foreign companies can offer a set of mobile, tangible and intangible assets that include the capital, technology, know-how, skills, organizational and managerial practices that drive innovation.

3. METHODOLOGY

Our study is based on data for 55 emerging and developing countries[1] in six five-year periods (1980-1984, 1985-1989, 1990-1994, 1995-1999, 2000-2004 and 2005-2009).

3.1. Choice of Variables and Measuring Instruments

3.1.1. The Dependent Variable

While technological innovation cannot be accurately measured, patenting is often considered a suitable proxy for the level of innovation (Eaton & Kortum, 1996; Furman et al., 2002; Griliches, 1990; Kanwar & Evenson, 2003).

The choice of patents as a variable representative of the output of innovation is justified by several advantages. The first benefit is the availability of very long time series for nations and regions. The second concerns patent databases that are publicly available and are increasingly in computer readable form. The data are classified in detail by technical field. In addition, patents provide the most comprehensive and detailed overview of technical knowledge over long periods.

[1]In this paper, we adopt the ranking of countries according to the report of the IMF (2012) which classifies countries into two categories: "Advanced Economies" and "Emerging and Developing Economies." Countries included in our sample are: Algeria, Argentina, Bangladesh, Benin, Bolivia, Brazil, Burundi, Cameroon, Chile, Colombia, Congo, Costa Rica, Dominican Republic, Equador, Egypt, El Salvador, Fiji, Gabon, Ghana, Guatemala, Guyana, Haiti, Honduras, Indonesia, Iran, Jamaica, Jordon, Kenya, Malawi, Malaysia, Mali, Mauritius, Mexico, Morocco, Nepal, Nicaragua, Niger, Pakistan, Panama, Paraguay, Peru, Philippines, Senegal, Sierra Leone, South Africa, Sri Lanka, Syria, Thailand, Tunisia, Turkey, Uganda, Uruguay, Venezuela, Zambia, Zimbabwe.

However, this measure has some limitations. On the one hand, the patent indicator lacks several non-patented inventions since certain types of technologies are not patentable. On the other hand, the patents filed do not measure the economic value of the technologies (Acs, Anselin, & Varga, 2002; Grasjo, 2004; Hall, Link, & Scott, 2001).

In the absence of more reliable data, we use data from the United States Patent and Trademark Office (USPTO). Our measure of technological innovation is the number of patent applications filed by residents of a given country with the USPTO. Because of the time lag between the filing process and the granting of a patent[2], using data on patent applications rather than granted patents reflects the more immediate and faster innovative activity. Data on patent applications are transformed by taking their natural logarithms. Therefore, the dependent variable (PAT) is defined as the logarithm of the number of patent applications filed by a country's residents with the USPTO for a given period (Source: USPTO).

3.1.2. Explanatory Variables

1) The index of intellectual property rights

The variable IPR is the Ginarte and Park (GP) index developed by Ginarte and Park (1997) which represents a measure of intellectual property protection often used in empirical studies.

This index has the advantage of being built on a five-year basis from 1960 to 2005. The authors examined patent rights in more than 100 countries by considering five aspects: 1) duration of protection, 2) extent of coverage, 3) membership in international patent agreements, 4) provisions for loss of protection; and 5) enforcement measures. The GP index of patent right is between 0 and 5, a high number reflects a higher level of protection. It is available for five-year periods. Since it is a quinquennially index, we have collected the other variables in every 5 years for the 1980–2009 period.

2) The level of economic development

To measure the level of economic development, we use the real GDP per capita in 2005 constant dollars. Data are transformed by taking their natural logarithms and come from Heston, Summers and Atten, 2012 Penn World Table 7.1.

Thus, the variable GDP is the natural logarithm of real GDP per capita in 2005 constant dollars.

3) The human capital stock

In this study, the stock of human capital will be measured by two metrics: the percentage of the total enrollment among the school-aged population over 15 at the secondary level (SEC) and the percentage of the total enrollment among the school-aged population over 15 at the tertiary level (TER). Data are from Barro and Lee dataset[3].

4) The size of the country

The size of the country is measured by the number of the population in thousands of people (POP). Data are transformed by taking their natural logarithms and come from World Development Indicators of the World Bank.

5) The foreign direct investment

The variable FDI represents the share of foreign direct investment inflows in GDP (Source: World Development Indicators of the World Bank).

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[2] The period for granting a patent to the applicant to the USPTO is on average three years.

