Three Essays on Intellectual Property Rights in Developing Countries

by
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ABSTRACT

KRISTIE N. BRIGGS: Three Essays on Intellectual Property Rights in Developing Countries
(Under the direction of Alfred J. Field, Jr.)

Developing countries today face different international policies and pressures than did the currently industrialized countries when they were in the midst of the development process. Recent external pressures on developing countries to implement intellectual property rights (IPRs) are just one example. In practice many developing countries have chosen to implement strong patent policies, despite the fact that these countries have limited capacity for innovation. Developing countries are instead better characterized as "imitators" that learn from technology transferred from innovating (industrialized) countries. Therefore, implementing IPRs would seem counterintuitive for developing countries as it restricts their ability to imitate. Despite the possible costs, many international organizations argue that developing countries do, in fact, benefit from implementing IPRs via increased trade and foreign direct investment. However, the true impact of IPR policy in developing countries remains largely unclear. This dissertation untangles some of the links between IPRs, trade, and development by focusing on a particular aspect of this issue in each of three essays.

The first essay considers how a country's choice in IPRs relates to their stage in development. The essay is novel in that it brings to light evidence that a country's choice in IPRs as it develops (the longitudinal relationship) has a distinctly different IPR-per capita GDP relationship than it has when considering the IPR choice for a variety of countries in different stages of development, but at one point in time (the cross-sectional relationship). The second essay looks at whether IPRs in developing countries stimulate high technology exports from industrialized countries. By analyzing an array of different high technology exports to developing countries, it was determined which types of high technology goods were responsive and which appeared to not be significantly effected when developing countries

strengthened domestic IPRs. The third essay explores whether stronger IPRs in developing countries will stimulate their export activity. The acquisition of IPRs in developing countries is found to have a significantly positive impact on developing country exports, suggesting a possible link between IPR policies and outward oriented development policies.

To Mom, Dad, and Jen.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

Introduction

Developing countries today face different international policies and pressures than did the currently industrialized countries when they were in the midst of the development process. Recent external pressures on developing countries to implement intellectual property rights (IPRs) are just one example. In practice many developing countries have chosen to implement strong patent policies, despite the fact that these countries have limited capacity for innovation. Developing countries are instead better characterized as "imitators" that learn from technology transferred from innovating (industrialized) countries. Therefore, implementing IPRs would seem counterintuitive for developing countries as it restricts their ability to imitate. Despite the possible costs, many international organizations argue that developing countries do, in fact, benefit from implementing IPRs via increased trade and foreign direct investment. However, the true impact of IPR policy in developing countries remains largely unclear. This dissertation untangles some of the links between IPRs, trade, and development by focusing on a particular aspect of this issue in each of three essays.

The first essay examines the role that a country's stage of development plays in its choice of IPRs. The essay is novel in that it brings to light evidence that a country's choice in IPRs as it develops (the longitudinal relationship) has a distinctly different IPR-per capita GDP relationship than it has when considering the IPR choice for a variety of countries in different stages of development, but at one point in time (the cross-sectional relationship). Past empirical observations on a panel of countries over time have found a U-shape relationship between IPRs and per capita GDP and taken it to imply a longitudinal U-relationship within countries. A longitudinal U-shape, however, does not correspond to historical observation; countries generally maintain or increase IPRs over time and demonstrate a similar trend as they progress through stages of development. This paper argues that the well known U-shape relationship between IPRs and per capita GDP is instead a result of cross country differences originating in the year that each country first chooses to implement IPRs. Distinguishing between the longitudinal and cross-sectional relationship between IPRs and per capita GDP will enable researchers to accurately estimate and interpret the effects of IPRs when using panel data.

The second essay examines how developed-country exports of high technology goods to developing countries are stimulated by IPRs in developing countries. One argument for implementing strong IPRs in developing countries is that they attract greater high technology exports from industrialized countries, which should consequently lead to economic growth. Past empirical observation using an aggregate of high technology goods, however, has suggested that bilateral exports of high technology goods is not impacted by the level of IPRs in the importing country. A disaggregated analysis of high technology goods provides a more precise insight into which high technology goods developed countries export in the presence of stronger developing country IPRs. The impact of developing country IPRs on high technology exports from developed countries is contingent on a combination of variables such as production and adaptation costs and whether innovations in the high technology group can readily be used in domestic production processes. Innovations in high technology groups such as potassic fertilizers, synthetic yarn, and artificial fibers are arguably very pertinent to production in developing countries that specialize in agricultural and textile production. Therefore, the markup in price for these high technology innovations is relatively high. In addition, marginal production and adaptation costs of innovated goods in these categories are expectedly low. The combination of high markups and low marginal costs result in a dominant market power effect when developing countries increase IPRs, indicating that an increase in IPRs does not increase developed country exports of these goods. On the other hand, industrialized high technology exports that have relatively higher production and adaptation costs (such as electrical machinery and apparatus) exhibit a dominant market expansion effect. In this latter case, stronger IPRs in developing countries lead to an increased receipt of high technology goods from industrialized countries.

The third essay examines the impact that patent policies have on export activity in developing countries. Outward looking development policies centered on export promotion have become increasingly popular strategies for stimulating economic growth in developing countries. At the same time, many developing countries have adopted IPRs in recent years, often upon the suggestion of industrialized countries and international organizations. This paper explores the possible link between export promotion and IPR policies by examining the impact that patent policies have on export activity in developing countries.

Chapter 2

Intellectual Property Rights and Development: A Longitudinal vs. Cross Sectional Study

2.1 Introduction

This paper examines the role that a country's stage of development plays in its choice of intellectual property rights (IPRs). Past empirical observations on a panel of countries over time have found a U-shape relationship between IPRs and per capita GDP and taken it to imply a longitudinal U-relationship within countries. A longitudinal U-shape, however, is counterfactual. Countries generally maintain or increase IPRs over time and, therefore, expectedly demonstrate a similar trend as they progress through stages of development. This paper argues that the well known U-shape is a result of cross country differences originating in the year that each country first chooses to implement IPRs, rather than a result of a longitudinal trend. To summarize, the conjecture of this paper is two-fold. First, the longitudinal relationship between IPRs and per capita GDP is monotonically increasing (rather than U-shaped). Second, a U-shape relationship between IPRs and per capita GDP exists cross-sectionally, when a variety of countries in different stages of development are examined at one point in time.

A longitudinal U-shape relationship between IPRs and per capita GDP would mean that

IPRs initially decrease and later increase as per capita GDP increases in a given country. The downward portion of a longitudinal U relationship is generally not obtained as countries generally do not actively weaken IPRs, barring a regime change or other alteration in their political economy. The longitudinal U conclusion was largely drawn from the results of panel data. Although longitudinal extrapolations of panel data are common, they are not always valid. The significant non-monotonic link empirically discovered using panel data is a result of cross sectional influences, not longitudinal influences. Interpretation of a cross-sectional U-shape relationship between IPRs and per capita GDP would mean that, in a given year, least developed countries exhibit stronger IPRs than middle-income developing countries, while high-income countries again exhibit strong IPRs.

The cross-sectional U-shape between IPRs and per capita GDP can be attributed to cross country differences in IPRs in the year IPRs were first implemented. In the year that countries first implemented IPRs, the least developed countries implement stronger patent rights, partially because these countries are the most vulnerable to international pressures to do so. Middle-income developing countries exercise more autonomy, however, and implement weaker patent rights that enable them to greater utilize imitation as a pathway for growth. Finally, when high-income countries first implement IPRs they implement relatively strong IPRs as they have innovation related incentives to do so.

This paper contributes to the IPR literature by making a distinction between the longitudinal and cross-sectional relationship between IPRs and per capita GDP, and by demonstrating that the U-shape relationship observed in panel data is a result of cross sectional differences in countries at different stages of development. Establishing this will enable researchers to accurately estimate and interpret the effects of IPRs when using panel data.

2.2 Review of Literature

Three key contributions to the literature on the U-shape relationship between IPRs and per capita income include Maskus (2000), Chen and Puttitanun (2005), and Primo

Braga, Fink, and Sepulveda (2000).[1] In addition, Ginarte and Park (1997) made ancillary contributions.

Ginarte and Park introduced their IPR index in 1997. In the same article, they examined the characteristics that influenced a country's choice in IPRs. Ginarte and Park concluded that a country's level of per capita income, research and development (*R&D*), political freedom, openness to trade, and secondary school enrollment rates together determine a country's choice in IPRs. While Ginarte and Park concluded a country's stage in development significantly impacts its choice of IPRs, they did not consider the possibility of a U-shape relationship.[2] Efforts to pinpoint the exact relationship between these two variables has since emerged.

Maskus (2000) empirically observed a U-shape link between per capita income and IPRs. He came to this conclusion in two separate analysis. He found this U-shape link in an expansion of his work with Penubarti (1995) using a 1984 cross-section of countries and the Rapp and Rozek IPR Index, as well as in analysis using the Ginarte and Park IPR Index for a panel of countries in 1985 and 1990. The U-shape link remained significant even when Maskus expanded the IPR regression equation to include independent variables such as *R&D* expenditures as a proportion of GDP, secondary school enrollment, political freedom, openness to trade, and market freedom. (These results can be found in Appendix *A*.1.) While Maskus empirically observed the U-shape, and interpreted it longitudinally to explain a country's choice in IPRs as it develops, he did not provide a theoretical explanation for the U-shape.

Chen and Puttitanun (2005) provided the first theoretical explanation for the U-shape relationship between IPRs and per capita GDP by using a game theoretic approach to model a country's choice of optimal IPRs. (This model will be outlined in detail in the next section.) They then tested their theory using a panel of 62 *developing* countries for the years 1985, 1990, 1995, and 2000. Chen and Puttitanun concluded that countries in

[1] Most analysis of the U-shape has been explored using panel data for many countries over a series of years, while some has been strictly cross sectional analysis.

[2] The data used by Ginarte and Park include a panel of 48 developed and developing countries for the time periods 1965, 1975, 1985, and 1990.

the earliest stages of development implement higher IPRs to attract foreign technologies so that they can imitate and grow. As a country gains access to foreign technologies, however, stronger IPRs actually hinder its ability to imitate. As a result, Chen and Puttitanun argue that these countries decrease the strength of IPRs so they can utilize imitation to foster technological advancement. Once a certain level of development is reached,[3] countries are capable of obtaining benefits from domestic innovation and therefore begin to strengthen their IPRs.[4] Chen and Puttitanun's theoretical argument for the U-shape is examined thoroughly in the next section, as this paper suggests a revised longitudinal model for the IPR-per capita GDP relationship.

In Chen and Puttitanun's empirical estimation, they incorporate a two-stage regression in their evaluation of the U relationship where they estimate IPRs in the first stage and then estimate innovation as a function of IPRs in the second stage.[5] (This paper alternatively argues that per capita GDP *directly* influences IPRs.) Chen and Puttitanun ultimately found that there is a significant U-shape link between IPRs and per capita GDP.

Primo Braga, Fink, and Sepulveda (2000) consider the relationship between IPRs and per capita GDP for a cross section of countries in the year 1975. Although the U-shape is not a primary focus, the Primo Braga, Fink, and Sepulveda paper is important for a couple of reasons. First, it finds a statistically significant relationship between IPRs and per capita GDP using a strictly cross-sectional analysis for the year 1975. This is an important result as it provides preliminary evidence that the U-shape configuration captured by panel data could actually be driven by the cross-sectional variation. Secondly, in discussion unrelated to the U-shape, Primo Braga, Fink, and Sepulveda claim that one determinant of IPRs in developing countries is the international pressures they feel from more industrialized

[3] Chen and Puttitanun use development and technological advancement interchangeably in their model.

[4] Chen and Puttitanun argue that even developing countries benefit from domestic innovation, pointing out that the number of domestic patent application in 1985-1995 were particularly high in Brazil, India, South Africa, and South Korea.

[5] It should also be noted that Maskus and Penubarti (1995) also address the issue of endogeneity. Although the relationship between per capita income and the strength of IPRs is briefly examined in this paper, the purpose of the paper was to uncover the influence of IPRs on trade. Thus, the endogenous relationship accounted for by Maskus and Penubarti was that between the level of economic development and trade flows.

countries. In a similar line of thinking, this paper postulates that developing countries' vulnerability to international pressures are directly related to the cross-sectional U-shape between IPRs and per capita GDP.

Empirical results for papers discussed in this literature review found in Appendix $A.1$. Primo Braga, Fink, and Sepulveda did not provide specific results, but rather a scatter plot and the associated best-fit monotonic line.

2.3 Theoretical Model

The theoretical model explaining the U-shape link between IPRs and per capita GDP found in Chen and Puttitanun (2005) is the only theory I could locate addressing the possible relationship to date. In their model Chen and Puttitanun (CP) find support for a longitudinal U-shape link between IPRs and per capita GDP. Their model, however, considers a country's IPRs written into law and does not explicitly address how enforcement of these laws may impact perceived IPRs. The Ginarte-Park IPR index, which is most often used in empirical analysis of IPRs, includes a measure for enforcement. The suggested revised model for the longitudinal relationship between IPRs and per capita GDP explicitly considers enforcement of IPRs.

2.3.1 Chen and Puttitanun's Model

The CP theoretical model takes a game theoretic approach to finding how economic growth affects optimal IPRs. In their model, the developing (domestic) country chooses its level of IPR protection, $\beta \in [0; 1]$, where $\beta = 0$ indicates no protection and $\beta = 1$ indicates perfect protection. In addition, the parameter $\theta \in (0; 1]$ is a measure of the country's level of development such that higher levels of θ indicate greater development.

The domestic economy has two sectors, A and B. Sector A is comprised of two firms, a foreign (developed country) firm, F, and a domestic (developing country) firm, D. Sector B is comprised of two domestic firms, L and M. Each sector produces a different good and has its own individual set of consumers. In addition, each sector has one innovating firm and one imitating firm. Firms F and L are innovators in Sectors A and B, respectively, while firms D and M are imitators, respectively. Sectors A and B are linked through the shared IPRs.

In Sector A, the foreign firm sells a product of exogenous quality μ^F, which is under a patented technology. Domestic firm D may produce the good in Sector A, but with a quality level $\mu^D(\beta, \theta) = \mu_0 + \mu^F \phi(\theta)[1 - \alpha(\beta)]$ such that $\mu^D < \mu^F$ by assumption. The quality of the domestically produced good is dependent on the exogenous quality of the foreign produced good, as well as firm D's imitative abilities, represented by the parameter $\phi(\theta)$, and the limitation to imitation that results from stronger IPRs, $\alpha(\beta)$. In addition, for every θ, $0 \leq \phi(\theta) \leq 1$, $\phi'(\theta) > 0$, $\alpha'(\beta) > 0, \alpha(1) = 1$, and $0 \leq \mu_0 \leq \mu^F(1 - \phi(1))$. Countries that are more developed (as identified by higher levels of θ) have greater imitative ability. Perfect IPR protection (as identified by $\beta = 1$) results in no imitative capabilities for firm D. Finally, all firms in Sector A have a constant unit cost of $c^A \in [0, \mu_0]$.

In Sector B, firm L produces a good of quality $v(z; \theta)$, where $z(\beta; \theta) \geq 0$ represents firm L's investment in quality improvement through innovative activities. CP argue that the function z can also be interpreted as a measure of domestic innovation. For every θ, $v_z(z, \theta) > 0$, $v_z(\infty, \theta) = 0$, $v_{zz}(z, \theta) < 0$, $v_\theta(z, \theta) > 0$, and $v_{z\theta}(z; \theta) > 0$. Firm M produces a good in Sector B of quality $v^M(\beta; \theta) = v(z; \theta) - \gamma(\beta)(v(z; \theta) - v_0)$ such that $v^M(\beta; \theta) < v(z; \theta)$ by assumption. Although firm M does not have innovative capabilities, they can increase the quality of their good by imitating the variety produced by firm L. For every θ, $0 \leq v_0$, $\gamma(0) > (1/v_z(0, \theta))$, $\gamma'(\beta) > 0$, and $\gamma(1) = 1$. These assumptions also ensure that $0 < \gamma(\beta) \leq 1$, which results in a non-negative valuation of v^M. CP also assume $v_0 \equiv 0$, arguing that they do so without loss of generality. This assumption leaves the quality of firm M's good equal to imitation-dependent fraction of firm L's variety $v^M(\beta; \theta) = v(z; \theta)(1 - \gamma(\beta))$. Finally, all firms in Sector B have a constant unit cost of $c^B \equiv 0$.

Each sector has its own individual set of consumers. In Sector A, there is a continuum of consumers of measure 1. Each consumer in A assigns a value to one unit of the good in A that is equal to the quality of that good. Since each consumer values only one unit of the good, additional units receive a valuation of zero. In Sector B, there is a continuum of consumers of measure $N > 0$. Each consumer in B assigns a value to one unit of the good that is equal to the quality of that good. Again, since each consumer values only one unit of the good, additional units receive a valuation of zero.

All consumers have identical preferences, such that a consumer's utility from consuming a good equals the quality of the good minus its price, or

$U = \mu - p$

where μ is the value the consumer assigns to the good (which is equivalent to the quality of that good) and p is its price. This functional form for consumer utility ultimately ensures the result that consumers will always purchase the high quality good in equilibrium. (This fact will be discussed in more detail below.)

