The University of Nottingham

research paper series

Internationalisation of Economic Policy

Research Paper 2004/12

Intellectual Property Rights and Economic Growth

by

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Leverhulme Centre for Research on Globalisation and Economic Policy

The Centre acknowledges financial support from The Leverhulme Trust under Programme Grant F114/BF

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Acknowledgements

We would like to thank Jesús Crespo-Cuaresma and Burcin Yurtoglu for many helpful comments and suggestions. Falvey and Greenaway gratefully acknowledge financial support from The Leverhulme Trust under Programme Grant F114/BF.

Intellectual Property Rights and Economic Growth

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Abstract

Interest in links between protection of intellectual property and growth has been revived by developments in new growth theory and by the WTO's TRIPS Agreement. The relationship between the strength of a country's intellectual property rights (IPRs) regime and its rate of growth is theoretically ambiguous, reflecting the variety of channels through which technology can be acquired and their differing importance at different levels of development. In this paper, we investigate the impact of IPR protection on economic growth in a panel data of 80 countries using threshold regression analysis. We show that whilst the impact of IPR protection on growth depends upon the level of development, IPR protection is positively and significantly related to growth for low- and high-income countries, but not for middle-income countries. This suggests that, while IPR protection encourages innovation in high-income countries, and technology flows to low income countries, middle-income countries may have offsetting losses from reduced scope for imitation.

JEL Classifications: O34, O38

Keywords: Intellectual Property Rights, Economic Growth

Outline

Non-Technical Summary

Recent theories of economic growth highlight the importance of R&D and innovation for growth. By allowing firms to profit from their R&D activities stronger IPR protection should encourage innovation and growth. Moreover, strong IPR protection should stimulate the acquisition and dissemination of knowledge, since the information in patent claims is made publicly available, which by lowering the cost of future innovation would encourage growth. Despite these arguments theoretically IPR protection has an ambiguous impact on growth. Strong IPR protection can also limit the spread of new ideas and encourage monopoly. Entry by rivals may be impeded, and successful innovators may have reduced incentives for developing and exploiting subsequent innovations. IPR protection can also have an ambiguous impact on other factors considered important for growth. In particular stronger IPR protection can have different and often opposing influences on the relationship between growth and trade, foreign direct investment, licensing, imitation and piracy.

Moreover the impact of IPR protection on growth is likely to depend upon the country in question and in particular a countries level of development, as reflected in its ability to innovate and imitate. Innovative activity tends to be concentrated in a small number of advanced countries. In these countries stronger IPR protection would be expected to encourage innovation and subsequent growth. For many other countries however, and for middle-income countries in particular, imitation can be an important source of technological development and growth. In these countries, providing stronger IPR protection to foreign firms could cripple domestic industry previously relying on pirated technologies.

Existing evidence suggests that IPR protection has a positive impact on growth, which is often significant. Both Gould and Gruben (1996) and Thompson and Rushing (1996) estimate cross-section growth regressions and find positive and significant coefficients on the IPR variable. Gould and Gruben go on to show that the impact of IPR protection on growth can be slightly larger in more open economies though the difference tends not to be significant. Thompson and Rushing find a positive and significant relationship between IPR protection and growth only when countries reach a certain level of development as measured by initial GDP. For countries below this level no significant relationship between IPR protection and growth exists.

In this paper we use panel data for 80 countries and for four five-year periods to address the impact of IPR protection on economic growth. Including an index of IPR protection in a standard empirical growth model we find a positive and generally significant relationship between the extent of IPR protection in a country and its growth rate. Given the potential for IPR protection to have differing impacts on growth in different countries we use recently developed threshold regression techniques to examine whether the relationship between IPR protection and output growth depends upon a third factor. This method allows us to split our observations into different regimes with the relationship between IPR protection and growth allowed to vary across regimes. Our results suggest that the relationship between IPR protection and growth depends upon the level of development, as proxied by initial GDP per capita. For low- and high-income countries we find that stronger IPR protection significantly improves growth, but for middle-income countries no such relationship is found.

The results for high-income countries are largely as expected; these countries undertake the vast majority of innovation and where strong IPR protection should encourage further innovation by allowing innovators to profit from their inventions. For low-income countries the positive relationship between IPR protection and growth clearly doesn't reflect a relationship between IPR protection and innovation, but more likely that strong IPR protection in these countries encourages imports and inward FDI that encourage growth without adversely affecting domestic imitative activities. Middle-income countries also do not engage in innovative activities to any extent, but may well rely on imitative activities. The lack of a relationship between IPR protection and growth in these countries is likely to reflect two opposing forces. The positive impact of IPR protection on growth that works indirectly through trade and FDI is being offset by a negative impact slowing knowledge diffusion and discouraging imitation. Despite the lack of evidence for a significant relationship between IPR protection and growth for middle-income countries in no case do we find evidence of a negative relationship between IPR protection and growth.

1. Introduction

Developments in the research and policy-making communities have stimulated renewed interest in the links between protection of intellectual property and economic growth. With regard to the former, the emphasis that new growth theory places on the role of technological progress in the growth process, with research and development (R&D) being undertaken either to improve existing products or develop new ones, has stimulated extensive academic research. This has been reinforced by the controversy surrounding the negotiation and implementation of the so-called TRIPs Agreement which followed the Uruguay Round of multilateral trade negotiations, and sets minimum IPR protection standards for WTO members.

In the global economy, individual countries acquire improved technologies through a variety of channels, both direct and indirectly via spillovers. These channels include innovation, licensing, trade, foreign direct investment, imitation and piracy. Since stronger IPR protection has different and sometimes opposing influences on the flow of technology through these channels, the overall effects of stronger IPRs on technology acquisition and aggregate growth are in general ambiguous. The impact of stronger IPR protection is likely to vary across countries depending on their levels of development, as reflected in their capacities to innovate and imitate.

In this paper we investigate the role of IPRs in an empirical growth model for a large panel of developed and developing countries, using threshold regression models. Our results suggest that the relationship between IPR protection and growth depends upon the level of development, as proxied by initial GDP per capita, but in a non-linear way. For low- and high-income countries we find that stronger IPR protection significantly improves growth, but for middle-income countries no such relationship is found. These outcomes are consistent with the view that middle-income countries engage in imitation rather than innovation and may be less likely to benefit from IPR protection.