[3] Source : www.barrolee.com/data/dataexp.htm

3.2. Descriptive Statistics

Table 1 provides the descriptive statistics on the number of patent applications filed with the USPTO as well as the explanatory variables (IPR, GDP, SEC, TER, POP, FDI) for the 1980-2009 period.

Table-1. Summary statistics.

Variable	Average	Median	Stand. Dev.	Minimum	Maximum
PAT	17,292	1,8	49,186	0	383,4
IPR	2,137	1,983	0,849	0,125	4,275
GDP	4045,054	3379,58	2996,92	310,92	12283,29
SEC	26,873	25,9	14,434	1,6	72,5
TER	5,933	4	5,272	0,1	27,2
POP	28743,54	12395,39	40667,88	668,032	232328,3
FDI	1,933	1,25	2,528	-5,281	20,906

The average number of patent applications filed with the USPTO by the countries of our sample is 17.292 with a large dispersion: the number of patents is zero for some countries while it reaches 383.4 for others. The index of protection of intellectual property rights is on average 2.137, with a minimum level equal to 0.125 and a maximum reaching 4.275. So, while some developing countries are aware of the importance of IPR in innovation, we find that some others are still neglecting this factor. The countries of our sample have an average level of real GDP per capita of 4045. Their average levels of secondary and tertiary education are respectively 26,873 and 5,933. They are home on average to 28743,54 thousand inhabitants. Foreign direct investment inflows in these economies reach in average 1.933% of GDP.

3.3. Overview of the Threshold Effect Model

Nonlinear effects can be demonstrated using a Panel Threshold Regression (PTR) developed initially by Hansen (1996); Hansen (1999). We will use the modelling of endogenous thresholds initially developed by Hansen (1996). It is a sweeping method according to which a reference equation is estimated for different values of the threshold variable. It consists of estimating the following relation:

$$Y_{it} = \alpha_i + \beta X_{it} + \delta c_{it} * I(d_{it} \leq \gamma) + \theta c_{it} * I(d_{it} > \gamma) + \varepsilon_{it} \quad (1)$$

Y_{it} is the dependant variable (log of the number of patent applications). c is the variable IPR. d is the threshold variable. It is the variable GDP. X_{it} represents a vector of control variables. γ is the common threshold for all countries.

I (.) is an indicator function that is equal to 1 if the condition in parentheses is true and 0 otherwise. δ and θ are the marginal effects that may be different depending on the level of economic development.

The specification (1) highlights two regimes: a first regime for which the variable d_{it} is less than or equal to the threshold γ and a second regime for which the variable d_{it} is greater than the threshold γ. Indeed, the variable relative to the economic development level is assumed to be negative below the γ threshold and positive above this threshold.

Y_{it} is the dependant variable (log of the number of patent applications filed with the USPTO). c_{it} is the variable IPR. d_{it} represents the threshold variable: the value of the real GDP per capita. The vector X contains the following variables: GDP = log (real GDP per capita at constant 2005 dollars); SEC = log (percentage of the total enrollment among the school-aged population over 15 at the secondary level); TER = log (percentage of the total enrollment among the school-aged population over 15 at the tertiary level); POP = log (number of population in thousands); FDI = log [(inward FDI inflows) / GDP].

3.4. The Estimation of the Threshold Effects Model

To estimate this model, we need to take several steps: It will be necessary to 1) determine the optimal threshold, 2) test the linearity of the process and 3) give a threshold confidence interval.

3.4.1. Determination of the Optimal Threshold

The first step is to determine the optimal value of the threshold γ. Hansen (1996); Hansen (1999) proposes, first of all, to remove the individual fixed effects. The elimination of the individual effects that are deterministic parameters consists of removing the individual means.

After eliminating the fixed effects, it is necessary to determine the optimal threshold level γ. To this end, it is advisable to estimate by ordinary least squares the Equation 1 for all the possible values of γ, and to determine in a second time the residual vector $\varepsilon\hat{}(\gamma)$ as well as the sum of the squares of the residuals S1. $S1(\gamma) = [\varepsilon\hat{}(\gamma)]'[\varepsilon\hat{}(\gamma)]$.

Hansen (1999) recommends minimizing the sum of squares of concentrated residuals using least squares. The optimal threshold will therefore be the one that will minimize the sum of the squares of residuals such as: $\hat{\gamma} = \text{argmin}_{\gamma} S_1(\gamma)$.

