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Hamid Mohtadi [a] & Stefan Ruediger [b]
[a] Department of Economics, University of Wisconsin at Milwaukee, Milwaukee, WI, 53201, USA
[b] University of Wisconsin at Stevens Point, School of Business and Economics, College of Professional Studies, WI, 54481, USA
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Intellectual Property Rights and Growth: Is there a Threshold Effect?

HAMID MOHTADI* & STEFAN RUEDIGER**

**Department of Economics, University of Wisconsin at Milwaukee, Milwaukee, WI 53201, USA;*
***University of Wisconsin at Stevens Point, School of Business and Economics, College of Professional Studies, WI 54481, USA*

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ABSTRACT Recent WTO agreements have forced developing countries to adopt stronger intellectual property rights (IPRs). However, theoretical research is critical at best, but largely undecided, on the impact of stronger IPRs on economies at lower stages of development. This paper is particularly concerned with a critical empirical examination of the impact of human capital on the relationship between IPRs and economic growth. Using a threshold estimation technique, originally developed by Hansen, the paper discovers a threshold level of human capital (robust to many different variations) such that for countries whose human capital is below this level, tighter intellectual property rights have a negative impact on economic growth, while for countries with human capital above this level, tighter intellectual property rights are unrelated to economic growth. Thus, we find a non-linear relationship associated with this switching regression.

KEY WORDS: Threshold, intellectual property rights, economic development, growth
JEL CLASSIFICATIONS: F15, O11, O34, O4

1. Introduction

A significant body of research has focused on the influence of Intellectual Property Rights (IPRs) on innovation and economic growth. The general presumption is that greater innovation leads to higher rates of economic growth

Correspondence Address: Stefan Ruediger, School of Business and Economics, College of Professional Studies, University of Wisconsin at Stevens Point, 1901 4th Avenue, Stevens Point, WI 54481, USA. Email: Stefan.ruediger@uwsp.edu

(Barro & Sala-i-Martin, 1995; Romer, 1987, 1990, just to name a few). However, the question of how IPRs influence the creation of innovation and knowledge is widely debated. On one hand, stronger IPRs promote innovation by allowing the appropriation of the benefits from innovation. On the other hand, stronger IPRs may hold back innovation by impeding diffusion of knowledge because less knowledge diffusion reduces the possibility of follow-up innovation. These two effects point in opposite directions. Separately, the literature acknowledges that any effect of IPRs on innovation and economic growth is conditional on human capital (Datta & Mohtadi, 2006; Grossman & Lai, 2004; Helpman, 1993; Siebeck, Evenson, Lesser, & Primo Braga, 1990). The contention of this paper is that the two issues – the conflicting role of IPRs in growth, and the conditioning role of Human Capital (HK) – are in fact related. Specifically, where the paucity of human capital is at issue, innovation is weak and vulnerable to barriers from the diffusion of knowledge erected by stronger IPRs. By contrast, where human capital is not the binding constraint, what inhibits innovation is not human capital, but whether the profits from innovation can be appropriated. It is only in this environment that IPRs allow profitability and thus can foster innovation.

The potential conditioning effect of human capital means that the relationship between IPRs and growth may be nonlinear. While there is some theoretical work on the influence of conditioning factors on the relationship between IPRs and growth, little attention has been paid to this issue empirically. This paper aims at addressing this gap. We do this by applying a threshold regression methodology, first developed by Hansen (2000). This method is based on a search algorithm that looks for a threshold level of human capital below and above which the effects of IPRs on growth would differ from one another. Moreover, the method has the additional advantage of allowing for the development of an empirical distribution for the threshold variable through a bootstrap method. As a result, it allows for hypothesis testing.

In Section 2 we explain the relationship between IPRs and economic growth and discuss the hypothesis surrounding the 'conditionality' impact of IPRs on economic growth, i.e. that IPRs promote growth once a certain threshold of human capital is surpassed; Section 3 contains a detailed empirical analysis of the conditionality hypothesis along with model development; in Section 4 we explain the policy implications of such a threshold and provide concluding observations.

2. IPR, Human Capital, and Growth

As mentioned, the endogenous growth literature cited above highlights the importance of innovation for economic growth. Central to the link between innovation and growth, however, is the role played by IPRs. The introduction of IPRs transforms the knowledge that is embedded in innovation from a public good into a private good. Thus, by guaranteeing the protection of ideas through stronger IPRs, one would expect a more rapid generation of new ideas because of the guaranteed financial returns.