In CP's model, the game is as follows: In the first stage, the domestic government chooses the level of IPRs, β. In the second stage, firm L chooses research and development expenditures, z, which is a proxy for the level of domestic innovation. After β and z are chosen, the product qualities are simultaneously determined. In the third stage of the game, firms F and D simultaneously choose prices for their good in market A. Similarly, firms L and M simultaneously choose prices for their good in market B. In the final stage, production by firms and purchases by consumers are carried out. Backward induction allows the subgame perfect equilibria to be solved.

Given β and $z > 0$, each firm chooses its price by maximizing profits subject to the constraint that consumers' utility from consumption of their good exceeds consumers' utility from consumption of the competing firm's good in that sector. Since both the low and high quality firms in each sector face identical unit costs to production, the low quality firms will drive prices as low as possible to try and achieve a differential between quality and price that exceeds that of the high quality firm, and therefore "win" the consumer. Thus, the low quality firm will push prices down so that the price of its good exactly equals its marginal cost. Given that firm D is the low quality firm in Sector A and firm M is the low quality firm in Sector B, the equilibrium prices in these firms are as follows:

$$p^D = c^A;$$
$$p^M = c^B.$$

The profit maximizing prices of firms F and L are similarly determined by each firm maximizing its profits subject to the constraint that consumers' utility from consuming their good exceeds that of consuming their competitor's good. Equilibrium prices for firms F and L are as follows:

$$\begin{aligned} p^F =& \mu^F - \mu^D + p^D \\ =& \mu^F - \mu_0 - \mu^F \phi(\theta)[1 - \alpha(\beta)] + c^A; \end{aligned}$$

$$\begin{aligned} p^L =& v(z;\theta) - v^M(\beta;\theta) + c^B \\ =& v(z;\theta) - v(z;\theta)(1 - \gamma(\beta)) + c^B \\ =& v(z;\theta)\gamma(\beta) + c^B \end{aligned}$$

CP assume that if consumers are indifferent between purchasing from firm F or D in Sector A and firm L or M in Sector B, they will choose to buy the respective goods from firms F and L. Even though equilibrium prices are higher in firms F and firm L, purchasing from these higher quality firms yields greater (or equal) utility for consumers. It follows that all consumers purchase from firm F in Sector A and firm L in Sector B.

In the next subgame, firm L chooses z, innovation (as proxied by *R&D* expenditures), such that profits are maximized. Profits for firm L are defined as follows:

$$\begin{aligned}\pi_L =& N[p^L - c^B] - z \\ =& N[v(z;\theta)\gamma(\beta) + c^B - c^B] - z.\end{aligned}$$

Accounting for the possible corner solution of $z = 0$,[6] the profit maximization equation implies that the optimal level of z satisfies $N\gamma(\beta)v_z - 1 \leq 0$. However, when $z > 0$, $N\gamma(\beta)v_z - 1 = 0$. Recall the assumption that $\gamma(0) > (1/v_z(0,\theta))$, which implies that $\gamma(0)v_z(0,\theta) > 1$. This implication violates the Kuhn-Tucker first order condition in which the optimal $z(\beta;\theta)$ satisfies $N\gamma(\beta)v_z - 1 \leq 0$. Therefore, it can be concluded that $z > 0$ and $N\gamma(\beta)v_z - 1 = 0$.

Applying the implicit function theorem (IFT) on the first order condition $N\gamma(\beta)v_z - 1 = 0$ shows how the optimal level of innovation, z, will respond to changes in IPRs, β, and the level of development, θ. If H is defined by the first order condition for z such that $H = N\gamma(\beta)v_z - 1$, then

$$z_\beta(\beta;\theta) = -\frac{\frac{\partial H}{\partial \beta}}{\frac{\partial H}{\partial z}} = -\frac{N\gamma'(\beta)v_z}{N\gamma(\beta)v_{zz}} > 0;$$

$$z_\theta(\beta;\theta) = -\frac{\frac{\partial H}{\partial \theta}}{\frac{\partial H}{\partial z}} = -\frac{N\gamma(\beta)v_{z\theta}}{N\gamma(\beta)v_{zz}} > 0.$$

While the above application of the IFT is not related to the IPR-per capita GDP relationship of primary concern for this paper, it does provide an important ancillary result; that the optimal level of domestic innovation increases both as the level of IPRs increase and as the country develops.

In the last stage of the game in CP's theoretical model, the domestic government chooses the level of IPRs, β, that maximizes domestic social welfare. Social welfare in this case

[6]Therefore, profits are maximized subject to $z \geq 0$.

consists of consumer surplus in Sectors A and B, as well as producer surplus in Sector B. (Producer surplus in Sector A is not included in domestic welfare since the foreign firm produces the good in Sector A.)

$$
\begin{aligned}
\textit{Domestic Social Welfare (CP's Model)} =& CS^F + CS^L + PS^L \\
=& (\mu^F - p^F) + N(\mu^L - p^L) + N(p^L - c^B) - z \\
=& \mu^F - p^F + N\mu^L - z \\
=& \mu_0 + \mu^F \phi(\theta)[1 - \alpha(\beta)] + Nv(z; \theta) - z
\end{aligned} \tag{2.1}
$$

where $z(\beta; \theta)$.

Maximizing domestic social welfare in CP's theoretical model with respect to β yields a unique, interior solution for the optimal β (such that $0 < \beta < 1$) characterized by the below first order condition:

$$\mu^F \phi(\theta)\alpha'(\beta(\theta)) = [Nv_z(z(\beta(\theta); \theta); \theta) - 1]z_\beta(\beta(\theta); \theta). \tag{2.2}$$

The left and right hand sides of equation (2.2) are the marginal cost and marginal benefit to increasing β, respectively. (According to CP, the marginal cost of increasing β is the cost associated with a country's decreased ability to imitate the competing firm's good. The marginal benefit of increasing β refers to the benefits to the domestic economy from increased innovation.) Notice that marginal benefits of increasing β are always non-negative. This can be shown by combining two facts: (1) $0 < \gamma(\beta) \leq 1$ and (2) the optimal z satisfies $N\gamma(\beta)v_z - 1 = 0$. This means that $Nv_z = \frac{1}{\gamma(\beta)}$, which implies that $Nv_z > 1$. When this fact along with $z_\beta > 0$ (as previously determined) is applied to the marginal benefit term in equation (2.2), we can conclude that $[Nv_z z - 1]z_\beta > 0$.

By this stage in the model, all the tools are available to evaluate the key relationship between IPRs and development. More specifically, the IFT can be applied to equation (2.2) to determine how the optimal β will respond to changes in θ. Given that the partial derivative of equation (2.2) with respect to β is always negative (since β in the above equation is the maximum β by definition), CP conclude that the sign of $\beta'(\theta)$ will take the same sign as the partial derivative of equation (2.2) with respect to θ. In other words, CP find that

$$\beta'(\theta) \begin{cases} > 0 \text{ if } \mu^F \phi'(\theta)\alpha'(\beta(\theta)) < [Nv_z(z(\beta(\theta);\theta);\theta) - 1]z_{\beta\theta}(\beta(\theta);\theta); \\ < 0 \text{ if } \mu^F \phi'(\theta)\alpha'(\beta(\theta)) > [Nv_z(z(\beta(\theta);\theta);\theta) - 1]z_{\beta\theta}(\beta(\theta);\theta). \end{cases} \tag{2.3}$$

where $\mu^F \phi'(\theta)\alpha'(\beta(\theta))$ represents the effect of a marginal increase in θ on the marginal cost of increasing β and $[Nv_z(z(\beta(\theta);\theta);\theta) - 1]z_{\beta\theta}(\beta(\theta);\theta)$ represents the effect of a marginal increase in θ on the marginal benefit of increasing β. More generally, the results in (2.3) imply that there exists a time when increases in per capita GDP, as embodied by θ, will cause a country's choice in optimal IPRs, as embodied by β, to fall. CP conclude that this result provides theoretical justification for the downward portion of the U-shape relationship empirically observed between IPRs and per capita GDP.

Now that CP's theoretical model of the relationship between IPRs and per capita GDP has been presented, a revised longitudinal theory will be proposed.

2.3.2 A Revised Longitudinal Theory

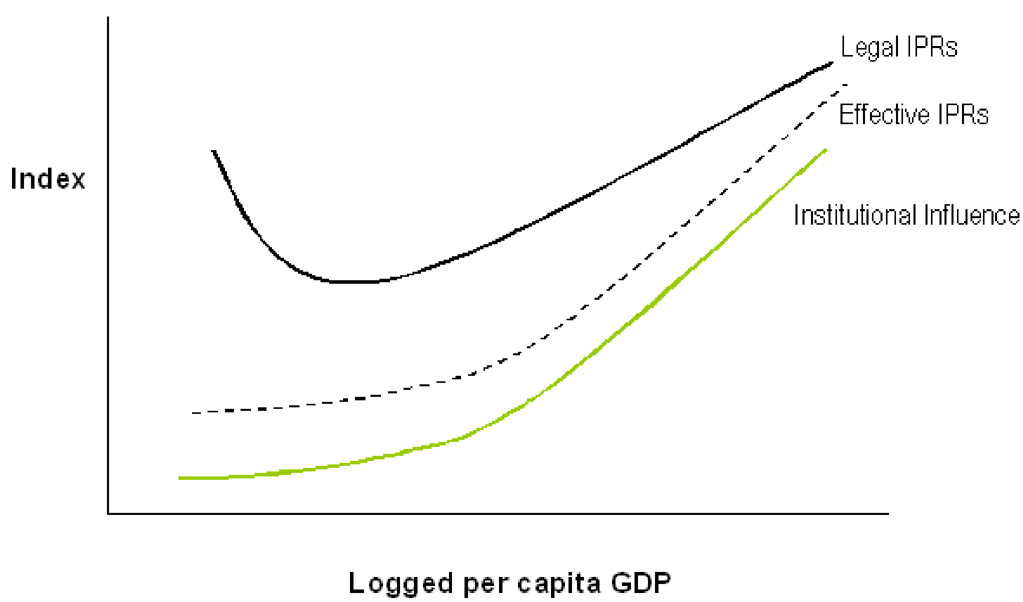
While CP present an interesting explanation for a U-shape link between IPRs and per capita GDP, the β that they optimize in their model represents a country's optimal choice in IPRs as it should be written into law. They assume that these "legal IPRs" are enforced. The effectiveness of these "legal IPRs," however, is dependent on the institutional environment. If institutions are relatively weak, IP protection likely will not be maintained and corresponding IP laws not effectively enforced.[7] Although the optimal level of legal IPRs

[7] The Ginarte-Park Index of IPRs used in empirical estimation later in this paper accounts for enforceability of patent laws. Although the index does not measure enforceability via institutional quality, the end result is nonetheless an index of enforced IPRs. This index will be discussed in greater detail in the next section.

may decrease for the least developed countries, as suggested by CP, the level of effectively enforced IPRs, or "effective IPRs," is monotonically increasing. The positive relationship between institutional quality and per capita GDP has been presented by individuals such as North (1990), Hall and Jones (1999), and Acemoglu, Johnson, and Robinson (2001).

Institutional quality is therefore assumed to be positively related to a country's level of economic development. In addition, the effectiveness of IPRs depends on the quality of institutions in a country. More specifically, "effective IPRs" in a country are a linear combination of institutional quality and "legal IPRs." This is demonstrated in Figure 2.1. So long as the positive influence of institutional improvement on IPRs exceeds any net imitative marginal benefit from decreasing IPRs as a country develops, the optimal level of effective IPRs will always increase as a country develops.

Figure 2.1: Legal vs. Effective IPRs



Let $\beta \in [0, 1]$ represent legal IPRs in Figure 2.1 and embody the characteristics previously outlined by CP. In addition, consider a measure of institutional influence $\psi \in [0, 1]$ such that stronger institutions correspond to larger values of ψ. In other words $\psi = 0$ means that a country has no institutional influence and no laws on the books are effective. A value of

$\psi = 1$ means there is perfect institutional quality and all laws on the books are completely effective. As previously stated, institutional quality will increase as a country develops. This suggests that $\psi'(\theta) > 0$. It is also assumed that $|\beta'(\theta)| < |\psi'(\theta)|$, indicating that an increase in per capita GDP will have a greater marginal impact on improving institutional influence in a country than it will have on changing the optimal level of legal IPRs.[8] The functional form for the linear combination demonstrated in Figure 2.1 is represented by $\frac{\beta+\psi}{2}$ such that $0 \leq \frac{\beta+\psi}{2} \leq 1$ captures effective IPRs.

Distinguishing between legal IPRs and effective IPRs, as outlined above, lends to a theoretical model that is similar in structure to that of CP. Structural differences arise in the quality of the domestically produced goods, as quality is now dependent not only on the legal IPRs but also on the institutional influences that impact the effectiveness of these IPRs. More specifically, in Sector A, firm F continues to supply a good of quality μ^F while the quality of firm D's good is $\mu^D(\frac{\beta+\psi}{2}, \theta) = \mu_0 + \mu^F \phi(\theta)[1 - \alpha(\frac{\beta+\psi}{2})]$. The limitation to imitation that results from stronger IPRs is now captured by $\alpha(\beta - \psi)$ such that $\alpha_\beta > 0$, $\alpha_\psi > 0$, $\alpha'(\frac{\beta+\psi}{2}) > 0$, $0 \leq \alpha(\frac{\beta+\psi}{2}) \leq 0$, $\alpha(1) = 1$, and $0 \leq \mu_0 \leq \mu^F(1-\phi(1))$. A combination of perfect IPR protection and perfectly effective IP laws (as identified by $\beta = 1$ and $\psi = 1$) results in no imitative capabilities for firm D. Finally, as in CP, all firms in Sector A have a constant unit cost of $c^A \in [0, \mu_0]$.

In Sector B, firm L now produces a good of quality $v(z;\theta)$, where $z(\beta - \psi;\theta) \geq 0$ represents firm L's quality improvement through innovation. Firm M produces a good in Sector B of quality $v^M(\frac{\beta+\psi}{2};\theta) = v(z;\theta) - \gamma(\frac{\beta+\psi}{2})(v(z;\theta) - v_0)$ such that for every θ, $0 \leq v_0$, $\gamma(0) > (1/v_z(0,\theta))$, $\gamma_\beta > 0$, $\gamma_\psi > 0$, $\gamma'(\frac{\beta+\psi}{2}) > 0$ and $\gamma(1) = 1$. These assumptions ensure that $0 < \gamma(\frac{\beta+\psi}{2}) \leq 1$, which results in a non-negative valuation of v^M. As in the CP model,

[8] This assumption is only critical during the downward sloping portion of the legal IPR curve. It should be noted that much of the literature on institutions and development has considered the impact of institutional quality on development. The rates of influence given this direction of causality have been examined. (See Acemoglu, Johnson, and Robinson (2001), Rodrik and Subramanian (2003), and Rodrik, Subramanian, and Trebbi (2004).) While the reverse causality is often recognized (see Rodrik and Subramanian, 2003), estimations of the degree or rate of this effect remain to be explored. Validating the assumption that an increase in per capita GDP will have a greater marginal impact on improving institutional influence in a country than it will have on changing the optimal level of legal IPRs will require a more in depth exploration of the impact of development on institutions so that a comparison can be made with the impact of development on legal IPRs. For the purposes of this paper, this inequality will be assumed.

it is again assumed that $v_0 \equiv 0$ and constant unit costs $c^B \equiv 0$.

The four stages of the game remain the same as those in CP's model: (1) the domestic government chooses legal IPRs, (2) firm L chooses domestic $R\&D$ expenditures, (3) all firms set prices, and (4) production and consumption is carried out in both sectors. Consider the first stage for a moment, in which the domestic government chooses legal IPRs as embodied by β. The government chooses legal IPRs given a set of ideologies regarding the decision. These ideologies may or may not be borne out in practice. Laws are not always written to correspond to what will necessarily happen, but rather because of what the government's ideologies are for making the law. This line of reasoning supports the idea that countries respond to international pressures to implementing IPRs, which will be discussed later in the paper. For the purposes of the current theoretical model, however, it is assumed that the government's choice in legal IPRs reflects their ideologies for implementing the law and does not necessarily depend on whether the law can and/or will be enforced. Therefore, the government still chooses legal IPRs that ideally maximize social welfare (rather than choosing effective IPRs).

Given these alterations, the prices set by firms in Stage 3 mirror those found by CP in their functional form based on product qualities. Specifically,

$$Sector\,A \begin{cases} p^D = & c^A \\ p^F = & \mu^F - \mu_0 - \mu^F \phi(\theta)[1 - \alpha(\frac{\beta+\psi}{2})] + c^A \end{cases}$$
$$Sector\,B \begin{cases} p^M = & c^B; \\ p^L = & v(z;\theta)\gamma(\frac{\beta+\psi}{2}) + c^B. \end{cases}$$

The same is true for firm L's choice in $R\&D$ expenditures in Stage 2. In the revised model, the optimal level of $R\&D$ expenditures satisfies the first order condition $N\gamma(\frac{\beta+\psi}{2})v_z - 1 = 0$.