Once $\hat{\gamma}$ is obtained, we can determine the slope coefficients as well as the residual vector that will make it possible to calculate the residual variance $\sigma\hat{}^2$:

$$\sigma\hat{}^2 = 1/N(T\text{-}1)\,[\varepsilon\hat{}(\gamma)]'\,[\varepsilon\hat{}(\gamma)] = 1/N(T\text{-}1)\,S_1(\gamma\hat{}).$$

For the threshold and the variance thus determined, we can proceed to the linearity test of the process.

3.4.2. Linearity Test and Threshold Confidence Interval

The second step consists in testing the hypothesis of linearity against that of non-linearity, namely:

$$\begin{cases} H0: \delta = \theta \\ H1: \delta \neq \theta \end{cases}$$

The statistic used by Hansen is: $F1= (S0+S1)/\ \sigma\hat{}2$, where S0 is the sum of the squares of residuals under H0 and S1 is the sum of the squares of residuals under H1. As the asymptotic distribution of F1 is not standard, the critical values must be bootstrapped. Hansen's procedure is followed: the idea is to simulate using the bootstrap method the asymptotic distribution of the likelihood ratio test in order to determine the p-value of the statistic. This p-value can also be generated using a distribution function (Hansen, 2000):

p-value = $1 - [1 - \exp(-1/2\ F1)]$.

The decision rule is as follows: If the p-value of F1 is smaller than the critical value retained (1%, 5% or 10%), then the null hypothesis of linearity is rejected.

Hansen (1999) then proposes to construct a confidence interval on the basis of the maximum likelihood ratio calculated for all γ in order to establish a "non-rejection" interval of the significance of the threshold: $LR1(\gamma) = S1(\gamma) - S1(\gamma\hat{})/\ \sigma\hat{}2$

Similarly, for the value of the identified endogenous threshold $\gamma\hat{}$, the maximum likelihood ratio LR1 $(\gamma\hat{})$ is equal to zero and tends to a random variable ζ whose distribution function is: $P(\zeta \leq x) = (1 - e^{-x/2})^2$. Inversion of this distribution makes it possible to derive the expression: $C(\alpha) = -2\log(1 - \sqrt{1 - \alpha})$. This expression is necessary to construct the confidence interval that corresponds to all the values of γ for any risk of α% such that: $LR1(\gamma) \leq C(\alpha)$.

4. PRESENTATION AND INTERPRETATION OF THE RESULTS

Before presenting findings, we proceed to analyse the independence of the explanatory variables. This is the multi collinearity test. To check the condition of absence of multi-collinearity, we use the simple correlation matrix and assume a limit of 0.7. According to the correlation matrix, strongest correlation is found between GDP per capita expressed in log and human capital stock measured by tertiary education (the correlation coefficient is equal to 0.583). Thus, the condition of absence of multi-collinearity between variables is verified.

4.1. Analysis of Simple Correlations

We begin our analysis by examining simple correlations. The matrix of simple correlations allows us to examine the correlation coefficients in order to study the null hypothesis of the absence of correlation between two variables. Table 2 summarizes the results found.

Table-2. Simple correlations between the dependent variable and the explanatory variables.

Explanatory variables	Predicted sign	Correlation
IPR	+ / -	0,355***
GDP	+	0,594***
SEC	+	0,359***
TER	+	0,489***
POP	+	0,502***
FDI	+	0,093*

Note: *and ***: significant correlations at 10% and 1% thresholds.

The analysis of simple correlations shows that the variable intellectual property rights (IPR) is positively and significantly associated with the innovation level. As expected, correlation coefficients for the variables GDP, SEC, TER, POP and FDI are positively and significantly associated with the number of US patent applications.

4.2. Results of Preliminary Regressions

Although this study aims to study the non-linear effects in the IPR / innovation relationship, we start with a simple linear approach. We begin to estimate the following model:

$$PAT_{it}=\beta 0+\beta 1IPR_{it}+\beta 2GDP_{it}+\beta 3SEC_{it}+\beta 4TER_{it}+\beta 5POP_{it}+\beta 6FDI_{it}+\varepsilon_{it} \qquad (2)$$

To deal with the question of non-linear effects, and before starting our main method (estimation of threshold effects model), we can use preliminary regressions.

In order to test whether the effect of IPR on innovation varies with the level of economic development, one possible method is to introduce into the model (2) the interaction term between the level of IPR protection and the level of economic development (IPRG = IPR * GDP) Equation 3.

$$PAT_{it}=\beta 0+\beta 1IPR_{it}+\beta 2GDP_{it}+\beta 3IPRG_{it}+\beta 4SEC_{it}+\beta 5TER_{it}+\beta 6POP_{it}+\beta 7FDI_{it}+\varepsilon_{it} \qquad \mathbf{(3)}$$

We begin by estimating our equations by the fixed-effect Ordinary Least Squares (OLS) method. This method corrects the biases caused by the problems of heteroscedasticity and auto-correlation errors. However, due to the potential endogeneity of intellectual property rights, we also use the Instrumental Variables (IV) or Double Ordinary Least Squares (DOLS) method to estimate the parameters.