However, more recent economic research has raised some doubts about the generality of this hypothesis. According to Aghion, Harris, Howitt, & Vickers (2001), more competition (i.e. less stringent IPRs) rather than less competition (i.e. more stringent IPRs) increases innovation. Based on the assumption that firms innovate to maintain an edge over their rival, Aghion *et al*. (2001) show that competition (through lower IPRs) increases innovative activity and also economic growth. Helpman (1993) and Datta and Mohtadi (2006) claim that stronger IPRs will lead to less growth in developing countries, because of adverse terms of trade effects and negative impacts on innovation activity (imitation or reverse engineering). Lorenczik and Newiak (2012) identify the existence of an IPRs threshold below which IPRs do not promote innovation. Furukawa (2010) and Parello (2008) conclude that a nonlinear relationship between IPRs and innovation exists caused by positive short-run effect of IPRs on innovation and negative long-run effects of IPRs on the process of learning-by-doing. Finally, Siebeck *et al*. (1990) have recognized that even if IPRs influence innovation positively, strengthening IPRs is unlikely to promote innovation in developing countries because of conditions that obstruct innovation such as the lack of human capital.

The importance of underlying conditions is best characterized by Maskus (2004) who writes, 'The poorest countries allocate virtually no resources to invention or innovation and have little intellectual property. As incomes and technical capabilities grow to moderate levels, some inventive capacity emerges, particular of the adaptive kind, but competition remains based on imitation and the majority of economic and political interests prefer weaker protection.' Maskus also points out that stronger IPRs need to be introduced into markets in which other competitive processes, such as firm entry, labor flexibility, distribution systems, and international trade, are already developed to a certain level; otherwise, IPRs may have no effect or may even be associated with negative effects for the economy. Usually, the early stages of development that are commonly associated with low levels of human capital also represent greater reliance on imitation technology (Datta & Mohtadi, 2006). Countries in these early stages of development rely on reverse engineering to gather knowledge, which may be subsequently used for future innovation as these countries advance (Aghion, Meghir, & Vandenbussche, 2006; Glass, 1999). Hence, tightening IPRs in an economy that depends on imitation may harm its transition towards innovation. Even if firms in countries with low levels of human capital had sufficient incentive to innovate because of the profit potential created by IPRs, they would not be able to do so successfully, since the R&D (Research & Development) sector lacks human capital. That is why strong IPRs will have positive effects only if IPRs and human capital increase jointly or if IPRs increase in an environment where human capital is abundant.

The existence of conditioning factors points to the likely occurrence of growth thresholds. Yet, as previously mentioned, the empirical literature does not sufficiently address the importance of human capital as a conditioning factor for the relationship between IPRs and growth. Overlooking human capital, research has instead focused on the role of trade and the general development level as conditioning factors (Ginarte & Park, 1997, hereafter referred to as GP; Gould & Gruben, 1996; Schneider, 2005).

It should be noted that if our view about the relationship between human capital, IPRs, and growth is borne out by the evidence, one must re-consider the common linearity assumption that prevails in the empirical growth approach.

3. Empirics

While nonlinearity in the relationship between IPRs and economic growth could be caused by external (conditioning) factors, one challenge is that there is a possibility that the nonlinear relationship may be related to the actual 'level' of IPRs. This possibility can be examined by simply including a squared term for IPRs in the regression. Following this step, the next step in our empirical analysis will be testing our main thesis, i.e. the role of human capital in the relationship between IPRs and growth. We will approach this in two ways: we start by including a simple interaction term between IPRS and human capital in our regressions. We will see that this approach will pose some limitations. Thus, we move to our central methodology. In this methodology, we will instead search for a 'threshold' level human capital, above and below which the effect of IPRs on growth differs. We do this by using a threshold regression technique in which a threshold level is endogenously determined.