Defining $H = N\gamma(\frac{\beta+\psi}{2})v_z - 1$, and applying the IFT lends to the following:

$$z_\beta(\beta, \psi, \theta) = -\frac{\frac{\partial H}{\partial \beta}}{\frac{\partial H}{\partial z}} = -\frac{N\gamma_\beta(\frac{\beta+\psi}{2})v_z}{N\gamma(\frac{\beta+\psi}{2})v_{zz}} > 0;$$

$$z_\theta(\beta,\psi,\theta) = -\frac{\frac{\partial H}{\partial \theta}}{\frac{\partial H}{\partial z}} = -\frac{N\gamma(\frac{\beta+\psi}{2})v_{z\theta}}{N\gamma(\frac{\beta+\psi}{2})v_{zz}} > 0;$$

$$z_\psi(\beta,\psi,\theta) = -\frac{\frac{\partial H}{\partial \psi}}{\frac{\partial H}{\partial z}} = -\frac{N\gamma_\psi(\frac{\beta+\psi}{2})v_{z}}{N\gamma(\frac{\beta+\psi}{2})v_{zz}} > 0.$$

Only the result $z_\psi(\beta,\psi,\theta) > 0$ is new. It indicates that, as expected, innovation will be lower the weaker a country's institutional quality.

Domestic social welfare now accounts for the institutional influence on legal IPRs.

$$\textit{Domestic Social Welfare (Revised Model)} = \mu_0 + \mu^F\phi(\theta)[1-\alpha(\frac{\beta+\psi}{2})] + Nv(z;\theta) - z \tag{2.4}$$

where $z(\frac{\beta+\psi}{2};\theta)$. The domestic government chooses legal IPRs to maximize domestic social welfare as represented in (2.4). The optimal level of IPRs satisfies

$$-\mu^F\phi(\theta)\alpha_\beta(\frac{\beta+\psi}{2}) + [Nv_z(z(\frac{\beta+\psi}{2};\theta);\theta)-1]z_\beta(\frac{\beta+\psi}{2};\theta) = 0. \tag{2.5}$$

where $\beta(\theta)$ and $\psi(\theta)$. In (2.5), $\mu^F\phi(\theta)\alpha_\beta(\frac{\beta+\psi}{2})$ represents the marginal cost to social welfare of increasing β and $[Nv_z(z(\frac{\beta+\psi}{2};\theta);\theta)-1]z_\beta(\frac{\beta+\psi}{2};\theta)$ represents the marginal benefit to social welfare of increasing β.

The relationship of primary interest is how the optimal level of effective IPRs (or $\frac{\beta+\psi}{2}$) changes as a country develops (or θ increases). Equation (2.6) embodies this effect. Notice that the effect of an increase in per capita GDP on effective IPRs can be broken into two components: (1) the effect of an increase in per capita GDP on legal IPRs and (2) the effect of an increase in per capita GDP on institutional quality.

$$\begin{aligned}\frac{d(\frac{\beta+\psi}{2})}{d\theta} =& \frac{\partial(\frac{\beta+\psi}{2})}{\partial\beta}\cdot\frac{d\beta}{d\theta}+\frac{\partial(\frac{\beta+\psi}{2})}{\partial\psi}\cdot\frac{d\psi}{d\theta} \\ =& \frac{1}{2}\cdot\frac{d\beta}{d\theta}+\frac{1}{2}\cdot\frac{d\psi}{d\theta}\end{aligned} \tag{2.6}$$

Since $|\beta'(\theta)| < |\psi'(\theta)|$ the effective level of IPRs is monotonically increasing as a country develops even when the optimal legal level of IPRs is decreasing.

2.4 Linking Theory and Empirical Analysis

The revised theory provides a theoretical rationale for a monotonically increasing relationship between effective IPRs and per capita GDP. The next step is to focus on empirical analysis of the longitudinal relationship between IPRs and per capita GDP. Before doing so, a few comments should be made about the empirical analysis in this paper compared to that of CP. Both this paper and CP's paper use the Ginarte and Park IPR Index to approximate a country's level of IPRs. Given the opposing theories captured in Figure 2.1, it is natural to ask whether the Ginarte and Park IPR Index best captures legal IPRs or effective IPRs. In order to answer this question, let's first examine the Ginarte and Park IPR Index in more detail.

2.4.1 The Ginarte-Park IPR Index

When empirically analyzing intellectual property rights, two indices for the strength of patent systems have commonly been used. In 1990, Rapp and Rozek developed an IPR index based on how closely a country's patent policies mirror those embodied by US patent laws. In 1997, Ginarte and Park introduced a broader index of patent strength. Specifically, the Ginarte-Park (GP) Index accounts for; (1) coverage, (2) membership in international treaties, (3) loss of protection, (4) enforcement, and (5) duration of protection. Since its introduction, the GP Index is the more common index of choice when conducting empirical

IPR analysis.[9] This is because the GP Index embodies a greater number of countries and years, and considers a greater scope of categories in its construction (which lends to a more precise estimate).

This paper utilizes an updated version of the GP Index that contains data for 121 countries at five-year intervals between 1960 and 2000.[10] A detailed description of the construction of the index, as outlined in Ginarte and Park (1997), can be found in Appendix $A.2$. However, further analysis of the enforcement component of the GP Index provides insight as to whether the measure is best approximating legal IPRs or effective IPRs in the above theories.

The enforcement component of the GP index generates a dummy variable based on whether the country (1) implements preliminary injunctions to protect the patentee until a final decision about infringement is made by the courts, (2) protects against third party induced infringement, and (3) implements burden-of-proof reversals to place the burden of proving "innocence" on the individual doing the alleged infringement rather than the patentee. It is important to justify whether or not this enforcement component is sufficient in capturing the *effective* level of enforcement of IPRs in these countries. If it does, then the GP Index measures effective IPRs in a country.

In fact, there is recent evidence to suggest that the GP Index does capture countries' effectively enforced level of IPRs. This support is provided in a recent comparison between the GP Index and a newly developed IPR rating created by the World Economic Forum. The World Economic Forum released an IPR rating in their 2000 Annual Global Competitiveness Report (GCR) that was based on surveys of opinions and experiences of firms and individuals in an array of countries.[11] Thus, the GCR Index provides information about *perceived* IPRs,

[9] For example, this is true in Maskus (2000), Schneider (2004), and Chen and Puttitanun (2005).

[10] I would like to thank Professor Walter Park for providing me with the updated index. Note that IPR data is available for 1960, 1965, 1970, 1975, 1980, 1985, 1990, 1995, and 2000.

[11] The IPR index found in the Global Competitiveness Report does not provide historical data, given that it is based on a collection of survey and opinion data.

which implicitly includes their effective enforcement.[12] Comparison of the two indices in the one year (2000) for which overlapping data is available reveals that the GCR rating and the GP Index are strikingly similar. In fact, the indices have a positive correlation of approximately 0.8.[13] This comparison suggests that there is little difference between perceived IPRs in these countries and the level of IPRs reported by GP, thereby providing support that the GP Index approximates effective IPRs.

If the GP Index best captures effective IPRs, then why did CP find a statistically significant U-shape link between the GP IPR Index and per capita GDP in their empirical analysis? The first answer to this question lies in the fact that the GP Index is an approximation of effective IPRs, meaning that some errors likely exist in the index's representation of effective IPRs. Secondly, regional influences on the longitudinal relationship between IPRs and per capita GDP are carefully examined in this paper and prove to play an important role in IPR choice. These regional influences were not included in CP's analysis.

The next section explores the longitudinal relationship, first by focusing on time series data and then by applying what has been observed in the time series data so to better analyze the longitudinal relationship between IPRs and per capital GDP using the entire panel data set.

2.5 Exploring the Longitudinal Data

In general, IPRs for a given country remain the same or increase over time barring any regime shift or other change in a country's political economy. Only 14 out of 121 countries show any decrease in the GP Index over time.[14] In addition, only India exhibited a decrease in IPRs at a point in time when their per capita GDP was at or below the critical US$785 level, which was found to be the level of per capita GDP that corresponds with the minimum

[12]The GCR Index includes patents as well as other varieties of IPRs such as copyrights and trademarks.

[13]Economic Freedom of the World: 2001 Annual Report; Chapter 4.

[14]Bolivia, Brazil, Colombia, Costa Rica, Ecuador, Germany, Guatemala, Honduras, India, Malaysia, Mexico, Netherlands, Nicaragua, Peru.

level of IPRs in a preliminary quadratic regression. (See Table A.2 in Appendix *A*.1.) The majority of countries that demonstrate a decrease in their IPR index are middle-income developing or already developed countries. This is an important point given that previous theories postulate that it is the *least* developed countries that decrease IPRs as they grow. Finally, ten of the fourteen countries with a decrease in IPRs over time are located in Latin America. This fact suggests that there may be a regional effect coming into play between IPRs and per capita GDP that may impact Latin American countries differently than the rest of the world.[15]

Given the fact that only 14 out of 121 countries ever show a decrease in IPRs over time, it can be concluded that, in general, IPRs within countries remain the same or increase over time. Since economic development is embodied by increases in per capita income over time, the strength of IPRs for a given country would expectedly remain the same or increase as a country develops. Time series regressions on each country largely reject the longitudinal U-shape proposed in past literature. Time series analysis is conducted even though a complete set of time series data contains only eight data points, which is small and lends to questionable asymptotic properties in estimation. In order to address the problems brought about by the small sample size in time-series analysis, a longitudinal relationship between IPRs and per capita GDP is later examined using the entire panel data set.

When time series regressions are run on the 102 countries that have a complete set of time series data,[16] only 24 countries[17] report a significant quadratic relationship between IPRs

[15]Such regional influences may implicitly appear in the theoretical model via the institutional quality variable. Institutional quality and institutional structure may vary between regions, resulting an a regional impact in empirical analysis. It is also possible that there are region-wide changes in the political economy for which a decrease in IPRs may result. Political economy "shocks" are not introduced into the theoretical model, but they do provide an intuitive caveat for stable or increasing IPRs as a country develops. This caveat will be emphasized throughout the paper. Nonetheless, there is not an explicit account of regional influences in the theoretical model. Therefore, the significance of regional effects found in the empirical longitudinal exploration explain more than what is presented in the theoretical model.

[16]A complete set of time series data would be data for 1965, 1970, 1975, 1980, 1985, 1990, 1995 and 2000 as a result of limitations in the GP Index and per capita GDP data. Countries with less than the maximum number of time series data points (eight data points) are omitted.

[17]Australia, Austria, Bangladesh, Benin, Canada, Colombia, Costa Rica, Dominican Republic, Egypt, Greece, Guatemala, Guyana, Iceland, India, Italy, Mauritania, Nepal, New Zealand, Panama, Portugal, Sierra Leone, Singapore, Spain, and Tunisia. Note, only 101 of these 121 countries have enough data points to run time series regressions.

and logged per capita GDP at the 90 percent level. Only four countries–Bangladesh, Costa Rica, Guatemala, and Sierra Leone–indicate a quadratic relationship that is significant at the 99 percent level. The distinction in levels of significance is important as the quadratic relationship for the entire panel data set has been consistently found at the 99 percent level in past research.

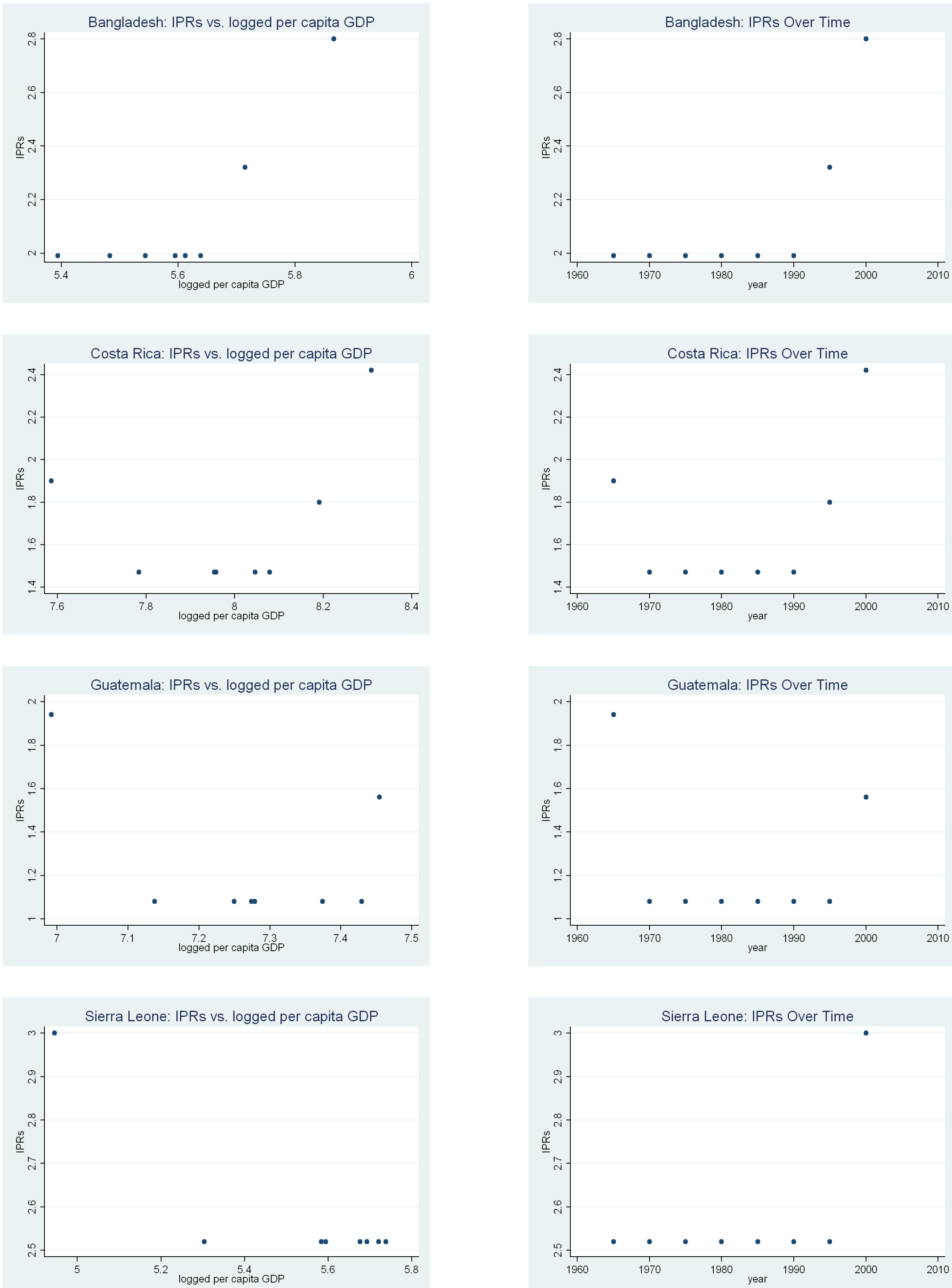
The graphical representation of these four countries indicates that only Costa Rica and Guatemala truly represent any downward swing in the strength of IPRs over *time*. Coincidentally, the decrease in IPRs in 1970 corresponds with the collapse of the Central American Common Market (CACM) of which both Costa Rica and Guatemala were members. This link is significant as the CACM established IPR guidelines for member countries. In addition, the IPR index increases in both Costa Rica and Guatemala after that CACM was reinstated in 1991. (Costa Rica shows an increase in 1995 and Guatemala in 2000.) This suggests that the downward longitudinal swing of IPRs in these countries is a consequence of a shift in the political economy rather than a consequence of development.

The graphs for Sierra Leone illustrate a curious relationship. While the strength of IPRs in Sierra Leone remains constant or increases over time, IPRs decrease with respect to per capita GDP. This suggests that per capita GDP in Sierra Leone is decreasing over time. When considering the complete data set, thirteen African countries exhibit the anomaly that per capita GDP is decreasing over time.[18] Each of these thirteen countries, however, either maintain or increase IPRs over time, but never decrease IPRs over time. This suggests that, in these countries the choice in IPRs is not necessarily driven by their stage in development. Accounting for sub-Saharan African countries in longitudinal analysis therefore becomes very important.

While time series analysis supports the claim that individual countries generally maintain or increase their IPRs as they develop, the small sample size is less than ideal. A maximum of only eight data points is available for each country to analyze the time series regression between IPRs and logged per capita GDP. As a result, methods to isolate the time-series

[18] Angola, Central African Republic, Chad, Democratic Republic of the Congo, Cote d'Ivoire, Ghana, Liberia, Madagascar, Niger, Senegal, Sierra Leone, Togo, and Zambia.

Figure 2.2: Selected Country Specific IPR Graphs



effect in the panel data provide improved asymptotic qualities of the estimators and are, therefore, worth exploring. This will be done first by looking at the IPR-per capita GDP relationship while pooling together countries with similar time series characteristics. Then, using the full panel of data, the choice in IPRs will be examined in the context of a fully specified model, where independent variables other than per capita GDP are included in the regression equation.

2.5.1 Pooled Data Analysis of the IPR-per capita GDP relationship

Most methods to isolate time effects in panel data impose a common per capita GDP slope coefficient for all countries. There are regional specific characteristics, which were discussed in the previous section, that suggest slope coefficients likely vary between certain regions. Therefore, in this study countries in regions with similar characteristics are pooled together, and slope coefficients vary between each pooled group.