The rest of the paper is organised as follows. In Section 2, we review the theoretical linkages between IPR protection and growth, while Section 3 considers the existing empirical literature. Section 4 discusses the empirical set-up for our model, the data employed and the results obtained. In Section 5 we summarise and interpret our results.

2. Theoretical Background

A role for IPR protection arises because intellectual property displays many of the characteristics of a public good. It is typically non-rival and can be non-excludable. In the extreme these characteristics could remove the incentive to invest in R&D, and IPR protection can therefore restore that incentive[1]. The importance of R&D and innovation has been emphasised by new growth theory, for example, Romer, (1990); Grossman and Helpman, (1991); and Rivera-Batiz and Romer, (1991). In these models entrepreneurs invest in R&D in the expectation of profiting from their inventions. In addition to new products, innovation adds to a public stock of knowledge which lowers the cost of future innovation. Besides rewarding innovation, IPR protection stimulates the acquisition and dissemination of knowledge, since the information in patent claims is then available to other potential inventors (Maskus, 2000). The rate of growth depends upon the rate of innovation and the stock of knowledge. Strong IPR protection need not always yield higher innovation and growth, however. Giving innovators too much protection may limit the spread of new ideas and lead to monopoly. Entry by rivals may be impeded, and successful innovators may have reduced incentives for developing and exploiting subsequent innovations[2].

In practise, R&D and innovation are heavily concentrated in a small number of advanced countries[3], with many developing countries undertaking little or none. But imitation can be a significant source of technological development in the latter. In this case, providing stronger IPR protection to foreign firms could cripple domestic industries previously relying on pirated technologies. In effect, a stronger regime would act to transfer profits to firms outside the country rather than encouraging domestic innovative activity (Deardorff, 1992), particularly in relatively closed

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[1] Maskus (2000) notes that even in the absence of IPR protection there may exist natural incentives to innovate, depending on market lead times, marketing strategies and difficulties in copying and imitating.

[2] Gilbert and Newbery (1982) show that under certain conditions a monopolist may accumulate patents and allow them to "sleep", thus deterring entry into an industry.

[3] The share of R&D financed by enterprises in advanced countries was 98% in the 1980s and 94% in the 1990s. See UNIDO (2002).

economies where few domestic alternatives to the imported product are available (Gould and Gruben, 1996). One should not overstate the case however, since IPR protection could help reward creativity and risk-taking even in developing economies, with countries that retain weak IPR protection remaining dependent on dynamically inefficient firms that rely on counterfeiting and imitation (Maskus, 2000).

The strength of IPR protection may also impact upon the levels of trade, inward foreign investment and technology licensing, all of which affect productivity and output growth through technology transfer[4]. Maskus and Penubarti (1995) argue that IPR protection has an indeterminate effect on trade. While firms should be encouraged to export their patented goods into foreign markets with strong IPR protection, since such protection reduces the risk of imitation or piracy, they may choose to reduce their export sales in a foreign market in response to stronger IPR protection, because their market power increases as the ability of local rivals to imitate the firm's product is curtailed[5]. Likewise there is no clear-cut relationship between IPR protection and inward FDI. Strong protection reduces the risks of technology leakage through armslength technology licensing, thus reducing the need for FDI (Yang and Maskus, 2001a and b). But, as Smith (2001) argues, weak IPR regimes tend to affect the investment climate adversely, thus discouraging FDI[6].

In summary, while theory highlights the potential importance of IPR protection for innovation and growth in the global economy, it also suggests that there could be important differences in the relationship between IPR protection and growth across countries, depending *inter alia*, on their capabilities for innovation and imitation.

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[4] For evidence of growth promoting knowledge spillovers through trade see Coe and Helpman (1995), Coe, Helpman and Hoffmaister (1997) and Falvey, Foster and Greenaway (2003). Mansfield *et al.* (1981) show that FDI is a principal source of technology transfer.

[5] In their empirical results Maskus and Penubarti find that stronger IPR protection has a positive impact on imports, an outcome largely confirmed by Primo-Braga and Fink (1997) and by Fink and Primo-Braga (1999). Smith (1999) qualifies these results somewhat by showing that the effect of IPRs hinges on whether local firms are capable of imitating the exporter's technology. This affects whether local firms can pose a credible threat of competition. If not, stronger IPR protection will merely reinforce the market power of exporters and restrict trade.

[6] Mansfield (1994) presents survey evidence that weak IPR protection deters both foreign investment and joint ventures by US firms. Similar results are found for Germany and Japan by Mansfield (1995).

3. Empirical Evidence

A few studies have investigated the impact of IPR protection on cross-country growth. Gould and Gruben (1996) estimate a growth model on a cross-section of up to 95 countries with data averaged over the period 1960-88, including in their regression the IPR measure of Rapp and Rozek (1990). They find IPR protection has a significant positive impact on growth. Thompson and Rushing (1996) estimate cross-section growth regressions including up to 112 countries for the period 1970-85, again using the Rapp and Rozek measure. While they find positive coefficients on the IPR variable, they are never significant. Both these studies also consider non-linearities in the growth-IPR relationship. Gould and Gruben (1996) examine whether IPR protection affects growth in open versus closed economies differently, by interacting their measure of IPRs with three measures of a country's trade orientation. Their results suggest that IPR protection can have a slightly larger impact on growth in open economies, but only for one measure is the coefficient ever significant and even then its significance is not robust to the inclusion of other variables.

Thompson and Rushing (1996) employ a switching regression model to examine whether increased IPR protection is more beneficial once a country has reached a particular level of development, as measured by initial GDP per capita[7]. Their results indicate a break point at an initial level of GDP of $3,400 (1980 dollars). For countries below this no relationship between IPR protection and growth is found, but above it a positive and significant relationship is found. They only test for the presence of a single break, however, which may give misleading results if more than one break is present, as is suggested by our results below. Thompson and Rushing (1999) extend this using a simultaneous equation model. They estimate their model on a cross-section of 55 developed and developing countries over the period 1975-90. The model is a system of three equations with average growth of GDP per capita, the ratio of TFP from 1975 to 1990 and the Rapp and Rozek index as the three dependent variables. They estimate this system for the full sample of countries, but also split the

[7]Thompson and Rushing split their data at various levels of initial GDP such that at each split one country is shifted from one regime to the other. The switch-point or threshold is chosen as the value of initial GDP that maximises the log likelihood function. Unfortunately, at that time methods were not available to determine whether the estimated threshold was significant or to form a confidence interval around the estimated threshold. Recently Hansen (1996, 1999, 2000) has developed such techniques and we employ these below. Moreover, we search for the possibility of more than two regimes (i.e. more than one threshold) in our empirical analysis.

sample in two, depending on initial GDP. The results once again suggest that patent protection only has a positive and significant impact upon TFP (and thereby growth) for the more advanced countries, with insignificant coefficients found for the full sample and the sample of developing countries.