3.1 *Empirical Setup and Data: Preliminary Regressions*

The baseline exploratory regression has the following form:

$$\text{GROWTH} = \alpha_0 + \alpha_1 \text{lnGDP} + \alpha_2 \text{SCHOOL} + \alpha_3 \text{IPR} + \alpha_4 \text{CONTROL} + u \tag{1}$$

where the dependent variable is the per capita growth of GDP 1980–2010 (GROWTH), and the explanatory variables are the GDP per capita in 1980 (lnGDP), average years of schooling 1980–2010 (SCHOOL), and the IPR index from GP 1980–2010 (IPR) (see below for a discussion). The equation also includes a list of 'control' variables. These controls consist of, the investment share of GDP 1980–2010 (INVEST), the population growth rate from 1980–2010 (pop growth), the average level of inflation 1980–2010 (Inflation), and the level of openness as a share of GDP 1980–2010 (TRADE). Given this 30-year history, one might ask why not use a panel data approach over, say, 5-year or 10-year sub-intervals (as is commonly done) instead of averaging the variables over the entire 30 years? While this would be certainly desirable, our examination of the IPR variable indicates that this variable does not produce adequate variability in any 5- or 10-year interval to warrant a panel regression approach.[1] Institutional variables generally vary slowly. Even though there may well be some countries in the sample for which sufficient variation in IPRS would justify a panel analysis, this is not the case for the majority of countries in the sample.

The IPR variable is of key import and deserves special attention. Several different IPRs indices are available in the literature. Among these indices are the GP index, the IPRs index of the World Economic Forum (WEF), and an index by Lesser (1998). While the GP index covers 116 countries from 1960 until 2005, it only measures protection of IPRs on paper and does not account for de facto protection of IPRs. Both the WEF index and the index from Lesser can account for de facto protection since these indices are based on surveys of opinions and experiences of managers of multinational corporations. However, neither of the

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[1] The within country standard deviation is 0.6911 from 1980 to 2010 for the GP index.

Table 1. OLS squared IPR and interaction term

Dependent Variable: $GROWTH_{1980-2010}$	Simple	Square	Interaction
Constant	0.5099	0.4582	0.7208
	(0.4786)	(0.5902)	(0.5082)
lnGDP	−0.1457***	−0.1446***	−0.1462***
	(0.0454)	(0.0467)	(0.0450)
School	0.0506**	0.0500**	0.0188
	(0.0243)	(0.0249)	(0.0407)
IPR	0.0027	0.0494	−0.0969
	(0.0719)	(0.2290)	(0.1165)
INVEST	0.0471***	0.0470***	0.0474***
	(0.0101)	(0.0102)	(0.0100)
Pop Growth	−0.6553**	−0.6652***	−0.6561**
	(0.2617)	(0.2454)	(0.2596)
TRADE	0.0007	0.0007	0.0008
	(0.0009)	(0.0009)	(0.0009)
Inflation	−0.0004***	−0.0005***	−0.0004**
	(0.0002)	(0.0002)	(0.0002)
IPR^2		−0.0088	
		(0.0349)	
IPR*School			0.0130
			(0.0117)
R^2	0.500	0.501	0.504
N	95	95	95

Heteroscedasticity robust standard errors reported in parenthesis
90% significance *; 95% significance **; 99% significance ***

two indices can be used in our research because of their limited coverage of years and countries: the WEF data cover the years 2000 onward and the data by Lesser are available for 1998 and for only 48 developing countries. At the same time, the values of the GP index and the WEF index are highly correlated for their overlapping years.[2] This correlation shows that the GP index can be used for this research, since the level of IPRs protection measured by the GP index closely resembles the level of IPRs protection as perceived by managers of multinational corporations.

Data for the additional variables are taken from the World Development Indicators and the Economic Freedom of the World dataset. Data on human capital are from the 2011 version of the Barro and Lee (2010) dataset. A more detailed description of the data and the data sources can be found in the Appendix.

Even though we suspect that nonlinear effects exist in the impact of IPRs on growth, we start our empirical investigation with a simple linear approach (Table 1 column 1). The results do not show a statistical significant impact of IPRs on growth. Other variables included in the regression have the expected impact on GDP growth. However, the simple linear regression does not address the possible existence of nonlinear effects. As a first approximation, one might argue that such an effect should be captured by introducing a squared term into

[2]See Economic Freedom of the World Annual Report 2002, Chapter 2 – correlation between GP and WEF is 0.8.

the regression:

$$\text{GROWTH} = \alpha_0 + \alpha_1 \ln\text{GDP} + \alpha_2\text{SCHOOL} + \alpha_3\text{IPR} + \alpha_4\text{IPR}^2 + \alpha_5\text{CONTROL} + u \tag{2}$$

Yet neither α_3 nor α_4 are found to be significant in the estimation (Table 1, columns 2). Thus, the hypothesis that the impact of IPRs on growth changes with the 'level' of IPRs does not seem to be supported by the evidence.