To be more specific, the entire panel data set is divided into four pooled groups. The first group includes countries in the region of Latin America and the Caribbean. As previously stated, ten of the fourteen countries showing a decrease in the IPR Index over time were from this region. Therefore, the pooled group of Latin America and the Caribbean will capture the similarities in this geographical region. Countries in this region were specified using the regional classifications of the United Nations.[19]

The second pooled group includes sub-Saharan African countries. Over a third of the countries in this region exhibit a dominant downward trend in per capita GDP over time.[20] Many of these countries continue to increase IPRs despite the decrease in per capita GDP. This effect was exhibited in the graph of Sierra Leone presented in the previous section. As with the regional classification of Latin America and the Caribbean, and the United Nations' classification was used to identify countries to the sub-Saharan region. In this classification, sub-Saharan Africa is designated as all of Africa except northern Africa, with the Sudan

[19] http://unstats.un.org/unsd/methods/m49/m49regin.htm.

[20] Angola, Central African Republic, Chad, Democratic Republic of the Congo, Cote d'Ivoire, Ghana, Liberia, Madagascar, Niger, Senegal, Sierra Leone, Togo, and Zambia.

included in sub-Saharan Africa.

The third pooled group consists of those countries for which there exist only two data points: 1995 and 2000. These are mostly transitional, Eastern European economies, but also include China and Vietnam. Specifically, only two data points are available for Bulgaria, China, Czech Republic, Hungary, Lithuania, Poland, Romania, Russian Federation, Slovak Republic, Ukraine, and Vietnam. It is possible that the limited time series in these countries, as well as their sudden inclusion in 1995, at a time when IPRs were internationally on the rise, may be skewing the panel results. The fourth and final group in the pooled analysis includes all other countries not otherwise specified in one of the three previously mentioned groups.

Table 2.1: Group Classification used in Pooled Regression Analysis

Group 1	Latin America & the Carribean
Group 2	Sub-Saharan Africa
Group 3	Transitional Economies, China, & Vietnam
Group 4	All Other Countries

Note: Transitional Economies, China, & Vietnam, are countries that have a limited sample size for IPRs.

For each pooled group, an interaction term is created between per capita GDP and a dummy variable, $POOL_i$, that equals 1 for each Group $j = i$, and zero otherwise. This allows each pooled group to have a different slope coefficient. Countries within groups do not necessarily have similar intercepts, however. To account for country differences within groups, each country is given its own intercept. In addition, year fixed effects are included to capture difference between years. (Given that the estimation finds country specific intercepts, intercepts for each pooled group are omitted.)

Equation (2.7) outlines the explicit form of the described estimation procedure.

$$IPR_{kt} = \alpha_k + \alpha_t + \sum_{i=1}^{4}(\beta_i \log(\text{per capita GDP}_{it}) * POOL_i) + \sum_{i=1}^{4}(\theta_i[\log(\text{per capita GDP}_{it})]^2 * POOL_i) + \varepsilon_{kt};$$

where,

$$POOL_i \begin{cases} = 1 \text{ if Group } j = i; \\ = 0 \text{ if Group } j \neq i \end{cases} \tag{2.7}$$

where α_k is the country specific intercept term and α_t is the year specific intercept term.

Results for the pooled regression are found in Table 2.2. As shown in column I, none of the groups exhibit a significant U-shape. In fact, the coefficients on the rest of the world (Group 4) instead tell a story more along the lines of a diminishing marginal choice in the strength of IPRs as a country develops. This is particularly encouraging as Group 4 contains 382 of the 840 total observations in the pooled regression.

Overall, accounting for variation in slope coefficients for the four specified groups enables the longitudinal effects in panel data to be better isolated. The results of the pooled regressions do not provide support for a longitudinal U-shape relationship. In the next section, the longitudinal relationship between IPRs and per capita GDP will be examined in more detail by considering a fully specified choice equation for IPRs.

2.6 The Fully Specified Model

The objective of the fully specified model is to account better for the variety of factors that influence a country's choice in IPRs. A fully specified model leads itself to a more accurate longitudinal interpretation of panel data. The first step of the process is to identify a more complete list of variables that influence a country's choice in IPRs.

Table 2.2: Pooled Regression Using Panel Data

	I	II
Group 1 log(pc GDP)	0.32	0.27**
	(0.24)	(2.28)
Group 1 $[\log(\text{pc GDP})]^2$	-0.01	
	(-0.07)	
Group 2 log(pc GDP)	0.12	-0.02
	(0.28)	(-0.33)
Group 2 $[\log(\text{pc GDP})]^2$	-0.01	
	(-0.34)	
Group 3 log(pc GDP)	-0.10	0.92***
	(-0.02)	(1.68)
Group 3 $[\log(\text{pc GDP})]^2$	0.07	
	(0.25)	
Group 4 log(pc GDP)	0.49*	0.42*
	(11.50)	(33.21)
Group 4 $[\log(\text{pc GDP})]^2$	-0.01***	
	(-1.69)	
1970	0.02	0.02
	(0.60)	(0.49)
1975	0.00	-0.01
	(0.04)	(-0.26)
1980	0.10*	0.09*
	(2.61)	(2.26)
1985	0.15*	0.13*
	(3.62)	(3.32)
1990	0.15*	0.13*
	(3.62)	(3.30)
1995	0.44*	0.41*
	(8.32)	(8.55)
2000	0.79*	0.75*
	(13.33)	(14.93)
Observations	840	840
R-squared	0.9920	0.9920

Note: Group 1 is Latin America & the Caribbean with a sample size of 180. Group 2 is sub-Saharan Africa with a sample size of 256. Group 3 are economies for which IPR data is limited to two data points (this includes Eastern European Transitional Economies, China, and Vietnam) with a sample size of 22. Group 4 is the rest of the world not otherwise included in Groups 1 through 3 and has a sample size of 382. t-statistics are in parenthesis ; $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance; Standard errors are corrected using White's correction. Individual country intercepts are included in the estimation procedure, but are not reported.

2.6.1 Estimating IPRs

Numerous variables impact a country's choice in IPRs. A country's choice in IPRs may depend not only on their level of development (or per capita GDP), but also on their level of openness and institutional quality. Proxies for each of these factors are included as regressors in the IPR equation and will be discussed further in a moment. In addition, a country's choice in IPRs may vary depending on their regional association. Latin American and the Caribbean, sub-Saharan Africa, and Eastern European Transitional Economies (including China and Vietnam) are the three regions with unique links that have already been discussed.[21] Dummy variables for these regions are therefore included in the fully specified model. Finally, time fixed effects are also included so to capture variation in the IPR choice related to a certain year. To summarize, the full specification of the IPR equation is as follows:

$$\begin{aligned} IPR_{it} =& \beta_1 \log(y_{it}) + \beta_2[\log(y_{it})]^2 + \beta_3 \log(\text{openness}_{it}) \\ &+\beta_4 \log(\text{institutional quality}_{it}) + \beta_5 \text{Latin}_i + \beta_6 \text{Africa}_i + \beta_7 \text{Transitional}_i + \varepsilon_{it}. \end{aligned} \tag{2.8}$$

Openness

The impact of openness to trade on a country's level of IPRs is ambiguous. It is possible that the more open a country is to trade, the stronger IPRs will be in order to entice high technology goods. On the other hand, greater openness may occur in hopes of imitating high technology goods, which would result in expectedly weak IPRs.

A country's level of openness to trade depends on such things as tariffs, quotas, and exchange controls. However, it is difficult to measure openness in a way that is not endogenous with per capita GDP. The "Freedom to Trade Internationally" Index mitigates the possibility of endogeneity. "Freedom to Trade Internationally" is a subindex included in the

[21] China and Vietnam are included in regional classification for Transitional Economies as all these countries are limited to two data points in the GP IPR Index.

Fraser Institute's *Economic Freedom of the World* Index (to be discussed in more detail in the below section on institutional quality). "Freedom to Trade Internationally" is estimated using equally weighted data on the following five areas: (1) taxes on international trade, (2) regulatory trade barriers such as non-tariff barriers, (3) the actual size of the trade sector compared to expected trade sector, (4) the difference between the official exchange rate and the black market rate, and (5) international capital market controls. Thus, this measure of openness captures many desirable aspects that are often difficult to quantify without using per capita GDP.

Institutional Quality

Institutional quality is a term used to describe a country's ability to sustain sound economic practices given their economic and political environment. Institutional quality is sometimes approximated using a broad measure for economic freedom. This has been the case in past literature analyzing IPRs.

There are two widely used indices of economic freedom: (1) The *Economic Freedom of the World* Index created by the Fraser Institute, and (2) The *Index of Economic Freedom* created by the Heritage Foundation and the Wall Street Journal. Chen and Puttitanun (2005) used the former in their previous research into the U-shape. The *Economic Freedom of the World* Index accounts for five different factors: (1) size of government as measured by expenditures, taxes, and enterprizes, (2) legal structure and security of property rights, (3) access to sound money, (4) freedom to trade internationally, and (5) regulation of credit, labor, and business.[22] The index ranges from zero to ten, with ten embodying complete economic freedom. Beginning in 1995 a measure for intellectual property right protection was included in the calculations of group 2. Therefore, using the *Economic Freedom of the World* Index as a regressor in my estimation equation would be erroneous.

In addition to having a limited data range (with data available only beginning in 1996), the Heritage Foundation's *Index of Economic Freedom* also perpetuates simultaneity with the IPR measure. The *Index of Economic Freedom* is comprised of ten freedoms: Busi-

[22]www.freetheworld.com.

ness, Trade, Fiscal, Freedom from Government, Monetary, Investment, Financial, Property Rights, Freedom from Corruption, and Labor Freedom. While the Heritage Foundation is not specific about what goes into their calculations for property rights, the sources they use to comprise data in this category are similar to those used in the *Economic Freedom of the World* Index. This fact is a red flag that using either of these two indices of economic freedom would bias my estimates. Using an index that, in part, measures a country's IPRs to approximate that country's IPRs violate the non-collinearity assumption among independent variables.

It is now apparent that, due to the breadth of categories included in economic freedom, such a measure will likely be correlated with a country's choice of IPRs. As a consequence, it is better to narrow the focus of institutional quality from the wide-ranging concept of economic freedom to those components of institutional quality that directly impact IPRs. These include rule of law, physical property rights, and the existence of a sound business environment.

Rule of law and physical property rights will have a clear consequence on a country's IPRs, but likely not the other way around. A country will only have incentive to implement IPRs if they know such laws will be adequately enforced and not overpowered by corruption. In addition, laws for physical property rights provide the precursor for laws for intellectual property rights. Thus stronger physical property rights suggest the onset of stronger IPRs. (Note, the direction of casualty is from physical property rights to IPRs.) Measures for rule of law and physical property rights can be calculated by removing the IPR measure from "legal structure and property rights" component of the *Economic Freedom of the World* Index.

A sound business environment supports innovation and IPR related growth.[23] Without sound business environment, firms' ability to innovate, as well as the benefits from innovation, will be stunted. Component 5 of the *Economic Freedom of the World* Index, which measures the "regulation of credit, labor, and business" effectively captures the sound busi-

[23]PCIPD recognizes the importance of a sound business environment and institutions in reaping potential benefits for strong IPRs in developing countries; PCIPD, page 4.

ness environment critical to institutional quality. Thus, the measure of institutional quality used in the empirical estimations of this paper combine rule of law, physical property rights, and business environment.

2.6.2 Endogeneity of IPRs and per capita GDP

Although the key relationship of interest is how IPRs are affected by levels of per capita GDP, the causality also works in the other direction: per capita GDP is a function of IPRs. Countries with stronger IPRs may generate more output and lead to more economic growth. Ginarte and Park (1997) acknowledge problems pertaining to simultaneity, but they did not account for it in their empirical analysis. Although Chen and Puttitanun (2005) do incorporate a two-stage regression in their evaluation of the U relationship, they estimate IPRs in the first stage and then estimate innovation as a function of IPRs in the second stage.

Since CP model innovation to be dependent on income levels, their endogenous relationship is similar to the simultaneity of IPRs and income used in this paper. However, the two-stage model CP used does not account for *all* the possible effects that IPRs could have on income. Intellectual property protection in a country not only impacts domestic innovation, but also affects things such as the country's attractiveness to foreign companies. A direct endogenous relationship between income and IPRs is therefore considered in this paper.

In the case of simultaneous equations, the IPR equation will be estimated using a two-stage least squares, instrumental variables approach. The next step, then, is to identify the estimating equation for the included endogenous variable, per capita GDP.

2.6.3 Estimating per capita GDP

Per capita GDP in a given period depends upon physical capital, population, human capital, and the level of intellectual property rights. Greater levels of physical and human capital would expectedly lead to higher levels of output. Similarly, countries with stronger IPRs may generate more output and lead to more economic growth. Population, on the other hand, expectedly has a negative relationship with per capita GDP. This relationship between per capita GDP and the mentioned explanatory variables can be captured in a traditional Cobb-Douglas production function as demonstrated below.

$$Y_{it} = A_{it} K_{it}^{\alpha_1} Pop_{it}^{\alpha_2} H_{it}^{\alpha_3} e^{\gamma IPR_{it}}$$

or

$$y_{it} = \frac{Y_{it}}{Pop_{it}} = \frac{A_{it} K_{it}^{\alpha_1} Pop_{it}^{\alpha_2} H_{it}^{\alpha_3} e^{\gamma IPR_{it}}}{Pop_{it}}$$

or

$$\log(y_{it}) = \log A_{it} + \alpha_1 \log K_{it} + (\alpha_2 - 1) \log Pop_{it} + \alpha_3 \log H_{it} + \gamma IPR_{it} + \varepsilon_{it} \qquad (2.9)$$

where Y_{it} = output for country i at time t;

Pop_{it} = Population;

K_{it} = Physical capital stock;

y_{it} = per capita GDP;

H_{it} = Human capital as approximated by tertiary school enrollment rates

IPR_{it} = Index of IPR strength.

In the two-stage estimation, human capital is approximated by tertiary school enrollment rates. Data on tertiary school enrollment rates is available on the UNESCO web site.[24] IPR strength is approximated by the GP IPR Index discussed previously. Data on per capita GDP (in constant 2000 US dollars) and total population are obtained from the World Bank's World Development Indicators (WDI).

[24] Recent data on tertiary school enrollment rates is available on UNESCO's main web site. Historical data on school enrollment is available at http://www.uis.unesco.org/en/stats/statistics/indicators/i_pages/indic_5.htm.

Data on physical capital stock between 1960 and 1990 is available from Nehru and Dhareshwar (1995). This data is provided in the domestic country's currency in constant 1987 prices. In order to make cross-country comparisons of capital stock, the Nehru and Dhareshwar data was converted into constant 1987 US dollars by using the average period market exchange rate obtained from the IMF's *International Financial Statistics* database. In addition, capital stock for the years since 1990 (for which Nehru and Dhareshwar data is unavailable) was estimated using gross capital formation data as provided by the World Bank's WDI database.

Expanding the Capital Stock

Data on gross capital formation in constant local currency units is available from the World Bank's online WDI database. The first step in expanding the capital stock data is to convert gross capital formation into constant 1987 US dollars by using the GDP deflator.[25] The GDP deflator was obtained from the WDI database. After compatible data on gross capital formation was calculated, the capital stock was expanded using the following equation for the evolution of capital stock:

$$K_{i,t+1} = K_{i,t}(1 - \delta_i) + \text{Gross Capital Formation}_{i,t+1}$$

where δ_i represents the average capital depreciation rate specific to each country. This country specific capital depreciation rate corresponds to the ten-year average rate of capital depreciation in a specific country for the years 1981 to 1990 (i.e. the last ten years for which capital stock data from Nehru and Dhareshwar was available). This ten year average was calculated using capital stock data from Nehru and Dhareshwar (1995) and gross capital formation from the WDI database.

2.6.4 Specification of the System of Equations

The complete specification of the system of equations is as follows:

[25] The base year in local currency units varies across countries.

$$\begin{aligned}\text{IPR Choice}: IPR_{it} =& \beta_1 \log(y_{it}) + \beta_2[\log(y_{it})]^2 + \beta_3 \log(\text{openness}_{it})\\ &+\beta_4 \log(\text{institutional quality}_{it}) + \beta_5 \text{Latin}_i + \beta_6 \text{Africa}_i\\ &+\beta_7 \text{Transitional}_i + \varepsilon_{it}.\end{aligned}$$

$$\text{Production}: \log y_{it} = \log A_{it} + \alpha_1 \log(K_{it}) + (\alpha_2 - 1)\log(Pop_{it}) + \alpha_3 \log(H_{it}) + \gamma \text{IPR}_{it} + \mu_{it}.$$

A two stage least squares procedure is used to estimate the above equations. Since the IPR Choice equation is of primary interest to address the first hypothesis of this paper, predicted values of logged per capita output are used to estimate the IPR equation. The two stage least squares procedure is necessary because, as previously discussed, per capita GDP and IPRs are simultaneously determined. This presents a problem for estimation as per capita GDP is an endogenous variable in the IPR equation. In other words E[per capita GDP*ε_{it}] $\neq 0$ (or E[ε_{it} | per capita GDP] $\neq 0$).[26]

The condition for identification of an equation states that the number of exogenous variables excluded from the IPR equation must be at least as large as the number of endogenous variables included in the IPR equation. In this case:

$$\textit{Included endogenous variables}: \log(y_{it}), (\log(y_{it}))^2$$

$$\textit{Excluded exogenous variables}: K_{it}, Pop_{it}, H_{it}.$$

indicating that the system of simultaneous equations are over-identified. Over or exact-identification is a necessary condition for two stage least squares estimation.