More recently Kanwar and Evenson (2003) estimate a panel model for two periods and up to 32 countries using the Ginarte and Park (1997) index of IPRs. They aim to measure the impact of IPR protection on innovation directly using as their explanatory variable R&D investment as a proportion of GNP. They find that IPRs have a positive and significant impact on R&D investment and conclude that stronger IPR protection can help spur innovation and technological progress, which in turn should positively impact on growth.

4. Empirical Estimation

Our brief review of the theoretical literature suggests that, for any individual country, improvements in technology can come through a variety of channels, the relative importance of which will depend on certain characteristics of the country concerned. This implies that the impact of stronger IPR protection on growth will also depend on country characteristics. This is largely confirmed by the small empirical literature, where the evidence of a simple linear relationship between IPR protection and growth is mixed, and the evidence for a non-linear relationship, particularly involving thresholds relating to the level of development rather stronger.

Our analysis uses an estimated growth equation to investigate these non-linearities further, focussing on thresholds in particular. There has been some standardisation of the independent variables included in growth equations, and we add to these standard variables a measure of IPRs. The starting point for our estimations is the following equation

$$GROW_{it} = \beta_1 INITGDP_{it} + \beta_2 GDI_{it} + \beta_3 POPGROW_{it} + \beta_4 SYR15_{it} + \beta_5 EXPGDP_{it} + \beta_6 INFLATION_{it} + \beta_7 IPR_{it} + \mu_i + \nu_t + \varepsilon_{it}$$

Where *GROW* is the average growth rate of GDP per capita for country *i* in period *t*, *INITGDP* is the (logged) level of per capita GDP at the beginning of each five-year period, *GDI* is the average (logged) level of gross domestic investment, *POPGROW* is the average growth rate of population, *SYR15* is the average years of secondary education for people over 15 at the beginning of each five-year period, *EXPGDP* is the average ratio of exports to GDP (a measure of openness), *INFLATION* is the average rate of inflation (typically included as a measure of economic instability), *IPR* is our measure of patent protection and μ_i and v_t are country and time-specific fixed-effects.

4.1 Data

Our data covers 80 countries[8] for four sub-periods: 1975-79, 1980-84, 1985-89 and 1990-94. Data on growth rates, population growth, investment, exports and inflation was drawn from the World Bank's World Development Indicators (2001). Secondary school education is from Barro and Lee (2000)[9]. We use the index of patent rights developed by Ginarte and Park (1997) to measure the strength of IPRs. This index was constructed for 110 countries quinquennially for the period 1960-1990. For our purposes it has the advantage over other indicators[10] that it is available for more periods (and more countries) allowing us to estimate a panel model. Five characteristics of patent laws are included: extent of coverage; membership in international patent agreements; provisions for loss of protection; enforcement mechanisms, and duration of protection. Each was assigned a value ranging from 0 to 1 and their unweighted sum formed the index, with a higher number signalling stronger patent protection [11].

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[8] The countries in our sample are Algeria, Australia, Austria, Argentina, Bangladesh, Belgium, Benin, Bolivia, Botswana, Brazil, Cameroon, Canada, Central African Republic, Chile, Colombia, Congo, Costa Rica, Denmark, Dominican Republic, Ecuador, Egypt, El Salvador, Fiji, Finland, France, Germany, Ghana, Greece, Guatemala, Haiti, Honduras, India, Indonesia, Iran, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kenya, Korea, Malawi, Malaysia, Mauritius, Mexico, Mozambique, New Zealand, Nepal, Netherlands, Nicaragua, Niger, Norway, Papua New Guinea, Pakistan, Panama, Paraguay, Peru, Philippines, Portugal, Rwanda, South Africa, Senegal, Singapore, Spain, Sri Lanka, Swaziland, Sweden, Switzerland, Syria, Thailand, Togo, Trinidad and Tobago, Uganda, USA, Uruguay, Venezuela, Zaire, Zambia, and Zimbabwe.

[9] Tables 4 and 5 in the appendix provide summary statistics and the correlation between variables.

[10] Measures of the strength of patent systems are typically based on dummy variables or on a survey of firms. Bosworth (1980) and Ferrantino (1993) for example, construct a dummy variable based on various indicators of whether certain features of patent laws exist. Rapp and Rozek (1990) aggregate their indicators (which are dummies) to form a composite index ranging from 1 to 6. Mansfield (1994) uses survey data, sampling the views of 94 US multinationals on the adequacy of patent rights in 16 countries.

[11] See Ginarte and Park (1997) for details.

4.2 Initial Results

Table 1 reports the results from preliminary estimations. We see that the coefficients on most of the standard variables have the expected sign and are significant. The exceptions are those on population growth, which is positive, but insignificant[12], and the coefficient on secondary schooling which is positive as expected, but not significant, a result common in the literature. When our IPR measure is added (in Column 3), we confirm previous findings of a coefficient that is positive and significant (though only at the 10 percent level) suggesting that growth may be positively related to IPR protection.

Table 1: Initial Results

Growth	1	2	3	4
INITGDP	-0.1	-0.11	-0.11	-0.12
	(-6.8)***	(-6.96)***	(-6.93)***	(-6.37)***
GDI	0.05	0.05	0.05	0.05
	(6.24)***	(6.35)***	(6.33)***	(6.41)***
Popgrowth	0.94	0.84	0.84	0.8
	(1.52)	(0.22)	(1.21)	(1.19)
SYR15	0.006	0.006	0.006	0.005
	(1.21)	(1.04)	(1.03)	(0.89)
EXPGDP	0.13	0.13	0.13	0.13
	(3.92)***	(3.97)***	(3.97)***	(3.99)***
INFLATION	-0.001	-0.001	-0.001	-0.001
	(-3.6)***	(-3.58)***	(-3.57)***	(-3.68)***
IPR		0.01	0.06	-0.03
		(1.8)*	(0.24)	(-0.57)
IPRSQ			0.001	
			(0.36)	
IPRGDP60				0.004
				(0.92)
F-Stat	6.75***	6.76***	6.66***	6.71***
Adjusted R^2	0.63	0.64	0.64	0.64

All equations include a full set of unreported country and time dummies. t-statistics are reported in brackets. All models estimated using White Heteroscedasticity-Consistent standard errors. *, **, *** indicate significance at the 10, 5 and 1 percent level respectively.