In our third step, we now ask whether the level of human capital influences the relationship between IPRs and growth: we introduce an interaction term between IPRs and human capital into the regression:

$$\text{GROWTH} = \alpha_0 + \alpha_1 \ln\text{GDP} + \alpha_2\text{SCHOOL} + \alpha_3\text{IPR} + \alpha_4\text{IPR} \times \text{SCHOOL} + \alpha_5\text{CONTROL} + u \tag{3}$$

Based on the literature, the marginal effect of IPRs on growth should change with increasing levels of human capital: if firms do not innovate, not because of human capital constraints, but because of the inability to appropriate profits from innovation, then α_3 should be positive and significant, and α_4 should be insignificant or close to zero. However, if human capital is a binding constraint, and countries with low levels of human capital rely primarily on reverse engineering (imitation) as their main R&D activity, IPRs would be not be helpful, unless sufficient human capital is also available to harness an innovative climate. Then, α_3 should be negative or insignificant and α_4 should be positive and significant.

Examination of the evidence supports neither of the two arguments presented above (Table 1 column 3). Thus, putting this together, the findings provide no support for the hypothesis that IPRs are important for growth and no support for the hypothesis that nonlinear effects associated with human capital exist. However, as we will see in the next section, this methodology is not particularly well suited to testing the main hypothesis of this paper. Instead, we turn to a threshold methodology for this purpose. We expand on this issue in the next section.

3.2 *IPRs, Human Capital, and Growth: Threshold Regressions*

The empirical approach in the previous section relied on interaction terms to determine if the relationship between IPRs and growth is influenced by the level of human capital of a country. However, this approach does not offer an adequately flexible framework for our hypothesis. To elaborate, it can only answer the question of whether or not the presence or the absence of human capital matters for the role of IPRs in growth. This all-or-none approach to human capital could miss the specific level of human capital at which its influence in the impact of IPRs on growth matters.

Thus, the search for such a level (i.e. a threshold) is critical. In this section, we apply Hansen's endogenous threshold estimation approach (Hansen, 1996, 2000) to determine if there exists such a threshold level of human capital. The theoretical literature on economic growth indicates that growth thresholds, or multiple growth regimes, may exist due to knowledge spillover effects or externalities (Azariadis & Drazen, 1990; Matsuyama, 1992). Empirically, Durlauf and Johnson (1995) first examine the multiple growth thesis of Azariadis and Drazen (1990) by using a decision-tree approach. While their technique is able to identify thresholds, it is not able to determine the statistical significance of the thresholds, leading subsequently to Hansen's (2000) key refinement of the threshold estimation technique. It is this refined technique that we use in this paper.[3]

Hansen's approach allows one both to determine the existence of thresholds and simultaneously also to test for the significance of the thresholds. The regimes are identified by searching for a threshold that minimizes the sum of squared errors of the regression. The significance of the threshold is tested by means of a likelihood ratio test, the distribution of which is generated using a bootstrap procedure. The existence of a threshold would split our sample of countries into two separate growth regimes. The threshold estimation can be described by the following two equations:[4]

$$\text{GROWTH}_i = \alpha_1{'}x_i + u_i, \quad HK_i < \gamma \tag{4}$$

$$\text{GROWTH}_i = \alpha_2{'}x_i + u_i, \quad HK_i > \gamma \tag{5}$$

Here *HK* (human capital) is the threshold variable and γ is the threshold level that splits the sample of countries into subgroups; x includes all previous listed explanatory variables. For estimation purposes we reduce equations (4) and (5) to a single equation:

$$\text{GROWTH}_i = \alpha{'}x_i + \delta_n{'}x_i(\gamma) + u_i \tag{6}$$

where $\alpha = \alpha_2$, $\delta = \alpha_1 - \alpha_2$, $x_i(\gamma) = x_i d_i(\gamma)$, and the dummy variable $d_i(\gamma) = \{HK_i \leq \gamma\}$. Following Hansen (2000) we estimate equation (6) with least-squares estimation. Hansen's contribution allows us to endogenize the search for the threshold level. The threshold location is determined based on minimizing the concentrated sum of squared errors function: $\hat{\gamma} = \arg\min S(\gamma)$ (Hansen, 2000). The minimum value of the sum of squared errors function is found by a grid search over all values of the variable γ. The distribution of the slope coefficients of equation (6) is asymptotically normal and hence usual distribution theory can be used to estimate slope coefficients (Hansen, 2000).