The excluded exogenous variables in the per capita GDP equation serve as instruments in the two stage least squares estimation procedure. Empirical tests support the validity of physical capital stock, population, and human capital as instruments in the IPR equation[27]

[26] E[x*ε_{it}] = 0 is an assumption of OLS estimation models, which must hold in order to ensure consistency and unbiasedness of the estimators. Another way to state this identity is the E[ε | x] = 0.

[27] All equations in columns I through IV are over-identified. In addition, standard errors have been corrected

2.6.5 Empirical Results

Descriptive statistics for all variables are found in Table 2.3, while Table 2.4 presents a correlation matrix of the variables used.

Table 2.3: Descriptive Statistics

	Mean	Std. Dev.	Min	Max	N
IPR	2.48	0.93	0	5	903
log(per capita GDP)	7.47	1.60	4.03	10.71	840
log(Institutional Quality)	1.66	0.30	0.14	2.22	590
log(Openness)	1.76	0.32	0.51	2.28	656
log(Population)	15.99	1.56	11.41	20.96	886
log(Capital Stock)	25.82	4.23	20.19	49.65	655
log(Tertiary)	1.85	1.49	-2.30	4.55	716

Table 2.4: Correlation Matrix

	IPR	log(pc GDP)	log(Open)	log(Ins.Q.)	log(Pop)	log(K)	log(Ter.)
IPR	1						
log(pc GDP)	0.4802	1					
log(Inst.Qual.)	0.5112	0.5946	1				
log(Openness)	0.4159	0.5333	0.6124	1			
log(Population)	0.0168	-0.1878	-0.0656	-0.1138	1		
log(K Stock)	0.1063	0.3286	0.1825	0.1422	0.348	1	
log(Tertiary)	0.3035	0.7796	0.4523	0.4639	0.0686	0.3247	1

Table 2.5 provides the results of the two-stage estimation procedure for the fully specified model. In addition to the variables shown in Table 2.5, each regression also accounts for time fixed effects. As columns II and IV indicate, there no longer exists a U-shape relationship between IPRs and per capita GDP in the fully specified model. Also notice that while the openness and institutional quality variables are positive and statistically insignificant, including them in columns III and IV shows little change in the slope coefficients for the other variables when compared to columns I and II, respectively. This creates confidence that the signs and significance levels of the per capita GDP variables are robust.

The results indicate that the U-shape relationship between IPRs and per capita GDP is

using White's correction method. As a result, Hansen's J-statistic can be used to test the validity of the instruments. A low Hansen J-statistic indicates that you cannot reject the null hypothesis that the excluded instruments are valid (i.e. uncorrelated with the error term in the IPR equation). The J-statistics for the two-stage least squares regression in columns I through IV of Table 2.5 indicate that the null hypothesis cannot be rejected and therefore lead to the conclusion that the excluded exogenous variables in the per capita GDP equation–physical capital stock, population, and human capital–serve as valid instruments.

Table 2.5: Choice of IPRs: The Fully Specified Model
(Two-Stage Least Squares Estimation)

	I	II	III	IV
log(pc GDP)	0.38*	1.86	0.29*	1.47
	(8.98)	(0.78)	(5.27)	(0.58)
[log(pc GDP)]^2		-0.10		-0.08
		(-0.46)		(-0.62)
log(Openness)			0.18	0.15
			(1.40)	(0.96)
log(Institutions)			0.21	0.36
			(1.31)	(0.97)
sub-Saharan Africa	0.64*	0.74*	0.66*	0.74*
	(5.74)	(3.65)	(5.22)	(3.19)
Latin America	-0.51*	-0.74**	-0.56*	-0.71**
	(-7.50)	(-2.00)	(-7.43)	(-2.18)
Transitional Economies	-0.69**	-0.87**	-0.86*	-0.95*
	(-2.40)	(-2.26)	(-2.97)	(-2.84)
Constant	-0.17	-5.57	-0.52***	-5.08
	(-0.21)	(-0.84)	(-1.78)	(-0.52)
N	513	513	425	425
Uncentered R-squared	0.9439	0.9385	0.9578	0.9510

Note: The above results reflect a two-stage least squares, instrumental variables approach to account for the simultaneity between IPRs and per capita GDP. Year dummy variables are also included in the estimation procedure of each of the above regressions. The comparison group for regional effects is the "rest of the world." z-statistics are in parenthesis. $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance. Standard errors have been adjusted using White's correction.

statistically insignificant. Attention will now turn to exploring the whether a cross-sectional U-shape link exists between IPRs and per capita GDP.

2.7 A Cross-Sectional Explanation for the U-shape

If the panel data set is broken down by year into eight different cross-sectional data sets (one for 1965, 1970,..., 1995, 2000), the simple IPR-per capita GDP regression consistently demonstrates the U-shape configuration. (See Table 2.6.) In each year there exists a statistically significant cross-sectional U.[28] At the very least, this empirical result supports the *possibility* that cross-sectional influences are driving the simple U-shape observed in past literature between IPRs and per capita GDP in panel data.

Table 2.6: Cross Section of IPRs for Each Available Year

	1965	1970	1975	1980	1985	1990	1995	2000
log(pc GDP)	-1.14*	-1.60*	-1.70*	-2.17*	-1.67**	-1.86*	-1.42*	-1.02**
	(-2.63)	(-3.76)	(-4.56)	(-4.35)	(-2.36)	(-2.95)	(-3.05)	(-2.53)
log(pc GDP)^2	0.09*	0.12*	0.12*	0.16*	0.13*	0.14*	0.11*	0.08*
	(3.04)	(4.22)	(4.97)	(4.91)	(2.84)	(3.47)	(3.79)	(3.24)
constant	5.68*	7.37*	7.81*	9.39*	7.49*	8.28*	6.83*	5.88*
	(3.66)	(4.80)	(5.86)	(5.03)	(2.77)	(3.42)	(3.81)	(3.81)
N	91	96	100	104	106	106	119	118
R^2	0.2125	0.2648	0.2720	0.3391	0.3021	0.3244	0.3814	0.3465

Note: t-statistics are in parenthesis. $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance. Standard errors have been adjusted using White's correction.

Examining the best fit quadratic line for each cross-sectional regression reveals that the U-shape is similar in each case. This is particularly true for the years 1965, 1970, 1975, 1980, 1985, and 1990, for which the best fit U-shape line are close to overlapping, with a slight shift to the right in up in each subsequent period. This trend satisfies the previous notion that once countries have IPRs in place they either maintain them or increase them as they develop, indicating that any existing cross-sectional U-shape should exhibit a shift

[28]Each cross-section was also tested including the regional dummy variables found to be important in the longitudinal analysis. The squared per capita GDP term remains positive and statistically significant in 6 of the 8 cross-sectional years. The results for the cross-sectional years including regional dummy variables can be found in Appendix *A*.5.

right and up over time. The cross-sectional U for 1995 and 2000 are distinct as they exhibit a minimum IPR point that is much higher than those in previous years.

Now that it has been shown that in year cross-sectional year a U-shape relationship between IPRs and per capita GDP is statistically significant, the next step is to address whether the U-shape relationship is logical for a cross section of countries. It is postulated that the rationale for a cross-sectional U lies partially in the fact that countries respond differently to international pressures to implement strong IPRs. This postulate will be explored in greater detail in the next sections.

2.7.1 The Role of International Pressure in IPR Choice

Historically there has been tremendous pressure for developing countries, even the least developed countries, to implement policies that protect intellectual property. The large number of international arrangements to strengthen IPRs exemplifies this pressure. One of the first international standards for patent protection occurred at the Paris Convention in 1883. Since that time, many developed countries have pushed hard for a new, robust international code. This is exemplified by the numerous treaties administered by the World Intellectual Property Right Organization (WIPO), an agency of the United Nations.[29] However, nothing illustrates the movement towards universally strong IPRs more than the Trade Related Aspects of Intellectual Property Rights (TRIPS) Agreement that came into existence after the General Agreement on Tariffs and Trade (GATT) 1986 to 1994 Uruguay Round.[30] The TRIPS Agreement outlines detailed procedures for implementing and enforcing various types of intellectual property rights.

Regardless of such agreements from international organizations it remains up to each country to formulate and enforce their own domestic policies on IPRs. Developed countries have been systematically quicker than developing countries at establishing the IPR regimes outlined in international agreements such as the Paris Convention and TRIPS. In many

[29]WIPO has administered 24 treaties related to intellectual property rights.

[30]The World Trade Organization (WTO) is the successor to the GATT and is largely established by the rules and regulations determined during the Uruguay Round. The TRIPS Agreement is now maintained under the WTO.

cases, the quality of institutions in developing countries has slowed the implementation of recommended IPR regulations. In addition, the incentives for implementing strong IPRs are less apparent for developing countries that traditionally rely on imitation rather than innovation to stimulate growth.

Political Economy Support

The political economy literature on intellectual property rights supports the assertion that developing countries experience pressures from developed countries to put in place strong patent policies in line with those outlined in international agreements. Perez Pugatch (2004) addresses the possible reasons why developing countries, which are assumed to have weak innovative capabilities, would adopt strong IPR regimes. He considers the possibility that developing countries may benefit from increased trade in intellectual property-related goods and increased technology transfer, but concludes that the justification of these arguments is weak and problematic.[31] Instead, Perez Pugatch concludes that the political reason that developing countries adopt strong IPR regimes is to avoid trade retaliation from developed countries that desire strong international IPR codes.

Industrialized countries have clear incentives for wanting universally strong IPRs as they expand their range of secure market access. Perfect international intellectual property protection would mean that the patentee possessed worldwide monopoly power over production and trade of the patented good. According to Perez Pugatch, "(a) country with strong IP capabilities will benefit from entering an international IP system as it essentially becomes an exporter of IP products. This in turn will improve its terms of trade and will increase its national income."[32] Since most innovation is conducted by industrialized economies, developed countries have consequently pressured developing countries to implement strong IPR regimes.

Developing countries may find the social cost to abstaining from a strong international IPR code to be high, as refusal to comply may result in trade retaliation from developed

[31] Perez Pugatch, page 72.

[32] Perez Pugatch, page 49.

countries with strong IPR capabilities. Perez Pugatch (2004) makes the following claim.

> ...(A) political economy oriented explanation...suggests that trade retaliation may be considered an important factor in the decisions of countries (mostly, but not only, those countries with weak IP capabilities) to support a stronger IP agenda. It is based on the assumption that the threat of trade retaliation may significantly affect the way in which countries, particularly those that are linked to the economies of countries with strong IP legislation, assess the costs and benefits of joining an international IP system. Most important is the potential loss of trade revenues that a country may face due to trade retaliation. (page 65)

Such trade retaliation was visibly effective in the case of Switzerland, which implemented national patent legislation in 1888 largely as a result of pressures from Germany. Switzerland later expanded its patent coverage in 1907 to include processes, after Germany announced it would raise import duties on Swiss coal-tar dyestuffs if the Swiss patent law was not amended (Perez Pugatch 2004; Penrose 1951).

The United States and European Community are often believed to have used trade retaliation during the Uruguay Round to force developing countries such as Argentina, Brazil, South Korea, and India to implement national patent policies agreed upon under the GATT/WTO (which were later embodied by the TRIPS Agreement).[33] Credible threats included (1) denying developing countries access to the General System of Preferences and (2) using section 337 of the US Tariff Act of 1930 and section 301 of the Trade Act of 1974 to allow the United States to take punitive action against imports from countries that the United States believed violated IPRs (Perez Pugatch 2004; Treibilcock and Howse 1995). Brazil and South Korea experienced pressures via US claims of section 301 violation of patent protected pharmaceutical products. Implementation and amendment of patent legislation in these countries was the ultimate result.

In conclusion, there is support in the political economy literature that developing countries have adopted strong national IPR regimes as a result of hegemonic pressures from the large industrialized countries. Nonetheless, it is unfair to suggest that developing countries receive no direct benefit from strengthening their IPR regimes. Instead, it is likely that

[33] Perez Pugatch (2004); as cited in Gadbaw and Richards (1988); Abbott (1989); and Emmert (1990).

developing countries choose IPR strength based on some combination of international pressures as well as in hopes that an IPR regime will stimulate growth. Briggs (2008a) explores whether stronger IPRs in developing countries stimulate their export activity. The acquisition of IPRs in developing countries was found to have a significantly positive impact on developing country exports, suggesting a possible link between IPR policies and outward oriented development policies.

Although the benefit of strong IPR regimes in developing countries via trade and technology transfer appears ambiguous,[34] there is an undeniable faction that advocates that strong IPRs stimulate economic development. In fact, the *Permanent Committee on Cooperation for Development Related to Intellectual Property* (PCIPD) is a branch of WIPO dedicated solely to educating developing countries on how appropriate adoption and implementation of IPRs can fuel growth. PCIPD proposes that implementing strong IPRs concurrently with policies to modernize infrastructure and implement sound business, academic, and institutional environments can increase developing countries' ability to "acquir(e) technology, creat(e) intellectual property assets and generat(e) income and employment."[35] Countries that were most hopeful (or desperate!) to achieve such benefits may have been more willing to yield to pressures from the developed world to implement strong IPRs.

The International Vulnerability Hypothesis for the Cross-Sectional U

From the above discussion, the U-shaped link between IPRs and per capita GDP can be explained as a consequence of cross sectional forces rather than longitudinal forces. These cross sectional outcomes are generated as a result of developing countries' varied responses to international pressures to adopt strong IPR regimes in the presence of domestic vulnerability to trade retaliation.[36] Given the dependence of the poorest countries on the

[34] Technology transfer is embodied in FDI, licensing, and joint ventures.

[35] World Intellectual Property Organization; Permanent Committee on Cooperation for Development Related to Intellectual Property. "Overview of Policy Directions, Priority Areas and Projects in WIPO's Support of the Development Objectives of Developing Countries." Fourth Session, Geneva, April 14 and 15, 2005.

[36] The vulnerability to trade retaliation is captured later in empirical analysis by taking into account the value of a country's exports to developed countries.

international community, these countries were the least resistant to pressures to implement IPR regimes. In addition, the poorest countries were also the most hopeful that strong IPRs would stimulate growth, thereby putting in place relatively stronger IPR regimes.

Countries with slightly higher per capita levels of income were better able to stand up against international pressures and implemented relatively weak IPR regimes that they feel better suited their desires and ability to imitate. These mid-range developing countries may have had a less dismal outlook on their country's ability to develop on its own and, as a result, had incentives to maintain some autonomy in their decision making about IPRs. As a result, one would expect IPRs in middle-income developing countries to be slightly weaker.

This variability in response to differing degrees of vulnerability as well as international pressures to implement strong IPRs is a possible explanation for the downward portion of the U-shape in a cross section of countries for a given period in time. Given greater innovative activity in industrializing and developing countries, these countries choose to adopt increasingly strong IPRs to correspond with domestic innovative activities. From this point forward, the hypothesis that the cross-sectional U-shape between IPRs and per capita GDP is a consequence of countries' varied responses to pressure and vulnerability to implement strong IPRs will be referred to as the "International Vulnerability Hypothesis."

Testing the International Vulnerability Hypothesis

The next step is to test empirically the International Vulnerability Hypothesis as the driving factor in the cross-sectional U-shape. In doing so, it is important to isolate the IPR-per capita GDP pair corresponding to a country's "first" choice in IPRs. Due to inconsistencies in data on the year countries implemented their first IP law, it is assumed that a country "first" chooses to implement IPRs in the year that it joined the first international IPR agreement – the Paris Convention. The Paris Convention took place in 1883, with membership beginning in 1884. The Paris Convention set in place the first minimum standard for patent protection.[37]

Data on the year each country decided to participate in the Paris Convention is provided on the WIPO's web site.[38] For example, the United Kingdom agreed to the Paris Convention contract in 1884, the United States in 1887, Argentina in 1967, and Botswana in 1998. The critical IPR-per capita GDP pairs for each country correspond to those years. Due to data limitations on per capita GDP, which is available beginning in 1965, critical data pairs corresponding to years prior to 1965 are approximated by using 1965 data point (i.e. the first available year). In addition, data limitations on the GP Index, which is available every five years beginning in 1960, means that data points must be rounded up to the closest 5th year. For example, although Argentina agreed to the Paris Convention in 1967, the critical data point for Argentina corresponds to the IPR-per capita GDP pair in 1970. Similarly, although Botswana agreed to the Paris Convention in 1998, the critical data point for Botswana corresponds to the IPR-per capita GDP pair in 2000. A list of all critical IPR-per capita GDP pairs can be found in Appendix $A.4$.[39] A summary of the number of observations in each critical year can be found in Table 2.7.