We then test for non-linearities. First we add the square of the IPR variable (*IPRSQ* in Column 4). Although the coefficients on both IPR terms are positive, suggesting that any benefits of IPR protection on growth increase as IPR protection is strengthened, neither is significant. Similarly, when we test for interaction effects between IPR protection and initial GDP (*IPRGDP60* in Column 5) we find a negative coefficient

[12] The positive coefficient on population growth appears to be related to the inclusion of country dummies. Estimating a random effects models gives us the usual negative and significant coefficient on population growth.

on the IPR variable and a positive coefficient on the interaction term, though again neither is significant. If a non-linear relationship between IPR protection and growth is present, neither of these specifications captures it convincingly.

4.3 Threshold Effects

Our review of the theory and evidence indicated that threshold effects are possible. Fortunately a general method of testing for thresholds is now available. Hansen (1996, 1999 and 2000) provides an econometric technique that allows the sample data to determine the number and location of the thresholds. The method, described in the Appendix, is based on a threshold regression model where observations fall into regimes that depend on an unknown value of an observed variable.

We begin by applying this technique directly to IPR protection itself. Our results suggest a positive relationship between IPR protection and growth. But does this reflect a relationship where such protection must exceed some minimum cutoff for growth-enhancing benefits to be obtained? Are the growth-enhancing benefits of stronger IPR protection still present if current levels of protection are relatively high? To investigate these we allow the parameter associated with IPR protection to change discretely depending upon the level of IPR protection. This is achieved by estimating the following model:

$$\begin{aligned} GROW_{it} &= \beta_1 INITGDP_{it} + \beta_2 GDI_{it} + \beta_3 POPGROW_{it} + \beta_4 SYR1560_{it} + \beta_5 EXPGDP_{it} \\ &+ \beta_6 INFLATION_{it} + \delta_1 IPR_{it} I(IPR_{it} \leq \lambda) + \delta_2 IPR_{it} I(IPR_{it} > \lambda) + \mu_i + v_t + u_{it} \end{aligned}$$

where λ is the breakpoint. Here the observations are divided into two regimes depending on whether the threshold variable, *IPR*, is smaller or larger than the value λ. The impact of IPR protection on growth will be given by δ_1 for countries in the low IPR regime and by δ_2 for countries in the high IPR regime.

To estimate this model we first need to jointly estimate the threshold value λ and the slope parameters. Chan (1993) and Hansen (2000) recommend obtaining the least squares estimate of λ as the value that minimises the concentrated sum of squared errors. We estimate our growth model for all values of the IPR variable between the 10^{th} and 90^{th} quantile and use as the threshold the value of IPR that minimises the sum of squared errors. After obtaining a value of λ, we can estimate the parameters of our growth equation.

Having found a threshold we need to identify whether it is statistically significant. This involves testing the null hypothesis that $\delta_1 = \delta_2$, where rejecting the null allows us to conclude that a threshold exists. One complication is that the threshold λ is not identified under the null hypothesis, implying that classical tests do not have standard distributions and critical values cannot be read off standard distribution tables. We follow Hansen (1996) and bootstrap to obtain the p-value for the test of a significant threshold.

Once a threshold is confirmed, it is important to be able to form some kind of confidence interval around it so that countries can be allocated to the two regimes. Once again standard methods are not ideal when estimating an unknown threshold (Dufour, 1997). Hansen (2000) derives the correct distribution function and provides the appropriate critical values for the likelihood ratio statistic. The confidence interval of the threshold estimate λ consists of those values of IPR for which the likelihood ratio statistic is less than the critical value. According to Hansen (2000) the 90% critical value is 5.94, which is the value we use.

Column 2 of Table 2 reports results from our estimation of a single threshold based on IPR protection. We find that an IPR level of 2.27 minimises the sum of squared residuals. The test of whether the threshold was significant resulted in a p-value of 0.04 allowing us to accept this non-linearity at the 5% level. The estimated coefficients show that growth is positively and significantly affected by an increase in IPR protection on both sides of the threshold, but that the growth-enhancing effect is smaller in magnitude above the threshold. This suggests that, rather than a minimum level of IPR protection being required; those countries with lower levels of IPR protection have more to gain in terms of growth from strengthening IPR protection.

Table 2: Results for a Threshold Based on IPR Protection

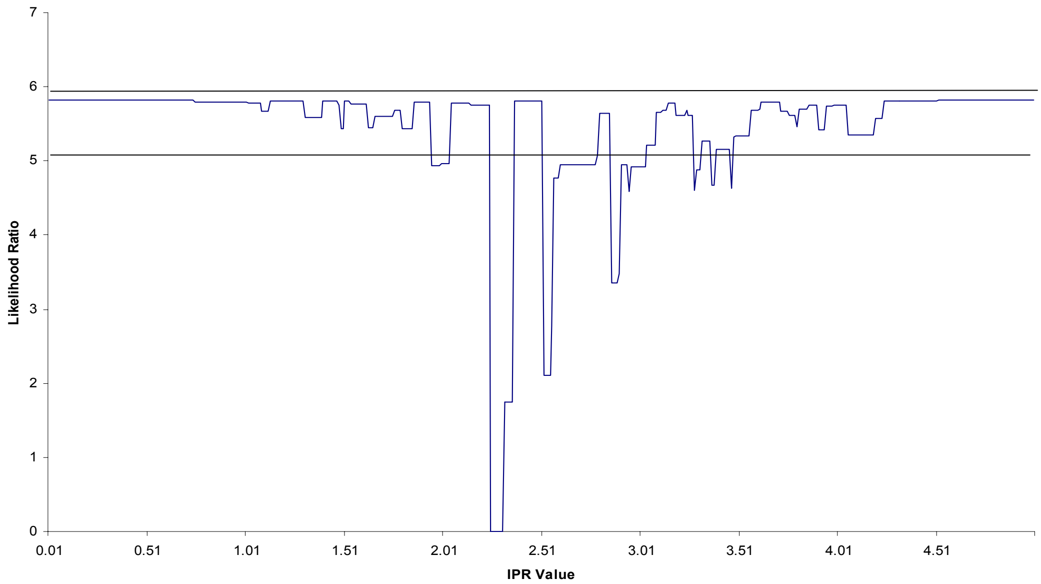
Growth	Single Threshold	Double Threshold
INITGDP	-0.11 (-7.08)***	-0.11 (-7.12)***
GDI	0.05 (6.53)***	0.05 (6.63)***
PopGrow	0.84 (1.2)	0.81 (1.16)
SYR15	0.006 (1.05)	0.005 (1.03)
EXPGDP	0.12 (3.73)***	0.12 (3.62)***
INFLATION	-0.001 (-3.66)***	-0.001 (-3.6)***
IPR ($IPR \leq 2.27$)	0.03 (2.39)**	0.02 (1.7)*
IPR ($IPR > 2.27$)	0.01 (1.88)*	
IPR $2.27 \leq IPR \leq 2.86$		0.006 (0.68)
IPR ($IPR > 2.87$)		0.01 (1.39)
p-value	0.04**	0.18
F-Stat	6.83***	6.81***
Adjusted R^2	0.64	0.64