The next step of the estimation process is crucial. We need to determine if a threshold effect exists. That means we test if the slope coefficients differ above and below the threshold. The null hypothesis is that $\text{H}_0 : \alpha_1 = \alpha_2$. The existence of a threshold effect would establish that the influences of IPRs on the growth of human capital differ above and below a certain level of human capital. The rejection of the null hypothesis would mean that a threshold exists. Specifically,

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[3]A paper by Minier (1998) also relies on the older approach, the decision-tree approach, to examine the relation between democracy and growth. A more recent paper by Minier (2007), however, does use Hansen's (2000) threshold approach, focusing on institutions and growth. Other non-linear growth regime papers have used a variety of different techniques. Three examples are Kalaitzidakis, Mamuneas, Savvides, and Stengos (2001), Liu and Stengos (1999), and Quah, (1997).

[4]Threshold variable (HK) can be a part of x.

following the theory we can expect that $\alpha_1 \neq \alpha_2$ and that the marginal effects of IPRs above and below the threshold differ. Above this threshold, IPRs should have a positive effect on growth, while below it we would expect a negative or zero effect. By contrast, if IPRs foster innovation regardless of the environment, the IPR coefficient should also be positive both below and above threshold.

We test the hypothesis of no threshold effect ($\mathrm{H}_0 : \alpha_1 = \alpha_2$) using a simple Lagrange Multiplier (LM) test. However, since under the null hypothesis no threshold is identified, the statistic for the LM test needs to be simulated. Hansen (1996) offers an approach for the simulation of the LM statistic: specifically, asymptotically valid p-values for this LM test can be constructed using a bootstrap procedure. Calculating the p-value involves several different steps: first, we calculate the actual LM test statistic using the regression residuals from equation (6); next, we draw a random sample with replacement from the previously obtained regression residuals. These residuals are part of generating a bootstrap dependent variable $Growth_i^b$ such that:

$$Growth_i^b = \hat{\alpha}' x_i + u_i^b \tag{7}$$

In this equation, the regressors are treated as fixed, i.e. no threshold effect is assumed. The residuals u_i^b are randomly generated from the distribution $\mathrm{N}(0, \hat{u}_i^2)$, where $\hat{u}_i^2$s are the randomly selected errors from the previous step. We compute the bootstrap LM value, using the bootstrap sample variables to estimate the model under both hypotheses. We repeat these steps 1000 times to obtain p-values to test the significance of the threshold effect. The asymptotic p-value is then given as the percentage of bootstrap LM values that exceed the actual LM statistic calculated in Step 1. Next, if the existence of a threshold effect is established we estimate a confidence interval for the threshold value of human capital. The hypothesis that we are testing is $\mathrm{H}_0 : \gamma = \gamma_0$. We use a likelihood ratio (LR) test to evaluate this hypothesis. Hansen (2000) shows that the LR test does not have a standard chi-squared distribution, but he also provides an alternative distribution function to establish critical values for this hypothesis. The likelihood ratio statistic[5] takes the form

$$LR_n(\gamma) = n\frac{S_n(\gamma) - S_n(\hat{\gamma})}{S_n(\hat{\gamma})} \tag{8}$$

Table 2 shows the results of applying this threshold estimation approach. Using the previously described bootstrap procedure for the LM test we are able to reject the null hypothesis of no threshold ($\mathrm{H}_0 : \alpha_1 = \alpha_2$). Finally, we show that, as expected, a human capital threshold ($\hat{\gamma}$) exists, which is located at 5.88 years of schooling (Table 2, Columns 2&3).[6] Thus, countries exhibit two different growth regimes based on their average human capital relative to the threshold. Stronger IPRs harm growth in countries with average schooling years below the threshold (columns 1). Yet, countries benefit from IPRs when their average years of schooling exceed this threshold (columns 2), although the positive impact of

[5]The table of asymptotical critical values can be found in Hansen (2000, Table 1, p. 582).
[6]We do not find support for the existence of a second human capital threshold.