The resulting data set is comprised of IPR-per capita GDP pairs that approximate the onset of a country's commitment to the international patent standards. The year in which countries' responded to the call to join the Paris Convention was two-fold. First, there were those countries that initially advocated for the Paris Convention and joined at its implementation. Advocating countries were largely European nations with strong political relationships to countries in other regions as a result of colonial ties. Non-European and

[37]Once a country decides to participate in the Paris Convention and becomes an active member in an international intellectual property agreement, it is expected to maintain the minimum standards outlined by the Convention. Article 25 of the Paris Convention states that, in order to be a participating member, a country party must take action at the domestic level to ensure the implementation and enforcement of the rules and regulations outlined by the constitution agreed upon in the Paris Convention. Once IPR laws are in place they often time intensive and costly to reverse. Therefore, once a country agrees to participate in the Paris Convention it is counterintuitive to expect that it would actively weaken its IPRs (banning any major institutional or revolutionary regime shift).

[38]http://wipo.int/treaties/en/ip/paris/

[39]Nepal, Pakistan, and Saudi Arabia have critical pairs after 2000. As a result, the critical pair is rounded down to 2000 so to keep the sample size as large as possible. (Data for IPRs is not available for 2005, so rounding up would omit these country data point.)

Table 2.7: Composition of the Critical Cross-Section of Years

Year	No. of Entries
1965	50
1970	6
1975	2
1980	5
1985	3
1990	1
1995	17
2000	13

non-colony countries may not have felt such a strong push to enter into an international IP agreement, especially if there was little domestic innovation to make the benefits obvious. Instead, these countries' willingness to comply with continuing international pressures to join the Paris Convention and implement IPRs was, in part, related to their vulnerability to pressures to join. Although this vulnerability could take various forms, fear of trade retaliation is the form best supported by the political economy literature.

Independent variables are included to test the vulnerability of countries to participate in the Paris Convention, as outlined by the International Vulnerability Hypothesis. To mirror the story of vulnerability, two regressors will be included in the estimating equation. First, a dummy variable is created for European countries and countries with close colonial ties to the United Kingdom. This variable captures those countries that likely the most vulnerable to agree to a universal IP code from the movement's onset. Use of this dummy variable is validated by the fact that all 22 non-transitional European countries in the data set have the critical IPR-per capita GDP pair in the first available year, 1965, as do 14 of 33 (or 42 percent of) countries with colonial ties to the United Kingdom. This variable is labeled *Euro & UKC* in the below tables.

The second regressor looks at the vulnerability felt by non-European and non-UK colony countries to implement strong IPRs as a consequence of their reliance on trade with industrialized countries. The greater a country's exports to developed countries as a percent of GDP, the more dependent that country is on stable trade relations for growth and, therefore, the more vulnerable that country is to pressures from industrialized countries. In order to capture this "vulnerability" to trade retaliation, a second regressor is included that measures non-European and non-UK colony country exports (as a percent of total GDP) to industrialized countries.[40] Bilateral export data for this variable was obtained from the United Nations Commodity Trade Database and converted into constant 2000 $US using Consumer Price Index available from the World Bank's World Development Indicators (WDI). GDP in constant 2000 $US was also obtained from WDI. This dummy variable is labeled *log(X to Dev)* in the below tables.

Multicollinearity exists between the two measures of vulnerability, *Euro & UKC* and *log(X to Dev)*. This is because the first variable is a dummy for European and UK colonies, while the second variable considers exports in non-European and non-UK colonized countries. Two empirical tests support the existence of multicollinearity. First, there is an 88 percent pairwise correlation between the two variables. Second, the variance inflation factor approaches eight when both variables are included in the estimating equation, also signalling possible multicollinearity. As the second test suggests, the problem with multicollinearity between regressors is that it inflates the standard errors of the guilty regressors, thereby causing the t-statistic to be artificially low. This can often lead to insignificance in variables that would otherwise yield statistical significance. A common way of dealing with multicollinearity in regressors is to omit one of the variables. Thus, empirical results testing the International Vulnerability Hypothesis are preferred when only one of "vulnerability" regressors is included in the estimation process.

Results for the critical cross section are found in Table 2.8. An OLS regression both with and without time trends supports that this critical cross section possesses the U-shape relationship between IPRs and logged per capita GDP that is in question. In addition, in the absence of multicollinearity there is a statistically positive impact for both the Europe and Colony Dummy and the measure of exports to industrialized countries by non-Europe and non-colony countries. These results indicate that the vulnerability measures are statistically

[40] Industrialized countries were classified as such by using the World Bank's high-income criteria of per capita GNI of $10,726 in 2005.

significant and positive in influencing a country's choice in IPRs in the year that they first decide to implement IPRs (as approximated by the year they join the Paris Convention).

Notice that the U-shape relationship between IPRs and per capita GDP remains statistically significant throughout columns III through VI. This suggests that, while a country's vulnerability to implement strong IPRs significantly impacts their choice in IPRs, vulnerability is only a piece of the puzzle. Accounting for vulnerability is not enough to explain the entire per capita GDP U-shape in the critical cross-section of years.[41]

In addition, the positive sign on the year dummy variables suggests that the choice in IPRs is generally greater in a given year compared to the IPR choice in 1965 than can be explained by a country's level of per capita GDP or international vulnerability. While the positive coefficient is not always significant, this sign suggests that IPR choice is generally greater in the years to follow 1965. The year 1970 is one consistent exception, as the coefficient for this year is negative, but not statistically significant.

Before continuing further, a few additional notes about the data used to estimate the results in Table 2.8 should be made. Papua New Guinea and Mozambique both have an IPR index of zero in the critical year. This result is clearly a discrepancy between the WIPO data and the GP Index, which states that membership in the international Paris Convention treaty is a contributory element of the index.[42] Given the discrepancies in the data, it is assumed that computational errors exist for these countries and therefore data points are omitted from the analysis of the International Vulnerability Hypothesis. In addition, with an IPR index of 0.33, Indonesia is a strong outlier in the data set, thereby biasing the results. This fact is exemplified in the below box plot.[43] As a result, Indonesia is omitted form the

[41]If the vulnerability measure did explain the entire U-shape, the coefficients on per capita GDP and per capita GDP squared would expectedly be insignificant.

[42]Mozambique and Papua New Guinea have a GP Index value of zero for all years.

[43]A box plot is a visual tool used to identify outliers. The rectangular portion of the box plot represents the inter-quartile range (from the lower quartile, Q1, to the upper quartile, Q3). The line in the middle of the box represents the median point. Points that lie more than 1.5 times the inter quartile range below Q1 or 1.5 times the inter quartile range above Q3 are considered to be outliers. These points are identified as dots that fall beyond the "whiskers" of the box plot.

Table 2.8: Critical Cross Sectional IPR Decision

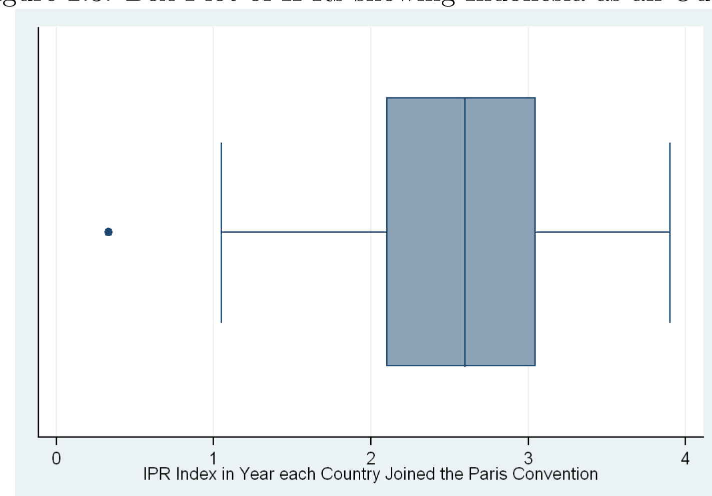
	I	II	III	IV	V	VI
log(pc GDP)	-0.84**	-0.79**	-0.72**	-0.69**	-1.15**	-1.06**
	(-2.52)	(-2.39)	(-2.16)	(-2.10)	(-2.34)	(-2.13)
$[\log(\text{pc GDP})]^2$	0.06*	0.06*	0.05**	0.05**	0.08*	0.08**
	(2.79)	(2.73)	(2.33)	(2.35)	(2.53)	(2.41)
Euro & UKC			0.25**	0.23***		
			(2.00)	(1.79)		
log(X to Dev)					0.06**	0.05***
					(2.49)	(1.73)
1970		-0.08		-0.01		-0.13
		(-0.32)		(-0.03)		(-0.62)
1975		0.02		-0.00		0.07
		(0.06)		(-0.01)		(0.16)
1980		0.50*		0.46*		0.53*
		(4.04)		(2.92)		(2.67)
1985		0.62**		0.63*		0.64***
		(2.31)		(2.97)		(1.68)
1990		0.24**		0.12		0.24***
		(2.42)		(1.08)		(1.88)
1995		0.22		0.23		0.25
		(0.38)		(1.65)		(1.53)
2000		0.08		0.08		0.10
		(0.38)		(0.36)		(0.40)
constant	5.16*	4.78*	4.74*	4.41*	6.44*	5.86*
	(4.51)	(0.38)	(4.11)	(3.94)	(3.69)	(3.22)
N	97	97	97	97	74	74
R^2	0.13000	0.2048	0.1697	0.2375	0.2795	0.3542

Note: Euro & UKC= dummy variable = 1 if the country is in the Europe Region or has colonial ties to the United Kingdom. log(X to Dev) is the logged value of exports to developed countries for all non-European and non-UK colony countries. The comparison year for the year dummies is 1965. t-statistics are in parenthesis. $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance. These results exclude Indonesia, Papua New Guinea, and Mozambique. Standard errors are corrected using White's correction.

analysis as well.[44]

The fitted lines in the scatter plot of the critical cross section of countries, as shown in Figure 2.4 and Figure 2.5, take the general form of the fitted lines in the scatter plot for the entire panel data set, as shown in Figure 2.6. In addition, the minimum value in the cross sectional critical values is approximately US$665 (in constant 2000 US$), which is comparable to the minimum value of US$785 in the entire panel data set.

Figure 2.3: Box Plot of IPRs showing Indonesia as an Outlier



The data restrictions on per capita GDP and IPR pairs generate a possible problem in evaluating the critical values that make-up the International Vulnerability Hypothesis' cross-sectional U-shape. Recall that per capita GDP is unavailable prior to 1965. Therefore any countries who joined the Paris Convention prior to 1965 have an approximated critical IPR-per capita GDP pair at the first available year, which is 1965.[45] Such rounding is consistent with estimation for later years for countries that joined the Paris Convention on or after 1961. However, considering that the Paris Convention was instituted in 1884,[46]

[44]The Indonesia outlier is not sensitive to the year Indonesia chosen, as Indonesia has an IPR index of 0.33 for the years 1965 through 1990. Since Indonesia's critical year is 1965, the timing of the critical year would not likely effect the fact that Indonesia's critical point serves as an outlier. It should also be mentioned that, in the complete panel data set (for which all data points are used) there do not exist any outlier IPR-per capita GDP pairs. This includes Indonesia.

[45]This rounding assumption is actually consistent with approximation of the more current year for countries that joined the Paris Convention on or after 1961.

[46]Recall that the Paris Convention was agreed to in 1883, but the implementation of the Paris Convention

Figure 2.4: Scatter Plot of Critical Cross-Section when Indonesia is Included

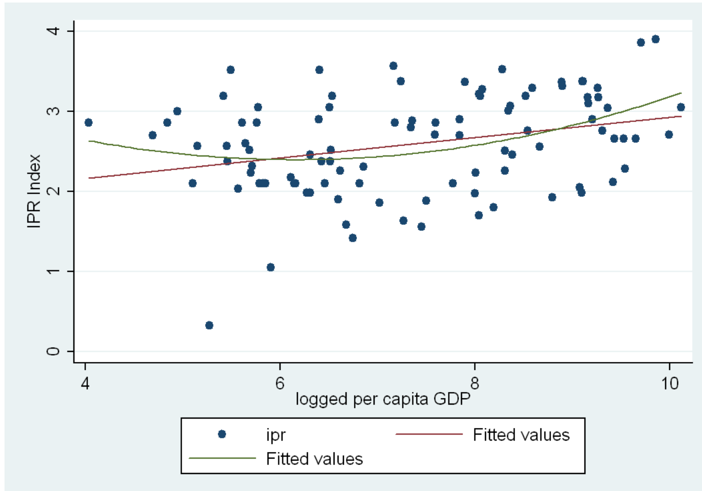


Figure 2.5: Scatter Plot of Critical Cross-Section when Indonesia is Omitted

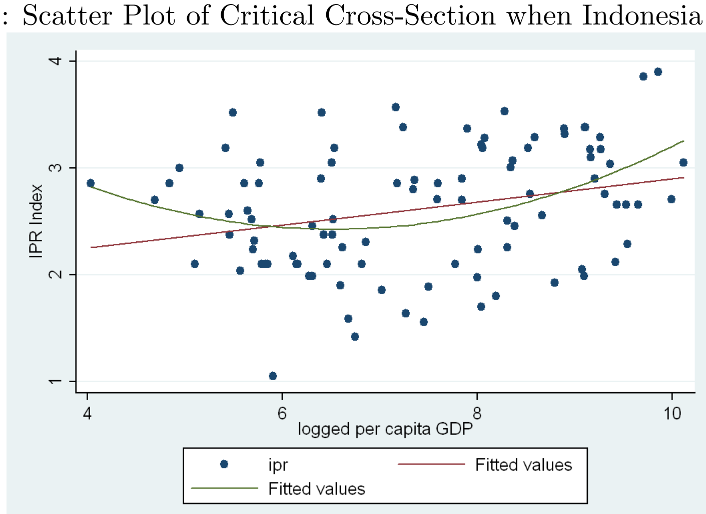
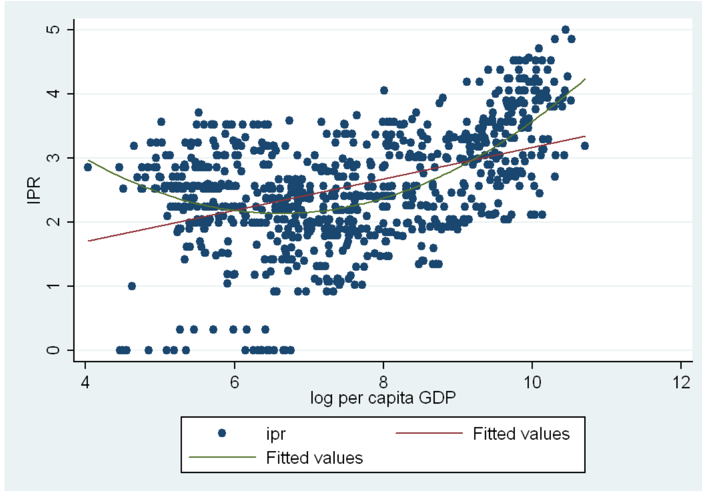


Figure 2.6: Scatter Plot of IPRs and Per Capita GDP (Panel Data)



using the 1965 pair as an approximation for the actual critical pair may generate bias if the majority of critical years occur in 1965. As we already know, the U-shape appears to exist for a cross section of countries in a given year. Therefore, we need to ensure that the critical cross section of Paris Convention years does not rely too heavily on 1965 data.

As indicated in Appendix *A*.3, 50 of the 97 countries considered use 1965 as their critical year. Thus, it is worthwhile to test the robustness of our U-shape result by adjusting for the possibility that the 1965 entries are driving this result. The immediate solution that jumps to mind is excluding countries who joined the Paris Convention between 1884 and 1961, as their critical years were subject to a rounding procedure dissimilar to the rest of the sample. Nonetheless, considering only countries that joined the Paris Convention since 1961 will exclude countries in the right portion of the U-shape that decided to participate in IPR treaties out of domestic incentives to support domestic innovation. As a result, analysis that considers just those countries that joined the Paris Convention since 1961 would result in another type of bias.

The proposed solution is to divide countries into two separate groups: (1) those who chose to join the Paris Convention immediately in 1884 and (2) those countries that joined the Paris Convention after 1884. Given the separation of countries into these two groups

occurred in 1884.

it would be sufficient to evaluate only the "critical" U using those countries who joined the Paris Convention in 1884 and those countries who joined after 1960. Even with this approach, however, the logical approximation of critical pairs for countries in 1884 is the 1965 pair as 1965 is the first year for which complete data is available.

This approach limits the possible 1965 bias. Table 2.9 shows the composition of years that makes up the critical cross section of years. Of the 28 countries with critical years in 1965, only ten countries joined the Paris Convention in 1884.[47] A total of 22 countries joined the Paris Convention between 1885 and 1960 and have been omitted from the sample. It also is intuitive that more countries experienced international pressures to join international treaties such as the Paris Convention and implement stronger IPRs in the later years (1995 and 2000) since the World Trade Organization, passed guidelines for IPRs in their Trade Related Intellectual Property Rights (TRIPS) Agreement in 1994.

Table 2.9: Composition of Critical Cross-Section: Omitting 1885-1960

Year	No. of Entries
1965	28
1970	6
1975	2
1980	5
1985	3
1990	1
1995	17
2000	13

Considering this more limited sample of countries, there still exists empirical evidence for the support of the International Vulnerability Hypothesis, as the critical cross-section of countries (again, indicated by the year that countries first joined the Paris Convention) yields a statistically significant U-shape between IPRs and per capita GDP. These results are found in Table 2.10. Also, note that the Indonesian outlier, which was present in the full sample case, is no longer an issue when the sample size is limited to countries that joined the Paris convention in 1884 or after 1960, as Indonesia joined the Paris Convention in 1950

[47] Belgium, Brazil, France, Italy, Netherlands, Portugal, Spain, Switzerland, Tunisia, and the United Kingdom.

and is, therefore, automatically omitted.