All equations include a full set of unreported country and time dummies. t-statistics in brackets. All models estimated using White Heteroscedasticity-Consistent standard errors. *, **, *** indicate significance at the 10, 5 and 1 percent level respectively.

Which countries are they? To obtain the confidence interval for the threshold estimate we identify the region where the likelihood ratio is less than the critical value. Figure 1 plots the normalised likelihood ratio for all values of IPR. This hits the x-axis at the value of the threshold. For all points below the horizontal line at 5.94 we cannot determine whether the observations are in the low or high regime at the 90 percent level. Unfortunately it is clear from Figure 1 that at the 90 percent level we cannot conclude for *any* of our observations whether they lie in the low or high regime[13]. Despite the evidence of a threshold in the IPR-growth relationship, our conclusions are limited by the large confidence interval.

[13] Also included in Figure 1 is a horizontal line at 5.1, which is the 85% level of confidence. Using this figure we see that at the 85% level of confidence countries with an IPR value less than 1.96 are classed as being in the low regime (64 of our observations lie in this region), while countries with an IPR level above 3.48 are classed as being in the high regime (44 observations). For countries with an IPR level between 1.96 and 3.48 we cannot be certain (at the 85% level) whether they are in the low or high regime (188 observations fall into this category).

Figure 1: Confidence Interval for First Threshold Based on IPR Protection



This could be because there is more than one threshold. We explore this by re-specifying our estimating equation:

$$GROW_{it} = \beta_j X_{jit} + \delta_1 IPR_{it} I(IPR_{it} \leq \lambda_1) + \delta_2 IPR_{it} I(\lambda_1 \leq IPR_{it} \leq \lambda_2) + \delta_3 IPR_{it} I(IPR_{it} > \lambda_2) + \mu_i + v_t + u_{it}$$

Where X_{jit} now refers to the vector of standard variables included in our model. Given that $\lambda_1 < \lambda_2$ we fix λ_1 at 2.27 (the estimated first threshold) and search for a second threshold in the relationship, which appears to be at 2.86. However, as can be seen in Column 3 of Table 2, the test for significance returns a bootstrapped p-value of 0.18, leading us to reject the hypothesis of a second threshold at standard significance levels.

In summary, although we do find evidence of a single threshold in the IPR-growth relationship, the confidence interval is so large that we are unable to reach conclusions relating to specific countries. One possibility that remains to be investigated, however, is that any thresholds work through one of the other explanatory variables. Having regard to the discussion in Section 2 and the results of Thompson and Rushing summarised in Section 3, the natural candidate for such a threshold is initial GDP per capita.

We therefore renew our search for threshold effects using:

$$GROW_{it} = \beta_1 INITGDP_{it} + \beta_2 GDI_{it} + \beta_3 POPGROW_{it} + \beta_4 SYR1560_{it} + \beta_5 EXPGDP_{it}$$
$$+ \beta_6 INFLATION_{it} + \delta_1 IPR_{it} I(INITGDP_{it} \leq \lambda) + \delta_2 IPR_{it} I(INITGDP_{it} > \lambda) + \mu_i + \nu_t + u_{it}$$

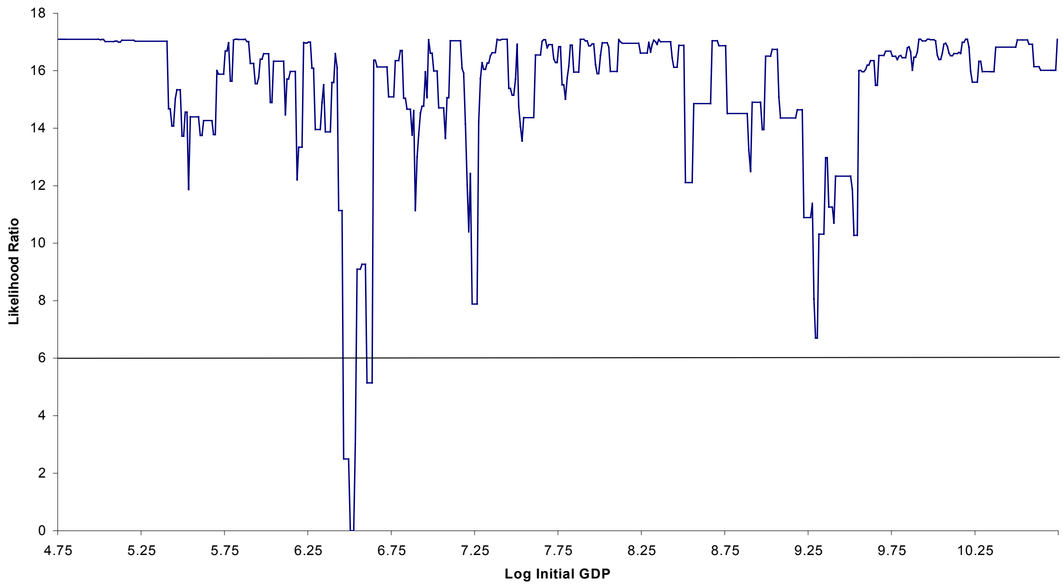
to first estimate a single threshold, which turns out to be at *INITGDP* = 6.51 (i.e. $670.67 at 1995 constant $US). The test of a significant threshold returns a p-value of 0.00, suggesting that we can reject the hypothesis that $\delta_1 = \delta_2$ at the 1% level. The corresponding results in Column 2 of Table 3 indicate that an increase in IPR protection significantly increases growth at low levels of *INITGD*P (less than $670), but not at higher levels of *INITGDP*. Figure 2 plots the normalised likelihood ratio for all values of *INITGDP* allowing us to derive the 90% confidence interval. The asymptotic 90% confidence interval is in the range 6.46 and 6.63. For countries with *INITGDP* less than 6.46 (80 observations) we can be 90% certain that they lie in the first regime and for countries with *INITGDP* above 6.63 (223 observations) we can be 90% certain that they lie in the second regime. The remaining 11 observations could lie in either regime.