Table 2. Threshold regression

	OLS		IV	
	Below Threshold Avg yrs of schooling	Above Threshold	Below Threshold Avg yrs of schooling	Above Threshold
	<= 5.8834330	> 5.8834330	<= 5.8834330	> 5.8834330
	41	54	41	54
Constant	1.5798***	0.3363	1.7014***	0.2957
	(0.4109)	(0.4547)	(0.4665)	(0.4928)
lnGDP	−0.1678***	−0.1501***	−0.1603***	−0.1206***
	(0.0441)	(0.0499)	(0.0457)	(0.0571)
School	0.0345	0.033	0.0444	0.0495
	(0.0335)	(0.0248)	(0.0383	(0.0309)
IPR	−0.2177***	0.1225	−0.3083*	0.0231
	(0.0838)	(0.0836)	(0.1655)	(0.0965)
INVEST	0.0677***	0.0352***	0.0661***	0.035***
	(0.0097)	(0.0134)	(0.0098	(0.014)
Pop Growth	−0.9563***	−0.2486	−0.9297***	−0.3154
	(0.2626)	(0.2656)	(0.2871)	(0.2952)
TRADE	−0.0102***	0.0021***	−0.0006***	−0.0002
	(0.0021)	(0.0005)	(0.0001)	(0.0002)
Inflation	−0.0006***	−0.0001	−0.0105***	0.0019***
	(0.0001)	(0.0003)	(0.0024)	(0.0006)
Threshold	5.8834330		5.8834330	
CI (95%)	[5.883433 , 5.883433]		[5.3455760 , 5.8834330]	
p-value	0.00			
joint R^2	0.70827235			
N	95		95	

Heterogeneity robust standard errors reported in parenthesis;
90% significance *; 95% significance **; 99% significance ***

IPRs on growth above the human capital threshold is not statistically significant (marginally significant in the OLS regression). These findings and their relation to the literature are discussed shortly below. First, however, let us understand the meaning of the threshold of 5.88 years of schooling. This finding has to be interpreted carefully. Each country in the sample may be viewed as being characterized by a given underlying distribution of educational attainments among its population. For example, there is a statistically significant difference in the quality of science, literacy and mathematics education above and below the human capital threshold. Countries above the human capital threshold have significantly higher education quality scores than countries below the threshold.[7] Thus, we can conclude that countries with high levels of years of schooling also have, on average, high schooling quality. Additional measures of schooling quality show similar results: countries above the human capital threshold have a statistically significantly higher persistence to grade 5, significantly smaller student teacher ratios, significantly fewer students repeating grades, significant more researchers

[7]Education quality data can be found on the webpage of the institute for education science http://ies.ed.gov/

and spend significantly more on R&D.[8] Thus we can consider years of schooling to be a not only a good measure of human capital, but also a good indicator for quality of schooling.

Let us now relate our findings to what has been found in the literature thus far. The existing empirical literature analyzing the relationship between IPRs and economic growth has not yet considered the conditioning impact of human capital on this relationship. Nonlinear relationships between IPRs and growth have been analyzed by Gould and Gruben (1996) using interaction terms, by Thompson and Rushing (1996) using regression switching, and by Falvey, Foster, and Greenaway (2006) using a threshold method verity. None of these papers, however, consider human capital as a source of the nonlinearity, making our approach unique in the literature. Thompson and Rushing (1996) as well as Falvey *et al.* (2006) consider GDP as the source of nonlinearity and find that stronger IPRs have a positive significant impact on growth above a certain GDP threshold.[9] However, while Thompson and Rushing (1996) find a negative but insignificant relationship below this threshold, Falvey *et al.* (1996), who discover two thresholds, find a significant and positive relationship throughout except between a first and second threshold where the relationship is still positive but insignificant. Thus, despite considerable variation between these two findings, both seem the weigh on the side of a significant positive relationship between IPR and growth, especially after the threshold GDP. By contrast, we find statistically negative and statistically significant results below the threshold, while our positive results above the threshold are marginally significant at best. At first glance, one explanation for the differences in our findings from both Thompson and Rushing (1996) and Falvey *et al.* (2006) is our use of human capital rather than GDP as the conditioning variable. However, in a robustness test that we will discuss in the next section, even using GDP does not change the pattern reported above. A second and more likely explanation has to do with the data itself. Both Thompson and Rushing (1996), and Falvey *et al.* (2006) use data that stop prior to the establishment of the new minimum standards for intellectual property laws for WTO member states via the 1995 TRIPS agreement.[10] Specifically, Falvey *et al.*'s (2006) data stop at 1995, and Thompson and Rushing's (2006) data stopsat 1985. Thus, not only is our approach in terms of threshold human capital unique in the literature, but our data (up to date as 2010), encompasses a very important watershed period in the history of intellectual property rights that is missing from the other two papers. Finally, the result that IPRs negatively affect growth below a certain level of human capital is consistent with a broad range of theoretical models that predict negative impact of IPRs on innovation and growth when countries rely primarily on imitation as their source of knowledge creation (see Datta & Mohtadi, 2006; or Helpman, 1993). At the same time, our result that IPRs have at best a marginally significant favorable effect on growth above a certain level of human capital can be explained by the models of Furukawa (2010) and Parello

[8]The variables persistence to grade 5, student teacher ratios, students repeating grades, number of researchers and R&D spending are part of WDI.