The endogeneity of intellectual property rights may come from many sources. First, because of the complexity of the innovation process, omitted variables are likely to influence the level of technological innovation. Secondly, the variable IPR used may suffer from measurement errors. Indeed, the major disadvantage of the index of Ginarte and Park is that it does not distinguish between regulatory changes and the effective implementation of laws. Rather, it is based on the laws themselves, not on their implementation. As a result, this index tends to overestimate the level of protection in a country where strong anti-counterfeiting laws exist, but are not enforced. This is the case for many emerging and developing countries that have inherited IPR laws from their colonial powers, but lack the administrative capacity or willingness to respect them (Gould & Gruben, 1996). Third, the endogeneity bias may stem from the existence of an inverse causality between intellectual property rights and innovation if the most innovative countries impose a strong system of IPR protection.

Like Ginarte and Park (1997) and Chen and Puttitanun (2005) we use the following variables as instruments: real GDP per capita, the level of human capital (secondary and tertiary education), the indicator of economic freedom, the level of international trade and a WTO dummy taking 1 if country i is a member of the World Trade Organization at time t and 0 otherwise.

The metric of Intellectual property rights interacting with the threshold variable (IPRG) is instrumented by the product of these six instruments and the threshold variable.

To judge the quality of the identification strategy used, we rely on Sargan's over-identification test.

The results of the estimation of our two models Equations 2 and 3 are described in the Table 3.

For each of these models, two estimates are presented: one using the ordinary least squares method and the other deriving from the instrumental variables method. However, we only comment on the results obtained by the instrumental variable method, which is more robust and efficient.

Table-3. Results of model estimates (2) and (3).

	Predicted Sign	Model (2)		Model (3)	
		Coef. OLS	Coef. IV	Coef. OLS	Coef. IV
Constant		-13.361*** (1.486)	-13.644*** (1.935)	-11.906*** (0.820)	-4.174 (3.166)
IPR	+/-	0.132*** (0.046)	0.011 (0.089)		
GDP	+	0.768*** (0.106)	0.847*** (0.120)	0.637*** (0.068)	0.408** (0.184)
IPRG	+			0.012*** (0.004)	0.084*** (0.021)
SEC	+	0.008* (0.004)	0.014*** (0.004)	0.002 (0.003)	-0.0006 (0.006)
TER	+	0.028** (0.012)	0.031** (0.012)	0.045*** (0.011)	-0.013 (0.017)
POP	+	0.487*** (0.074)	0.470*** (0.1)	0.467*** (0.038)	0.065 (0.149)
FDI	+	-0.007 (0.011)	-0.009 (0.013)	0.005 (0.009)	-0.058*** (0.018)
N		325	323	325	325
Chi2		266.94***	291.08***	506.76***	213.28***
Sargan statistic P-value			4.407 0.110		1.359 0.243

Note: ***, **,* : significant at 1%, 5% and 10% respectively.

The results show that the Chi2 statistic testing the joint significance of the explanatory variables is significant at 1%, allowing us to reject the null hypothesis that the regression coefficients β are zero. As a result, our models are globally significant. The p-value of the Sargan statistic is greater than 0.05. Thus, the instruments used are valid.

Table 3 shows that IPR protection has not a significant effect on innovation in emerging and developing countries.

For control variables, we find that GDP per capita, the human capital stock and the population affect positively and significantly the number of patent applications filed with the USPTO in emerging and developing countries. In contrast, foreign direct investment does not have a significant effect on the innovation output.

In the last column of Table 3, we introduce the interaction term between GP index and GDP. We note that there is a strong correlation between the metric IPR and the interaction term IPRG (The correlation coefficient is equal to 0.96). So, IPR is excluded from this estimated model. Results show that IPRG is positive and significant at 1%. As expected, there is a non-linear relationship between IPR and innovation according to the level of economic development. The results indicate that the protection of intellectual property rights stimulates technological innovation in the most developed countries.

This finding explains the precedent result (i.e. the non-significant effect of IPR). In fact, some economies are able to generate innovations thanks to a strong IPR system whereas some others cannot benefit from such a system. So, the overall impact of intellectual property rights protection is ambiguous for the countries of our sample.