Table 3: Results for a Threshold Based on Initial GDP

Growth	Single Threshold	Double Threshold
INITGDP	-0.1 (-6.58)***	-0.1 (-6.94)***
GDI	0.05 (6.5)	0.05 (6.68)***
PopGrow	0.86 (1.23)	0.9 (1.32)
SYR15	0.007 (1.4)	0.007 (1.44)
EXPGDP	0.13 (3.9)***	0.12 (3.67)***
INFLATION	-0.001 (-3.57)***	-0.001 (-3.57)***
IPR (*INITGDP* $\leq$ 6.51)	0.02 (2.84)***	0.02 (2.28)**
IPR *(INITGDP > 6.51)*	0.008 (1.07)	
IPR (6.51 $\leq$ *INITGDP* $\leq$ 9.29)		0.004 (0.54)
IPR *(INITGDP > 9.29)*		0.01 (1.8)*
p-value F-Stat Adjusted R^2	0.00*** 7.17*** 0.65	0.01** 7.38*** 0.67

All equations include a full set of unreported country and time dummies. p-values in brackets. All models estimated using robust standard errors. *, **, *** indicate significance at the 10, 5 and 1 percent level respectively.

Figure 2: Confidence Interval for First Threshold Based on Initial GDP



Since the group above the threshold includes 75% of our observations and covers a wide range of per capita incomes, we next examine whether there is a second threshold based on initial GDP per capita. Our estimating equation becomes:

$$GROW_{it} = \beta_j X_{jit} + \delta_1 IPR_{it} I(INITGDP_{it} \leq \lambda_1) + \delta_2 IPR_{it} I(\lambda_1 \leq INITGDP_{it} \leq \lambda_2)$$
$$+ \delta_3 IPR_{it} I(INITGDP_{it} > \lambda_2) + \mu_i + v_t + u_{it}$$

Fixing λ_1 at the value of our first threshold (i.e. 6.51) and estimating this model gives us a value for λ_2 of 9.29 (i.e. \$10829)[14]. Moreover, the bootstrapped p-value is found to be 0.01 implying that we cannot reject the hypothesis of a second threshold at the 5% level. Column 3 of Table 3 once again shows that for low income countries (*INITGDP* less than 6.51), growth is positively and significantly affected by IPR protection. For the middle regime (*INITGDP* between 6.51 and 9.29) we find a positive but insignificant relationship and for the high regime (*INITGDP* above 9.29) a positive and significant relationship[15]. It seems that although stronger IPR protection is growth enhancing in the low- and high-income countries in our sample, middle-income countries receive no such benefits[16].

Finally, we plot the confidence intervals for the first and second thresholds using the threshold estimates $\hat{\lambda}_1^r$ and $\hat{\lambda}_2$. These are shown in Figures 3A and 3B respectively. The values in Figure 3B hint at the possible existence of a third threshold (estimated at 7.23), but the bootstrapped p-value allows us to reject this. However, one consequence is that the asymptotic 90% confidence interval for the second threshold is both large and asymmetric (ranging from 6.89 to 9.55). The confidence interval for the first threshold remains relatively small (ranging from 6.46 to 6.63).

[14] In the two threshold model the estimate of λ_1 is no longer asymptotically efficient (see Appendix). Estimating the refined estimator $\hat{\lambda}_1^r$ however gives us the same value of *INITGDP* as an estimate for λ_1, namely 6.51.

[15] While the estimated coefficient for the low regime (0.02) is larger than that for the high regime (0.01), we cannot reject the hypothesis that they are equal at standard significance levels.

[16] Interestingly this outcome is reflected in the average IPR protection levels chosen by the observations in each range – i.e. 3.48 in the high income range, 2.15 in the middle income range and 2.34 in the low income range.