Finally, it should be noted that creation of the WTO has no underlying implications for the rational behind the International Vulnerability Hypothesis. Rather, WTO guidelines, such as the TRIPS Agreement, provide industrialized countries with more leverage for which to exert international pressure to implement strong IPR laws. Countries that wanted to join the WTO may have implemented domestic IPR policies simply to obtain positive trade benefits.

The International Vulnerability Hypothesis does not negate this possibility. In fact, developing countries' desires to join the WTO gives developed countries a better position by which they can exert their pressure and more acutely pick up factors of vulnerability. The question is whether agreeing to the implementation of stronger IPRs just to gain ancillary trade benefits will ultimately result in stronger and enforced IPRs in these countries. Since agreement to participate in international trade agreements (specifically, the Paris Convention and its revisions, the Patent Cooperation Treaty, and Protection of New Plant Varieties (UPOV)) is only a small portion of the GP Index[48] in order to be considered to have strong IPRs, according to empirical underpinnings of the GP Index, a country must have crucial components of national patent laws in place. And, as argued earlier, the GP Index does a good job at capturing the enforcement of these laws.

2.8 Conclusion

Past empirical observation of a U-shape link between IPRs and per capita GDP in panel data has lead many researchers to conclude that the optimal choice of IPRs will first decrease as a country develops before it increases. While longitudinal interpretations from panel data are common, they are not always valid. This is certainly the case for the IPR-per capita GDP relationship. A longitudinal U relationship is counter-intuitive, barring any change to a country's political economy. This paper demonstrates that when the longitudinal IPR

[48]The maximum index value obtained if a country has agreed to all three of the listed international treaties, but has not changed domestic law to outline implementation of IPRs is one. This value is much lower than the average IPR value for all countries, which is 2.46.

Table 2.10: Critical Cross Sectional IPR Decision: Omitting 1885-1960

	I	II	III	IV	V	VI
log(pc GDP)	-0.92**	-0.89**	-0.83**	-0.80**	-1.08**	-0.94***
	(-2.55)	(-2.50)	(-2.26)	(-2.29)	(-2.05)	(-1.73)
$[\log(\text{pc GDP})]^2$	0.07*	0.07*	0.06**	0.06**	0.08**	0.07***
	(2.75)	(2.77)	(2.40)	(2.49)	(2.18)	(1.96)
Euro & UKC			0.30**	0.27***		
			(2.15)	(1.82)		
log(X to Dev)					0.09*	0.06
					(2.83)	(1.64)
1970		-0.04		0.03		-0.12
		(-0.15)		(0.12)		(-0.51)
1975		0.07		0.04		0.04
		(0.18)		(0.07)		(0.09)
1980		0.54*		0.48*		0.52**
		(3.83)		(2.76)		(2.22)
1985		0.67**		0.66*		0.61
		(2.35)		(3.10)		(1.54)
1990		0.28**		0.14		0.19
		(2.27)		(0.96)		(1.10)
1995		0.26		0.26***		0.24
		(1.63)		(1.71)		(1.31)
2000		0.11		0.10		0.08
		(0.50)		(0.42)		(0.30)
Constant	5.42*	5.07*	5.05*	4.73*	6.34*	5.54*
	(4.43)	(4.25)	(4.06)	(4.01)	(3.36)	(2.74)
Observations	75	75	75	75	57	57
R^2	0.1262	0.2245	0.1848	0.2700	0.2662	0.3461

Note: Euro & UKC= dummy variable = 1 if the country is in the Europe Region or has colonial ties to the United Kingdom. log(X to Dev) is the logged value of exports to developed countries for all non-European and non-UK colony countries. The comparison year for the year dummies is 1965. t-statistics are in parenthesis. $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance. These results exclude Papua New Guinea, and Mozambique. Standard errors are corrected using White's correction.

choice is carefully examined, the U-shape relationship between IPRs and per capita GDP is not statistically supported.

Instead, the true driving force behind the U-shape link between IPRs and per capita GDP observed in the panel data is a result of cross sectional differences. Specifically, the poorest countries implemented relatively strong IPR regimes largely as a result of vulnerability to increasing pressures from the industrialized world. Middle income developing countries that are further along in the development process when they agree to participate in international treaties are less vulnerable to these pressures and therefore implement IPR regimes that are less stringent and enable greater growth via imitation. Empirical tests of this "International Vulnerability Hypothesis" provide evidence that a significant U-shape link between IPRs and per capita GDP exists in the critical year that countries first choose to implement IPRs and that a country's vulnerability to pressures to implement strong IPRs positively contributes to the IPR choice.

Since data on IPRs are relatively scarce, the majority of analysis presented in the IPR literature is done using panel data or cross-sectional data. As a result, it is important to understand the different longitudinal and cross-sectional relationships between IPRs and per capita GDP, so that future analysis of IPRs can be interpreted accurately. This paper provides further clarity on this point.

Chapter 3

The Effect of Intellectual Property Rights on High Technology Exports to Developing Countries

3.1 Introduction

Developing countries have been persuaded by the industrialized world in recent years to implement strong intellectual property rights (IPRs). Current international arrangements attempting to establish a robust international standard for IPRs exemplify this fact.[1] The benefits of strengthening IPRs in developing countries is still being examined. Many argue that stronger IPRs in developing countries will increase developed country exports of high technology goods to developing countries. The effects of IPRs on trade, however, are multifaceted and may not necessarily yield such beneficial expansion of developed country exports to developing countries.

In general, IPRs can impact trade via two avenues: the market power effect and the market expansion effect. The market power effect refers to the reduction in trade that

[1]Nothing illustrates the movement towards universally strong IPRs more than the Trade Related Aspects of Intellectual Property Rights (TRIPS) Agreement that came into existence after the General Agreement on Tariffs and Trade (GATT)/World Trade Organization (WTO) 1986 to 1994 Uruguay Round. The TRIPS Agreement outlines detailed procedures for implementing and enforcing various types of intellectual property rights. Although the least developed countries have been given extended time to implement IPR policies outlined in TRIPS guidelines, the intended outcome is that all member countries abide by the TRIPS agreement.

occurs because patents limit competition and thereby enable innovating firms to charge relatively higher prices. The market expansion effect refers to the possibility that IPRs increase the variety of goods in markets by attracting producers who would otherwise fear loss of profitability in the absence of exclusive rights. Determination of the dominant effect has, in the past, been left to empirical tests.

There have been past empirical observations suggesting that IPRs do not impact bilateral aggregate trade of high technology goods.[2] One explanation for this result has been that there is a dominant market power effect of IPRs. This paper contributes to the literature in that it (1) considers a disaggregation of high technology goods and (2) provides a theoretical model that outlines the commodity specific characteristics that lead to a dominant market power versus market expansion effect of increased IPRs.

The theoretical model in this paper suggests that the market expansion effect will dominate if the markup in price for a certain variety of a good exceeds production costs inclusive of the cost of adapting the technology for use in the developing country market. In this case, stronger IPRs will lead the innovating firm to increase exports of the adapted variety they choose to sell on the foreign market. If the markup in price is sufficiently greater than production costs inclusive of adaptation costs, such that the ratio of costs to the markup is statistically negligible (or rather, converges to zero) then strengthening IPRs will lead to an insignificant change in the innovating firm's exports of high technology goods. This result suggests a dominant market expansion effect.

In order to analyze the theory empirically, this paper focuses on the impact of developing country IPRs on disaggregated, high technology, developed country exports to developing countries. In doing so, predictions can be made about the types of high-technology goods that enable net market expansion and therefore enhance high-technology exports to developing countries.

In the next section, relevant literature is summarized. Section 3 presents the theoretical model. Empirical observations and results are presented in Section 4. Section 5 provides a summary and concludes.

[2]Such a result was observed in Primo Braga and Fink (1999).

3.2 Review of Literature

There is an array of relevant literature contributing to the IPR-trade relationship being considered in this paper. The review will begin by presenting an overview of literature on IPRs and trade in the North-South context. Then, specific attention will be given to literature on IPRs and bilateral trade flows. Finally, a brief review of literature on the theoretical underpinnings of the gravity model is provided, as the empirical estimations of bilateral trade flows in Section 4 are done using a gravity estimation equation.

3.2.1 Literature on IPRs and Trade in the North-South Context

Although IPRs lead to higher prices by providing innovating firms with monopoly rights, IPRs are necessary to protect innovators, which take on large up-front research and development costs, from losing profits at the hands of imitators. Most innovation occurs in the North, while the South benefits from technology transfer via imitation of Northern innovated goods. Stronger IPRs, however, limit imitation in the South. A great deal of literature exists comparing the trade-offs between innovation and imitation in the context of a North-South trade model.

Helpman (1993) used a dynamic general equilibrium model to evaluate the innovation-imitation trade-off between the North and South. Helpman considered a variety of scenarios, which often built off one another. For example, he considered the innovation-imitation trade-off in the case of an exogenous and endogenous rate of innovation, as well as in the presence and absence of foreign direct investment. In the absence of foreign direct investment (FDI), Helpman noted that stronger IPRs in the South are welfare decreasing in the South as they cause manufactured production to shift to Southern firms that can now receive higher prices, even though efficiency in production remains with Northern production. The introduction of FDI complicates the story as it introduces an increase in efficiency of Southern firms. Helpman ultimately concludes that, while theoretical models are helpful to determine the pathways in which IPRs impact the welfare of developing countries, empirical analysis is necessary to determine whether an increase in IPRs in the South is welfare decreasing or improving.

Lai and Qiu (2001) considered the effect of IPRs on *global* welfare in the context of North-South trade. Using a multi-sector model with IPR protection, they concluded that global welfare would increase if the South increased IPRs. The improvement in global welfare, however, may occur at the expense of the South. Grossman and Lai (2004) came to a similar conclusion, finding that the harmonization of IPRs between the North and South benefits the North at the expense of the South.

Connolly and Valderrama (2005) theoretically examined technological diffusion to the South through imitation of traded goods during a period of trade liberalization.[3] Unlike their predecessors, Connolly and Valderrama found that stronger IPRs can be welfare increasing in both the North and the South if IPRs are "properly designed." For example, if Southern imitation is permitted, but Southern imitating firms are forced to pay a one time licensing fee to the Northern innovator, then stronger IPRs are welfare enhancing for both the North and the South. Without licensing fees for Southern imitation, the North will likely face comparatively less competition from the South, thereby decreasing the rate of Northern innovation. In the latter case, Connolly and Valderrama conclude that stronger IPRs will be welfare reducing for both regions.

The North-South trade models above focus on the implication of strengthening IPRs on regional and/or global welfare. These models, however, do not focus specifically on the impact of IPRs on bilateral trade flows.

3.2.2 Literature Review of Empirical Works on IPRs and Bilateral Trade Flows

The impact of IPRs on bilateral trade flows has been empirically examined by Maskus and Konan (1994), Maskus and Penubarti (1995), and Primo Braga and Fink (1999, as adapted in Fink and Maskus (2005)). Maskus and Konan were interested in unveiling the possible impact of the Trade Related Aspects of Intellectual Property Rights (TRIPS)

[3]Connolly and Valderrama specifically examine the tradeoffs during a period of Southern trade liberalization.

Agreement on bilateral exports using 1984 data. To do so, they used correlation coefficients to compare the magnitude and direction of residuals from a specified gravity equation for equilibrium trade flows within 2-digit SITC manufacturing categories against an IPR Index of patent strength. Such residual analysis allowed them to decipher whether IPRs impacted the equilibrium flow of trade between five large technology-exporting countries. Maskus and Konan concluded that actual trade was below predicted trade in countries with weak IPRs, thereby signaling that the impact of IPRs on trade could be potentially large.

Maskus and Penubarti (1995) considered the IPR-trade relationship and found, using a Helpman-Krugman (1985) type analysis, that developing countries with strong IPR regimes experience an increased flow of imports. This is particularly true for large developing countries such as Mexico, South Korea, Argentina, and Brazil. Like Maskus and Konan, their analysis was static utilizing 1984 data only. In their model, Maskus and Penubarti accounted for possible endogeneity between a country's trade flows and its level of economic development by implementing a two-stage instrumental variables approach.

Primo Braga and Fink (1999) considered bilateral trade in both non-fuel and high-technology goods using a gravity model and estimated it in a normally distributed, bivariate probit regression to account for zero trade flows.[4] Primo Braga and Fink (1999) found IPRs had a significant and positive impact on bilateral trade of non-fuel goods, but did not have a significant impact on high technology trade. They proposed the following five possible explanations for their result: (1) Market power effects are particularly strong for high-technology goods and may offset positive market expansion effects; (2) Stronger IPRs may result in FDI by high-tech firms rather than increased trade; (3) The Ginarte-Park IPR Index inappropriately captures IPR strength; (4) The availability of the high-technology

[4]The explanatory variables included in the Primo Braga and Fink gravity model include gross domestic product and population of each trading partner, the distance between the two countries, a dummy variable for whether the two countries share a common border, a dummy variable for whether the two countries share a common language, dummy variables to account for preferential trading agreements, and, finally, the Ginarte-Park IPR Index (which will be discussed in greater detail later in the paper) in the destination country. In a footnote, Primo Braga and Fink (1999) indicate that they estimated a gravity model similar to that of Maskus and Penubarti (1995) where they interacted the Rapp-Rozek IPR index with three dummy variables for high-income countries, large developing countries, and small developing countries. They ultimately conclude that, given that the interaction terms causes large changes in the coefficients on GDP and population, including such an interaction picks up a "misspecification in the functional form of per capita income." As a result, they discredit this method.

imports considered may be insensitive to the domestic country's IPR regime; and/ or (5) Specification error, such as the exclusion of variables for tariff and non-tariff trade barriers, may bias the results. The theory outlined in this paper focuses on the validity of the first reason, and provides a set of conditions under which increasing IPRs will lead to a dominant market power (versus a market expansion) effect.

3.2.3 Review of Literature on Gravity Models

The gravity model is commonly used to estimate bilateral trade flows between countries by incorporating GDP of each partner country as well as the distance between trade partners in a log linear specification. Although the gravity equation can be used to explain a great deal of bilateral trade that occurs between countries, theoretical underpinnings of the equation are not as apparent. In general, the theoretical basis of the gravity model for trade hinges on the supply and demand forces between two countries. These supply and demand forces are related to the relative economic size of the two trading countries, adjusting for the distance between them.

Key contributors to the theoretical models behind the gravity equation include Anderson (1979), Bergstrand (1985, 1989), Deardorff (1995), Feenstra et. al. (2001) and Eaton and Kortum (2002). The theoretical model developed by Anderson (1979) assumed that each country produced differentiated goods and consumers had identical Cobb-Douglas preferences. He concluded that the gravity equation is most applicable for countries with similar preferences in traded goods, tax structures, and transportation costs.

Bergstrand (1985) constructed his theoretical model for the gravity equation from a general equilibrium model of world trade in which international products are perfectly substitutable. Bergstrand (1989) expanded his theory to consider a two-factor, two (differentiated) industry, N-country general equilibrium framework in order to account for both inter-industry and intra-industry trade.

Deardorff (1995) constructed two theoretical models for the gravity model stemming from two variations of the Heckscher-Ohlin model of trade. First, Deardorff considered a model of "frictionless" trade where products are homogenous and consumer preferences are identical and homothetic. Second, Deardorff constructed a theoretical model in the case of complete product specialization by countries and either Cobb-Douglas or constant elasticity of substitution (CES) preferences by consumers.

Feenstra, Markusen, and Rose (2001) argued that the gravity equation can be derived using a various number of different trade models. They concluded that expectations about the coefficient estimates should differ depending on which trade model the equation is theoretically rooted in. They paid particular attention to the impact of an increase in the home country's income on export activity.[5]

In a somewhat different approach, Eaton and Kortum (2002) used a Ricardian trade model for a continuum of goods based on comparative advantage as the underpinning theory for the gravity equation. A unique characteristic of this model is that more than one country can produce the same good, with each producer supplying the good to different parts of the world. Consumers in this model have CES preferences.

3.3 Theoretical Model

The theoretical model established in this section considers an innovating firm's choice to export a less-technologically advanced version of its newly innovated good to developing countries. To illustrate the modeling, a general story will first be presented, followed by a discussion of the formal theoretical model.

3.3.1 The Story

Developed country (Northern) innovations may not be immediately appropriate for use in developing countries (the South). Therefore, Northern firms must adapt the good to lower technology levels if they want to supply the good to the South. If they decide that it is profitable to adapt the innovated good for use in the foreign market, they must decide the avenue by which they will introduce the new good. The Northern innovating firm can introduce an adapted version of the newly innovated good into Southern markets via exports

[5]This income effect is most commonly referred to as the "home market" effect.

of the final good or foreign direct investment (FDI).[6] While both avenues are important to the story, this paper focuses on the introduction of newly innovated goods to the South by means of the first avenue, exports. It would be useful in future explorations to consider the impact of the choice to introduce high technology goods into these markets through FDI.[7]

The innovating firm's choice to export an adapted version of its good is dependent on demand for the good abroad. If the innovated good at the adapted technology level is useful to domestic production processes in the South, demand for the innovated good will be higher. In addition, stronger IPRs reduce the threat of piracy, making the market for the innovated good less competitive. This will result in higher prices and a lower quantity demanded of the good.