To summarize the results of the preliminary regressions, we confirm:

- The non-significant effect of IPR protection on innovation.
- The presence of non-linear effects in the IPR / innovation relationship associated with the level of economic development.

4.3. Threshold Effect Model Results[4]

To determine the number of thresholds, the model (1) was estimated by least squares allowing one, two and three thresholds. The F1, F2 and F3 test statistics with their p-values[5] bootstrap are shown in Table 4. We find that the test for a single F1 threshold is significant with a p-value of 0.01. On the other hand, the tests for a double threshold F2 and for a triple threshold F3 are insignificant with p-values equal to 0.2 and 0.15 respectively. We conclude that there is only one threshold in the regression relationship. For the rest of the analysis, we work with this single threshold model.

Table-4. Tests for threshold effects.

Single threshold effect test	
F1	32,829
P-value	0,01
(Critical value of F 10%, 5%, 1%)	(20,8 ; 24,6 ; 32,6)
Double threshold effect test	
F2	14,667
P-value	0,2
(Critical value of F 10%, 5%, 1%)	(17,5 ; 21,4 ; 24,4)
Triple threshold effect test	
F3	12,689
P-value	0,15
(Critical value of F 10%, 5%, 1%)	(13,8 ; 14,7 ; 20,2)

The threshold value and its 99% confidence interval are reported in Table 5. The value is 1106,95 dollars.

Table-5. The estimated value of the threshold.

	Estimated value	**99% Confidence interval**
$\hat{\gamma}$	1106,95	[1106,95 ; 1113,862]

Thus, the two classes of countries indicated by the estimated point are those with a "low level" and a "high level" of initial economic development.

More information can be learned about the threshold estimate from plot of the concentrated likelihood ratio function LR1(γ) in Figure 1.

[4] The model was estimated using the matlab 2012b software. The matlab program used is that of Hansen B.E on the following web page: http://www.ssc.wisc.edu/~bhansen/progs/joe_99.html

[5] 300 replications were used for each of the three bootstrap method tests.

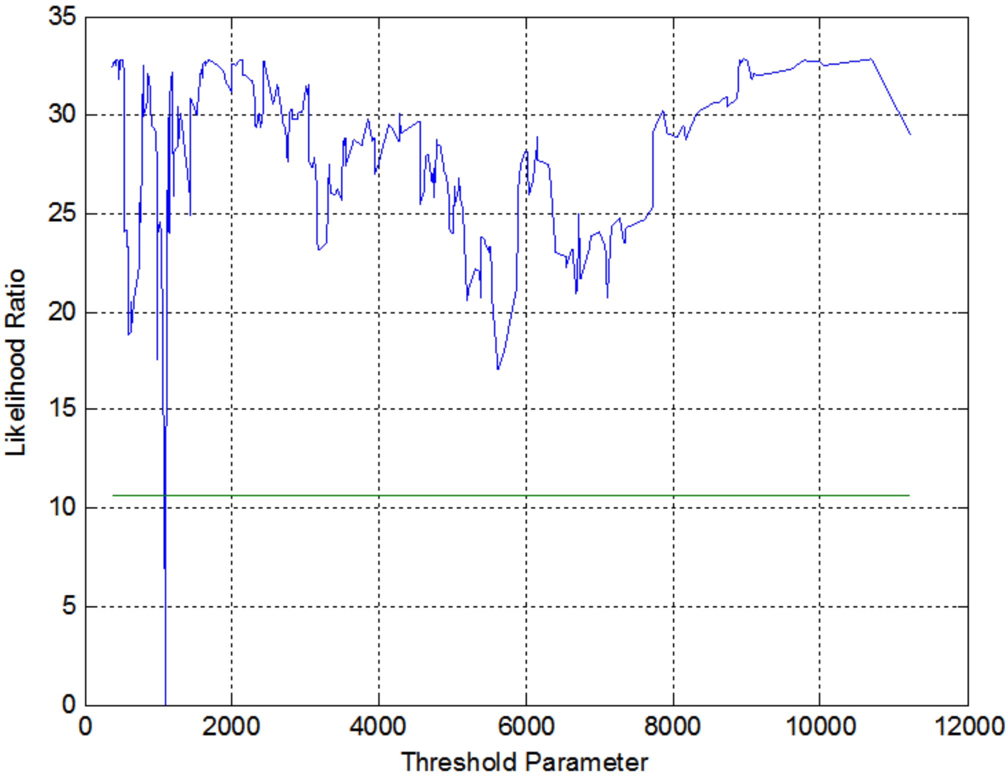

Figure-1. LConfidence interval contruction in single threshold model.