[9]Gruben uses trade as the source of nonlinearity and so is not as closely related to our analysis here.

[10]TRIPS – agreement on trade related aspects of intellectual property rights.

(2008) who show that IPRs may have a positive short-run effect on innovation, but a negative long-run effect on the process of learning-by-doing. Thus, given that we analyze a period of 30 years, we may be capturing a situation where a positive short-run effect is offset by the negative long-run effect of IPRs on innovation and growth. Another explanation, consistent with the theoretical perspective that we presented in the introduction, is with regard to the two opposing effects of IPRs, i.e. their ability to promote innovation via appropriation of profits from innovation, versus their propensity to suppress downstream innovation by repressing the diffusion of knowledge. Specifically, as stated in the introduction, where the paucity of human capital is at issue, innovation is weak and vulnerable to barriers from the diffusion of knowledge, erected by stronger IPRs. Thus, it must be the case that in this range, the negative 'diffusion repression' effects of IPRs dominate the positive 'appropriation' effects, resulting in a net negative impact whereas in the high human capital region, the 'appropriation' and the 'diffusion repression' effects just offset one other, yielding an outcome that is at best only marginally significant, even if positive.

Finally, we must address a potential endogeneity concern: is it possible that countries that experience higher rates of economic growth and also possess higher levels of human capital actually introduce stronger IPRs to protect their innovation sector? If this were the case, then it is economic growth that leads to stronger IPRs and not the reverse. We examine and address this possibility by adopting an instrumental variable (IV) estimation technique (Caner & Hansen, 2004) to account for the effect of endogeneity on the results. We use past levels of IPRs (1960–1975) as instruments for current levels of IPRs (1980–2005).

The results of the IV estimation support the earlier findings (Table 2, columns 3 and 4). The results not only support, but in fact seem to amplify, the bifurcating role of IPRs found earlier. IPRs have stronger negative impact on growth in the below-threshold human capital region (Table 2, column 3).

3.3 *Robustness of Threshold and IPR Effects*

We use a variety of estimation approaches to further test for the robustness of our results. As a first robustness test we check for the possibility that the IPR index simply acts as a proxy for the general level and quality of institutions of a country. Thus, we include several institutional measures into the threshold regressions. We use the Economic Freedom of the World Index provided annually by the Frasier Institute to measure the level and quality of institutions.[11] We separately include the comprehensive economic freedom index and the sub-indices legal structure and security of property rights and regulation of credit, labor, and business into our threshold regression. The human capital threshold remains significant and IPRs still negatively influence growth below the human capital threshold when each of these variables is included alongside the IPR variable. We also find that the coefficients for all three institutional variables are positive and statistically significant above and below the human capital threshold. Thus, our results are robust to the inclusion of additional institutional variables. In addition, the IPR

[11]Data are available on the webpage http://www.freetheworld.com/

index is not acting as a mere proxy for the general level and quality of institutions of a country.

In a second robustness test, we use the initial level of per capita GDP (1980) as a threshold variable. This is to verify that the average years of schooling threshold does not just act as a proxy for the level of development of a country. The result implies the existence of a GDP threshold at about $682.40. Countries below this threshold are also harmed by large levels of IPRs, whereas IPRs do not have a statistically significant impact on growth above the GDP threshold, echoing the pattern we found for human capital.[12] As explained earlier, the insignificance of our results above the threshold (even if their sign is positive), stands at odds with the findings of Thompson and Rushing (1996), and Falvey *et al*. (2006), a difference that is likely traceable to the inclusion in our paper, but not the other two, of the important watershed post-1995 period when global IPR laws were universally adopted.

For the final robustness test we constrain all of variables, with the exception of IPRs, to be identical across growth regimes. Hansen's threshold test relies on measuring R^2 with and without threshold. But since any differences in R^2 can be caused by differential IPR effects or by the impacts of any other variable, the constrained threshold regressions will provide further insight into the role of IPRs. The results do not confirm the existence of a human capital threshold where only the marginal effects of IPR differ above and below a possible human capital threshold. It might be noted that although the constrained regressions approach may have certain empirical appeal, the fact that the sample is not split below and above threshold any longer implies an underlying assumption that all countries belong to the same sample. In effect, the constrained results do not allow for the possibility that different growth regimes may exist (e.g. with different production functions), since only the IPR coefficient differs across regimes.