Figure 3A: Confidence Interval In Two Threshold Model: Threshold 1

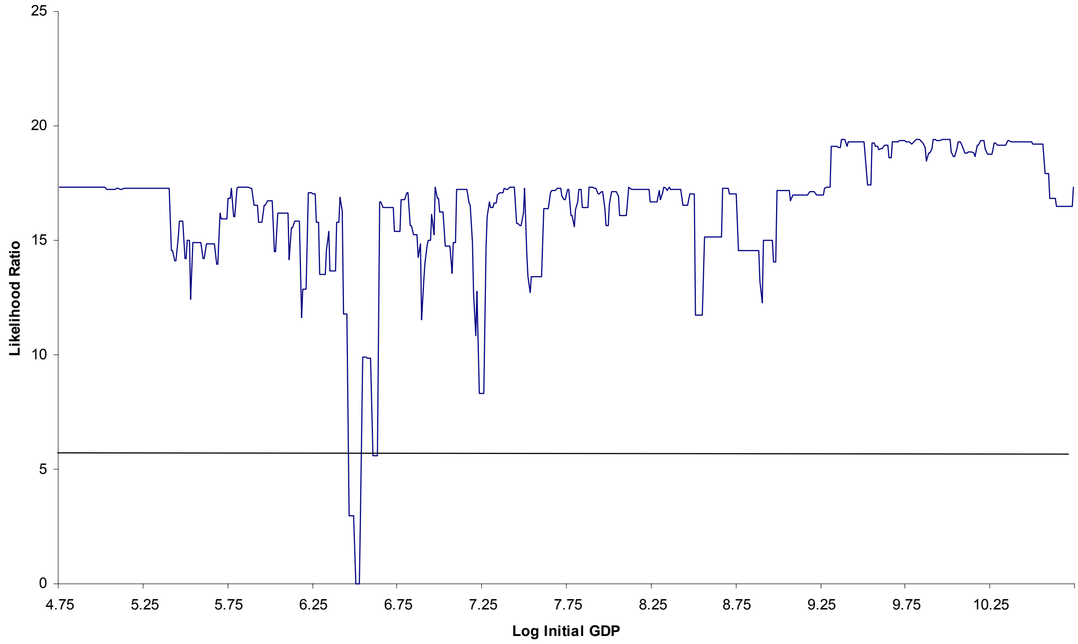
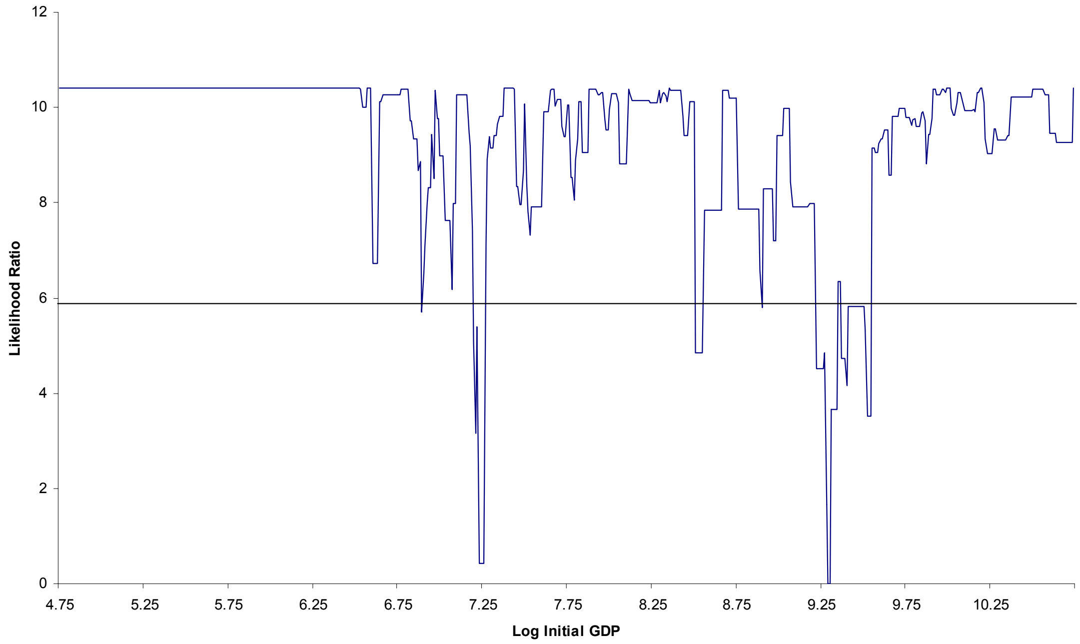


Figure 3B: Confidence Interval In Two Threshold Model: Threshold 2



Reviewing our results then, we reveal 80 observations in the low regime (log per capita income less than 6.46), 17 in the middle regime (6.63 and 6.9), and 63 in the high regime (above 9.55). The remainder are indeterminate cases, of which 11 can only be classified as in either the low or middle regimes (6.46 to 6.63), and the imprecision on the second threshold is reflected in 143 observations only being classified as either in the middle or high regimes (6.9 to 9.55). The latter group is quite diverse, encompassing at its high end countries such as Ireland, Portugal and Spain and, at its low end, countries such as Guatemala, Iran and the Philippines.[17]

5. Discussion and Conclusions

Our objective has been to explore empirically the relationship between IPR protection and growth. We began by noting the importance of innovation for growth and IPR protection for innovation. We also observed that individual countries can acquire improved technologies through a variety of channels (domestic innovation, trade, FDI, licensing, imitation and piracy), and that the relative importance of these channels is likely to differ across countries, depending on their levels of development in particular. Since strengthening IPR protection will impact on these channels in different ways, its effects on growth rates may well differ across countries, depending, *inter alia*, on their levels of development. This is the broad hypothesis that we set out to investigate.

We began by estimating a linear relationship between IPR protection and growth obtaining a positive coefficient, which was just significant. Adding a quadratic term and allowing interaction between initial per capita income and IPR protection provided limited support for a non-linear relationship, which we explored further using threshold regression techniques.

Estimating thresholds based directly on the level of IPR protection yielded little of interest due to the large confidence interval found for the single significant threshold. Estimating thresholds based on initial GDP per capita proved more fruitful, and two significant thresholds were found. Our results indicate that countries with high per capita incomes are likely to grow more rapidly the stronger their IPR protection. This finding, which supports that of Thompson and Rushing, is not unexpected. These are the countries where almost all of the world's R&D is conducted and where the innovations that IPR protects are generated. By allowing for more than one threshold however, we are able to reveal patterns that Thompson and Rushing could not. Among the lower-income countries there are differences in the relationship between IPR protection and growth. IPR protection can also have a significantly positive

[17] The impression that membership of the middle regime may represent a transition period is reinforced by the observation that no country falls in this regime for all of our four sample sub-periods.

impact on growth in the very poorest countries. But for the middle-income countries no significant relationship was found.

The positive and significant relationship between IPR protection and growth in the low income countries clearly does not result from the encouragement of domestic R&D and innovation. The explanation is more likely to be that stronger IPR protection encourages imports and inward FDI from advanced countries without adversely affecting a domestic industry relying on imitation. The finding that growth in middle-income countries is not significantly affected by IPR protection, may reflect two opposing effects. The positive impact of IPR protection on growth that works indirectly through trade and inward FDI is being offset by a negative impact slowing the diffusion of knowledge and discouraging imitation. The middle-income countries in our sample are not likely to be significant innovators, but they may well have the adaptive capabilities to engage in imitation activities.

Finally, it should be emphasised that while IPR protection appears not to exhibit significant growth-enhancing effects for middle-income countries, nowhere do we find evidence that stronger IPR protection *reduces* growth. This is important because the TRIPs Agreement imposes minimum standards of IPR protection on WTO members. On this evidence at least, developing countries joining the WTO should be able to reap the broad benefits of freer trade without sacrificing growth in order to meet the accompanying TRIPs obligations.

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Appendix: Threshold Regression Models.

In a series of papers Hansen (1996, 1999 and 2000) identifies three issues that need to be addressed when employing threshold regression techniques, namely the joint estimation of the regression coefficients and the threshold value, testing for the significance of the estimated thresholds and the formation of confidence intervals around the estimated threshold. In this Appendix we discuss each of these issues briefly.