Table-6. Results of the specification (1).

Variables	Coef.	SD (OLS)	T(OLS)	SD (White)	T(White)
GDP	0,854	0,199	4,291***	0,22	3,881***
SEC	0,016	0,006	2,666***	0,004	4***
TER	0,023	0,018	1,277	0,018	1,277
POP	0,173	0,265	0,652	0,232	0,745
FDI	-0,009	0,016	-0,562	0,013	-0,692
IPR I(GDP <= 1106.95)	-0,484	0,153	-3,163***	0,15	-3,226***
IPR I(GDP > 1106.95)	0,23	0,073	3,15***	0,059	3,898***

Note: SD (White): this is the standard deviation taking into account heteroscedasticity.

As Table 6 shows, IPR protection influences the level of innovation in a significant way. However, this impact is different depending on the regimes. In fact, in regime n°1, where the level of economic development is lower than or equal to the threshold value (1106.95 dollars), the effect of the GP index is negative and significant at 1%. In the second regime where countries are characterized by a high level of economic development, the effect is positive and significant at 1%. In the first class, when the index of the patent right increases by one point, the number of patents granted by the USPTO decreases by 0.48 percentage points. On the other hand, in the second regime, when the GDP per capita is higher than 1106.95 dollars, a one-point increase of GP index results in an increase in the number of patents by 0.23 percentage points. Thus, we find that only countries with a high level of economic development can benefit in terms of innovation from increasing the level of protection of patent rights.

Our results support those found from the preliminary regression (3) and confirm the nonlinear U-shaped relationship between the degree of intellectual property protection and the level of technological innovation. They are consistent with those found by Chen and Puttitanun (2005). These findings highlight the advantages of TRIPS for emerging and developing countries, but also its disadvantages for some others. In fact, to ensure their economic growth, some countries having a low economic development level are based on the imitation of new technologies developed in the most advanced countries. Therefore, the increase in IPR standards will make it expensive to imitate and adapt foreign technologies to their national needs, which hampers their innovation activity.

For control variables, only real GDP per capita and human capital measured by secondary education level have a positive and significant impact on innovation, the others are not significant.

We find that the effect of economic development is positive since patents are increasing with log of GDP (0.85). This means that a 10% increase in GDP is accompanied by an 8.5% increase in the international patenting rate. This result corroborates that found by Jaumotte and Pain (2005c) and Hu and Mathews (2005).

The level of secondary education has a significant effect on the number of patent applications. Whereas, the level of tertiary education does not have a significant effect on the number of patents. This result can be explained by the imitative and adaptive nature of innovation activities in developing countries that do not require a highly qualified workforce.

5. CONCLUSION

The purpose of this paper was to analyse the impact of intellectual property rights protection on technological innovation on a range of emerging and developing countries.

The previous literature has allowed us to argue that the nature of the IPR protection / innovation relationship may be non-linear depending on the level of economic development. In attempting to address the econometric problems of previous studies, we used Hansen (1999) threshold panel model. The application of this model to 55 countries during the period 1980-2009 confirms our research hypothesis. Findings show that the introduction of a strong IPR protection system and the harmonization of IPR standards at the international level are beneficial for emerging and developing countries. Such measures allow to generate innovation. So, the intellectual property rights system is an efficient instrument of innovation policy in these countries. However, it is not adequate for the poorest countries. In fact, a low level of IP protection must be maintained to encourage companies to emulate foreign technologies.

Our findings have important methodological and practical implications. First, the significant presence of threshold effects calls into question the relevance of any econometric specification presupposing a linear relationship between IPR protection and innovation. Then, and to summarize our results, we can affirm that "One size does not fit all". In other words, there is not a single model for all countries to stimulate innovation. We have shown in this study that economies that are differentiated by their level of economic development may not converge and thus find themselves on different paths of innovation.

Our analysis suffers however from some weaknesses. For example, the panel threshold regression used to estimate the models ignores the issue of endogeneity of intellectual property rights. In addition, data relative to GP index is only available until 2005, preventing us from an analysis over more recent years. Finally, the use of USPTO data imposes restrictions on the scope of our research. In fact, the innovations recorded in the USPTO are international in character, excluding local innovations which are so important in developing countries.

For future research, we propose to use another indicator other than the GP index to measure the robustness of the IPR system and to compare the results found with those of the present study.

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