4. Conclusion

The stock of human capital seems to influence the size of the marginal effect of IPR on a country's economic growth. We find that a human capital threshold exists below which IPRs have a strong negative impact on growth and above which IPRs have at best only a marginally significant positive impact on growth. These results are not entirely unexpected, especially once one recognizes the inherent complementariness between human capital and intellectual property. Yet, this simple observation yields an insight into the non-linearity of the role of IPRs in economic growth that has not been stressed, far less empirically verified thus far.

These results bear important policy implications: when human capital is low, the binding constraint to growth (to borrow the terminology of Haussman and

[12]However, we find a somewhat different location for our threshold GDP: only 26 countries are located below the GDP threshold, while 41 countries were located below the human capital threshold (with the exception of Ghana and Sri Lanka, all countries located below the GDP threshold are also located below the human capital threshold). Thus, for the 15 countries whose GDP is above our threshold GDP but whose human capital is below out threshold human capital, an ambiguity exists in the effect of IPR on growth. We might think of this region as a 'threshold region' (for lack of a better terminology) where strong results of one form or other are missing.

also Rodrik) is human capital, rather than lax intellectual property rights. Thus, investments in human capital are more important for economic growth than investments in IPRs. The scarce financial resources of developing countries should be directed at the development of human capital rather than to maintain a system of IPRs. The results further imply that the enforcing of a universally uniform level of IPRs would lead growth rates to diverge, thereby actually reducing the probability of catch up by human-capital poor countries. This result provides an important guideline for future negotiations on the international harmonization of IPRs. It also contains a further note of caution: stronger IPRs may not be a guarantee for a more rapid rate of economic growth even when countries are human-capital rich.

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Appendix

Descriptive Statistics

Variable	Definition	Source	mean	sd
GROWTH	Difference of ln(GDP) 1980–2010 measured with chain price	WDI	0.3998	0.4542
lnGDP	Natural logarithm of the value of GDP 1980	WDI	7.6465	1.5429
School	Average years of schooling above 15 years of age 1980–2010	BL	6.3995	2.7221
IPR	Intellectual property rights index average 1980–2010	GP	2.5244	0.8934
INVEST	Investment per GDP - average 1980–2010	WDI	20.658	4.4761
Pop Growth	Log Differences between population size 1980 and 2010	WDI	0.5151	0.2678
Trade	Openness - sum of exports and imports per GDP - 1980–2010	WDI	77.036	52.01
Inflation	Average inflation 1980–2010	WDI	39.694	144.31

World Development Indicators (WDI), Barro Lee dataset (BL), Ginarte-Park IPR dataset (GP).

List of Countries

Countries below Human Capital Threshold ($<=5.8834330$ of average years of schooling)

Algeria, Bangladesh, Benin, Brazil, Burundi, Cameroon, Central African Republic, Congo, Dem. Rep., Congo, Rep., Cote d'Ivoire, Egypt, Arab Rep., El Salvador, Gabon, Guatemala, Honduras, India, Indonesia, Kenya, Liberia, Malawi, Mali, Mauritania, Morocco, Mozambique, Nepal, Nicaragua, Niger, Pakistan, Papua New Guinea, Rwanda, Senegal, Sierra Leone, Sudan, Syrian Arab Republic, Thailand, Togo, Tunisia, Turkey, Venezuela, RB, Zambia, Zimbabwe

Countries above Human Capital Threshold

Argentina, Australia, Austria, Belgium, Bolivia, Botswana, Canada, Chile, Colombia, Costa Rica, Cyprus, Denmark, Dominican Republic, Ecuador, Fiji, Finland, France, Germany, Ghana, Greece, Guyana, Hong Kong SAR, China, Iceland, Israel, Italy, Jamaica, Japan, Jordan, Korea, Rep., Luxembourg, Malaysia, Malta, Mauritius, Mexico, Netherlands, New Zealand, Norway, Panama, Paraguay, Peru, Philippines, Portugal, Saudi Arabia, Singapore, South Africa, Spain, Sri Lanka, Swaziland, Sweden, Switzerland, Trinidad and Tobago, United Kingdom, United States, Uruguay