1. Estimation

The model we have above for a single threshold is given by the following,

$$GROW_{it} = \beta_j X_{jit} + \delta_1 IPR_{it} I(Q_{it} \leq \lambda_1) + \delta_2 IPR_{it} I(Q_{it} > \lambda_1) + \mu_i + v_t + u_{it}$$

where Q is the threshold variable, which in our case is either IPR protection or initial GDP. Here the observations are divided into two regimes depending on whether the threshold variable is smaller or larger than the threshold λ_1. The two regimes are distinguished by different regression slopes δ_1 and δ_2. Chan (1993) and Hansen (1999) recommend estimation of λ_1 by least squares, which involves finding the value of λ_1 that minimises the concentrated sum of squared errors. In practice this involves searching over distinct values of Q_{it} for the value of λ_1 at which the sum of squared errors is smallest. This value of λ_1 is our estimate of the threshold $\hat{\lambda}_1$. To avoid the possibility of too few observations being in any particular regime we restrict the search for λ_1 such that at least 10 percent of observations are in each regime. Once we have a value for $\hat{\lambda}_1$ it is straightforward to estimate the coefficients of the regression model.

In the case of the two regime threshold model we have the following,

$$GROW_{it} = \beta_j X_{jit} + \delta_1 IPR_{it} I(Q_{it} \leq \lambda_1) + \delta_2 IPR_{it} I(\lambda_1 \leq Q_{it} \leq \lambda_2)$$
$$+ \delta_3 IPR_{it} I(Q_{it} > \lambda_2) + \mu_i + v_t + u_{it}$$

where λ_2 is the second threshold and the thresholds are ordered so that $\lambda_1 < \lambda_2$. It is a straightforward extension to search for the values of λ_1 and λ_2 that minimise the sum of squared errors. At the same time however this can be quite expensive in terms of computation time. Chong (1994), Bai (1997) and Bai and Perron (1998) have shown however that sequential estimation is consistent, thus avoiding this computation problem. This involves fixing the first threshold at $\hat{\lambda}_1$ and searching for a second threshold assuming that the first threshold is fixed. It can be shown that the estimate of $\hat{\lambda}_2$ is asymptotically efficient, but that $\hat{\lambda}_1$ is not. This is because the estimate $\hat{\lambda}_1$ was estimated from a sum of squared errors function that was contaminated by the presence of a neglected regime. Bai (1997) suggests a refinement estimator for $\hat{\lambda}_1$, which involves fixing the second threshold at $\hat{\lambda}_2$ and searching for the first threshold, λ_1, now including the second threshold. We denote this refined estimate by $\hat{\lambda}_1^r$.

2. Testing for a Threshold

Having found a threshold it is important to determine whether it is statistically significant or not, that is, to test the null hypothesis H_0: $\delta_1 = \delta_2$. Given that the threshold λ_1 is not identified under the null hypothesis this test has a non-standard distribution and critical values cannot be read off standard distribution tables. Hansen (1996) suggests bootstrapping to simulate the asymptotic distribution of the likelihood ratio test allowing us to obtain a p-value for this test. Firstly, one estimates the model under the null (linearity) and alternative (threshold occurring at λ_1). This gives the actual value of the likelihood ratio test, (F_1),

$$F_1 = \frac{S_0 - S_1(\hat{\lambda}_1)}{\hat{\sigma}^2} \qquad \text{where} \qquad \hat{\sigma}^2 = \frac{1}{n(t-1)} S_1(\hat{\lambda}_1)$$

Then a bootstrap is created by drawing from the normal distribution of the residuals of the estimated threshold model. Hansen (2000) recommends fixing the regressors in repeated bootstrap samples. Using this generated sample, the model is estimated under the null and alternative and the likelihood ratio F_1 is obtained. This process is repeated a large number of times (in our case 1000). The bootstrap estimate of the p-value for F_1 under the null is given by the percentage of draws for which the simulated statistic F_1 exceeds the actual one.

In the case of the two threshold model we would like a test to discriminate between one and two thresholds. An approximate likelihood ratio test of one versus two thresholds is given by the following statistic,

$$F_2 = \frac{S_1(\hat{\lambda}_1) - S_2(\hat{\lambda}_2)}{\hat{\sigma}^2} \qquad \text{where} \qquad \hat{\sigma}^2 = \frac{1}{n(t-1)} S_2(\hat{\lambda}_2)$$

To obtain the p-value a bootstrap procedure is once again followed with the dependent variable $GROW_{it}$ being generated under the null hypothesis of a single threshold.

3. Confidence Intervals

Finally, once we have found a threshold that is significant we would like to classify observations in each regime with some degree of certainty. Normally the confidence interval for a parameter is found by inverting the Wald or *t* statistics, but in cases where the parameter is unidentified in a certain region Wald statistics have poorly behaved sampling statistics (Dufour, 1997). Hansen (2000) however derives the correct distribution function and provides the appropriate critical values, c(α), for the likelihood ratio statistic given by $LR_1 = n(t-1)\frac{S_1(\lambda_1) - S_1(\hat{\lambda}_1)}{S_1(\hat{\lambda}_1)}$. From Hansen (2000) the 90, 95 and 99 percent critical values are given by 5.94, 7.35 and 10.59 respectively.

In the case of the two threshold model we can construct confidence intervals for the two thresholds along similar lines using the refined estimator for λ_1, $\hat{\lambda}_1^r$ and the estimator for λ_2, $\hat{\lambda}_2$, calculating the likelihood ratio statistic separately for each threshold in the two threshold model.

Table 4: Summary Statistics

	Mean	Standard Devi n	M um	Maximum
Growth	0.01	0.03	-0.11	0.11
INITGDP	7.7	1.56	4.75	10.74
GDI	22.43	2.21	17.54	28.0
Popgrowth	0.02	0.01	-0.01	0.06
SYR15	1.45	1.16	0.06	5.74
EXPGDP	0.3	0.25	0.04	2.11
INFLATION	0.85	4.73	-0.03	64.25
IPR	2.5	0.9	0	4.52

Table 5: Correlation Matrix

	Growth	*INITGDP*	*G*	*Popgrowth*	*SYR15*	*EXPGDP*	*INFLATION*	*IPR*
Growth	1.0							
INITGDP	0.21	1.0						
GDI	0.3	0.75	1.0					
Popgrowth	-0.18	-0.72	-0.57	1.0				
SYR15	0.18	0.81	0.67	-0.65	1.0			
EXPGDP	0.24	0.21	-0.06	-0.02	0.11	1.0		
INFLATION	-0.3	-0.11	-0.08	0.08	-0.09	-0.08	1.0	
IPR	0.02	0.52	0.4	-0.45	0.58	0.02	-0.12	1.0