Ultimately, the Northern innovating firm's decision to supply the adapted innovation to the South via export is contingent on how the mark-up in price relates to production costs inclusive of adaptation costs of the innovated good. The next section takes this general story and establishes a more concrete theoretical model of a Northern innovating firm's choice in adapting and supplying their innovated good by means of exports to a developing country. The theoretical model in this paper combines ideologies from Gaisford, Hobbs, and Kerr (2007) and Diwan and Rodrik (1987) in order to establish a set of conditions necessary for market expansion.

3.3.2 The Model

Let j denote the variety of a manufactured good. Every variety j can be adapted into a version with technology level $i \in [0, \frac{1}{2}]$ where 0 represents the least technologically advanced version of variety j and $\frac{1}{2}$ represents the most technologically advanced version of variety j. Each variety introduced to the market can potentially be adapted so that it is appropriate to all levels of technology within this range.

[6]The FDI may include exports of high technology capital equipment needed to produce the good abroad or it may be non-export related FDI in which investments are made in existing domestic firms.

[7]It is possible that the introduction of an FDI choice into the model may cancel the export related effects discussed in the next sections. It is also possible that the FDI and export choices are both utilized, thereby leading to the export effect discuss below, although to a lesser degree.

It is assumed that, in period 1, a Northern firm innovates variety j with technology level $i = \frac{1}{2}$. If the Northern innovating firm chooses to adapt the innovated variety to a level of technology $i \in [0, \frac{1}{2}]$, so that it can be sold on the world market, it does so in period 2. The model below focuses on the adaptation, production, and export decision of the Northern innovating firm in period 2.

Consumers' demand for the innovated variety j with technology level i is $\lambda_{ji} \in [0, \frac{1}{2}]$. Demand is a function of price, "pertinent usage", and the level of IPR protection. More specifically,

$$\lambda_{ji} = \lambda(p_{ji}, U_{ji}, \varepsilon) \tag{3.1}$$

where p_{ji} is the price of the innovated variety j with technology level i, $0 < U_{ji} \leq \frac{1}{2}$ represents "pertinent usage" for the innovated variety j with technology level i, and $0 < \varepsilon \leq 1$ represents the level of domestic IPRs, which are country specific.[8]

Pertinent usage refers to how useful the innovated technology is to production processes common in the importing country's market. The "pertinent usage" variable falls within $0 < U_{ji} \leq \frac{1}{2}$ such that higher values indicate that the innovation is more pertinent for use in domestic production processes. U_{ji} varies by both the variety of the innovation j and the technology within a given variety i.[9] At any technology level i, a variety will be more pertinent the greater its impact on domestic production. For example, a developing country that relies heavily on agricultural production may find innovations in genetically modified seeds to be more pertinent than innovations in radioactive materials, therefore causing U_{ji} to be greater (at any technology level i) for agricultural related innovations than for innovations in radioactive materials. Ranking the varieties available to a country in ascending order from those that are the least useful in domestic production processes to those that are most useful in domestic production processes yields a relationship between

[8] Although IPRs vary by country, they are uniform throughout all varieties and technologies.

[9] In order to keep things simple, the impact of j on pertinent usage is examined while assuming that technology i is held constant. In addition, the impact of i on pertinent usage is examined while assuming that variety j is held constant.

U_{ji} and j characterized by $\frac{\partial U_{ji}}{\partial j} > 0$.

In each country, pertinent usage for each innovated variety j also differs by the technology level i. The pertinent usage of each variety on the domestic market will depend on the appropriateness of technology i in the supply chain to domestic production. Specifically, U_{ji} is related to the resource endowment of the importing country, such that (for any variety j) U_{ji} will be greater the better a country can incorporate technology i into its supply chain given its endowment of resources. It is assumed that pertinent usage for an innovated variety differs in each country by the technology i such that $\frac{\partial U_{ji}}{\partial i} < 0$. This indicates that pertinent usage for each variety j will be greater the less technologically advanced the innovated variety. This is a strong assumption that best characterizes the relationship between pertinent usage and technology levels in the least developed countries.

The demand for variety j with technology level i depends on pertinent usage, U_{ji}. This is because each variety j with technology level i will have a different bundle of complementary goods. These bundles of complementary goods will differ in price depending on their relative abundance given a country's resources. These bundles will differ across varieties as well as across technology levels. For example, at any technology level i, the complementary bundle of goods for genetically modified sees will differ from the complementary bundle for synthetic yarn. In addition, within a given variety j, the bundle of complementary goods corresponding to technology i may differ such that one technology requires electricity while the other requires the use of batteries. The availability and cost of different power sources in a country may vary, causing the price of the bundle of complementary goods to differ across technologies. As a general result, the demand for variety j with technology level i will be different at different levels of U_{ji}. The concept that changes in the price and availability of complementary goods will shift the demand curve is widely supported in microeconomic theory.[10]

The demand for the innovated variety j with technology level i also depends on the level of IPR protection. This occurs through a variety of avenues. First, IPRs influence the number of competitors in the market and, subsequently, the number of close substitutes competing for the export market. With fewer substitutes, demand for variety j with technology level i will be higher. Second, stronger IPRs attract complementary high technology goods. The level of IPRs may alter the bundle of complementary goods and, therefore, the price of complementary goods, which causes demand to shift at different levels of IPRs.

Assuming a functional form for the demand of variety j with technology level i will simplify the estimation of firm-level profit-maximizing quantities. The functional form assumed must satisfy the characteristics of demand described above. One such functional form is:

$$\lambda_{ji} = 1 - \frac{p_{ji}}{U_{ji}\varepsilon}. \tag{3.2}$$

Notice that the above specification satisfies $\lambda_{ji} \in [0, \frac{1}{2}]$ only when prices are constrained such that $\frac{1}{2} \leq \frac{p_{ji}}{U_{ji}\varepsilon} \leq 1$.[11] Following the law of demand, a higher price will lead to a lower quantity demanded. In addition, both greater pertinent usage and IPRs will lead to a greater quantity demanded, as previously discussed.

[10] For a clarifying example on how demand will differ across technologies within the same variety, consider laptop computers. Nicholas Negroponte had a mission to create a laptop that could be easily used by children in developing countries. In his design of such a computer, he acknowledged that the goods/resources that complemented the use of conventional laptops should ideally be altered. For example, access to electrical power sources was a primary concern. As a result, Negroponte's original design for the XO computer intended to be sold in developing countries included a hand-crank for power. While this power source has not yet been incorporated into XO laptops, and a new design for a "pull-cord hand-generator" is in the works, the design of the laptop has focused on minimizing power usage by omitting motor driven components such as fans and hard drives. The desire to reduce the need for electrical power addresses the fact that the price of power-related goods complementary to conventional computers is high. Although developing countries have a use for a computers, the price of complementary goods needed to use conventional computers causes the demand for conventional technologies to be relatively lower than technologies that require less use of power sources. In this example, the pertinent usage of hand-crank laptop in developing countries is greater than the pertinent usage of conventional laptops, satisfying the assumption that $\frac{\partial U_{ji}}{\partial i} < 0$ as well as the notion that each technology corresponds to a different bundle of complementary goods.

[11] Recall that, individually, $0 < U_{ji} \leq \frac{1}{2}$ and $0 < \varepsilon \leq 1$. From these assumptions in conjunction with the restriction that $\frac{1}{2} \leq \frac{p_{ji}}{U_{ji}\varepsilon} \leq 1$ it can be inferred that $0 < p_{ji} \leq \frac{1}{2}$.

Prices

From the demand function in (3.2), the inverse demand curve can be derived. The inverse demand curve provides a functional form for prices that can be used in the Northern innovating firm's profit function, which will be presented shortly. The inverse demand curve is presented in equation (3.3) below.

$$p_{ji} = U_{ji}\varepsilon(1 - \lambda_{ji}) \tag{3.3}$$

From the inverse demand curve it can be shown that $\frac{\partial p_{ji}}{\partial U_{ji}} > 0$ and $\frac{\partial p_{ji}}{\partial \varepsilon} > 0$. These comparative statics provide information about the relationship between p_{ji} and U_{ji} and ε along the demand curve.

Costs

The innovating firm for variety j with technology level i incurs marginal costs via two avenues: (1) c_{aji}, the marginal cost of adapting the innovated variety j to a version with technological advancement i, and (2) c_{pj}, the marginal cost of producing variety j.[12] Therefore, total marginal costs for producing variety j with technology level i is $c_{ji} = c_{aji} + c_{pj} \geq 0$.[13]

It is assumed that one firm, and only one firm, innovates each variety j. The original innovation of variety j has a technology level $i = \frac{1}{2}$, indicating that it is the most technologically advanced version of the good available on the world market. This high level of technology, however, may not be appropriate for use in less-developed (Southern) countries. Therefore, the Northern innovating firm must choose if it will adapt its variety to a lower-technology version and export it abroad. The Northern innovating firm will choose to produce and export the technology that maximizes all possible profits. The profit maximization equation for each technology, which will be explored in the next section, varies

[12]The marginal cost of producing variety j is assumed constant across technologies i within the same variety.

[13]The model described assumes that the Northern innovating firm has already chosen R&D expenditures in the previous period, which resulted in the original innovated variety. Therefore, in this one period, static model, R&D costs for the "original" innovated variety do not enter into the cost function in the current period.

depending on the marginal cost of adaptation. Therefore, it is worthwhile to consider briefly how, within each variety j, the marginal cost of adaptation will vary across the possible technologies i.

The marginal cost of adapting variety j, c_{aji}, varies systematically by i. It is more costly to adapt the variety to lower technologies such that $c_{ajm} > c_{ajk}$ for $k > m$. (Recall that the innovated variety can be adapted to a level of technology $i \in [0, \frac{1}{2}]$ where 0 represents the least technologically advanced version of the good and $\frac{1}{2}$ represents the most technologically advanced version of the good.) This implies that $\frac{\partial c_{aji}}{\partial i} < 0$.

Profits

Assume that there is one, and only one, Northern innovating firm for each variety j. The firm producing variety j will adapt this variety to a level of technology i that yields the highest profit across all possible technologies i. In order to determine this level of technology, the firm producing variety j must identify profits corresponding to each technology i.

For each variety j, the innovating firm's profit at technology level i (if it chooses to produce a good at this technological level) is:

$$\begin{aligned} \pi(\lambda_{ji}) =& (p_{ji} - c_{ji})\lambda_{ji} \\ =& U_{ji}\varepsilon(1 - \lambda_{ji})\lambda_{ji} - (c_{aji} + c_{pj})\lambda_{ji} \end{aligned} \tag{3.4}$$

where λ_{ji} represents the demand for the innovated variety j with technology level i. The firm producing variety j chooses the quantity, λ_{ji}, that maximizes the firm's profit function at each possible technology i. The corresponding first order condition for the profit maximization equation yields an optimal λ_{ji} that satisfies:

$$U_{ji}\varepsilon - 2U_{ji}\varepsilon\lambda^*_{ji} - (c_{aji} + c_{pj}) = 0$$

or

$$\lambda_{ji}^* = \frac{1}{2} - \frac{(c_{aji} + c_{pj})}{2U_{ji}\varepsilon}. \tag{3.5}$$

The firm that innovated variety j will then choose to produce the technology that maximizes the possible profits.

$$\max_{\lambda_{ji}^*} \Pi = \max(\pi(\lambda_{ji}) \quad \text{for } i \in [0, \frac{1}{2}]) \tag{3.6}$$

Let β_j^* be the optimal quantity of variety j that corresponds to the profit maximizing i.[14] Given that the quantity demanded for each technology i is somewhere within $0 \leq \beta_j^* \leq \frac{1}{2}$, the first order condition stated in (3.5) will be bounded by possible corner solutions. Taking into account these corner solutions, the optimal quantity produced of variety j is as follows:

$$\beta_j^* = \begin{cases} 0 & \text{if } U_{ji}\varepsilon \leq (c_{aji} + c_{pj}); \\ \frac{1}{2} - \frac{(c_{aji}+c_{pj})}{2U_{ji}\varepsilon} & \text{if } 0 < (c_{aji} + c_{pj}) < U_{ji}\varepsilon; \\ \frac{1}{2} & \text{if } (c_{aji} + c_{pj}) = 0. \end{cases} \tag{3.7}$$

From (3.7) it can be concluded that if the marginal cost of producing and adapting the innovated variety j is sufficiently lower than the markup in the price (which is related to the good's pertinent usage and IPR protection), then the innovating firm will produce and export the adapted good. If the marginal cost of adaptation and production exceeds the markup, then the innovated variety will not be adapted for sale abroad. Lastly, if the marginal cost of adaptation and production is zero (or negligible in terms of statistical significance) then the innovating firm will export the maximum it can produce of the adapted variety.

[14]It should be reiterated that this is the optimal quantity that maximizes the profit for the one firm that is producing and exporting variety j. This is not an equilibrium quantity for total exports across all varieties.

Equilibrium

The theoretical model above describes a one-period, profit maximizing condition for a single firm producing and exporting a single variety (and technology) of a good. The above model, however, does not account for competitors and, therefore, does not lend itself to a market equilibrium condition for export activity. A model in which the market equilibrium is derived would better lend itself to address the entrance of imitators in the domestic market via a contestable market framework.

In a contestable market, as described by Baumol (1982),[15] the price set by the Northern innovating firm in the above model would be influenced by the threat of possible entrants into the domestic market. Contestable markets assume ease of entry and exit of competitors, which leads the innovating (monopoly) firm to charge a price below monopoly rents so to keep competing firms out of the market. In the model by Gaisford, Hobbs, and Kerr (2007), for which this theoretical model is based, a contestable market is assumed such that the price set by the Northern innovating firm is just below what potential imitators in the domestic market can change and still cover the costs of production.[16] Deriving a market equilibrium for which this contestable market ideology can be applied would be a useful expansion of the current theoretical model in this paper.

3.3.3 What Impacts the Optimal Quantity to Produce and Export?

From the above theory, a hypothesis can be constructed as to the types of high technology goods developing countries should expect to see a dominant market expansion or dominant market power effect if they increase IPRs. If the markup in price resulting from IPR protection and pertinent usage of the good exceeds the marginal cost of producing and adapting the good, then the optimal volume of exports abroad will fall somewhere between zero and $\frac{1}{2}$ (otherwise stated, $0 < \beta_j^* < \frac{1}{2}$). Assuming this interior solution, it can be demonstrated that the optimal β_j^* increases when (1) IPRs, ε, increase, and (2) pertinent

[15]Other notable references include Baumol, Panzar, and Willig (1983) and Tirole (2003).

[16]Specifically, Gaisford, Hobbs, and Kerr (2007) assume that the upward bound on price is equal to some fraction of the cost reducing factor that the innovated good has on production.

usage, U_{ji}, increases.

$$\frac{\partial \beta_j^*}{\partial \varepsilon} : \frac{(c_{aji} + c_{pj})}{2U_{ji}\varepsilon^2} > 0; \tag{3.8}$$

$$\frac{\partial \beta_j^*}{\partial U_{ji}} : \frac{(c_{aji} + c_{pj})}{2U_{ji}^2\varepsilon} > 0; \tag{3.9}$$

An increase in β_j^* corresponds to increased exports of the adapted technology to countries abroad, including developing countries. Therefore, an increase in β_j^* corresponds to a dominant market expansion effect.

As the ratio of costs to markups approaches zero, the innovating firm will saturate production and exports will converge to the maximum possible volume, or $\beta_j^* = \frac{1}{2}$, of the adapted variety. The closer the innovating firm is to saturating its capacity to export that particular variety of the good, the less likely it is that an increase in IPRs will have a statistically significant impact on the quantity of exports. Therefore, as the ratio of costs to markups approaches zero, a strengthening of IPRs will lead to a dominant market power effect.

3.3.4 Predictions about the Empirical Results

Characteristics that cause the markup in price to exceed marginal production and adaptation costs will lead to an internal solution for β_j^* and, therefore, a dominant market expansion effect when IPRs are increased. The markup on price will be higher the more pertinent the variety (and technology) is in domestic production (i.e. the greater U_{ji}). In addition, if the variety is not "too" costly to produce and/or adapt for use in foreign markets it also has a greater likelihood of having an internal solution.

Convergence towards an upper corner solution of $\beta_j^* = \frac{1}{2}$ occurs for varieties with high pertinent usage coupled with low marginal production and adaptation costs. So, varieties that are highly pertinent to domestic production as well as relatively cheap to produce and adapt for use in the domestic market have the greatest likelihood of converging towards the corner solution $\beta_j^* = \frac{1}{2}$, ceteris paribus. In this case, production of the export good is already saturated and increasing IPRs will have an insignificant effect on export activity, thereby translating into a dominant market power effect.

These generalizations about the relationship between markups and costs can be made more clear by considering specific examples of high technology goods. An intuitive generalization is that developing countries have a comparative advantage in and, therefore, specialize in agricultural and textile production. As a result, developing countries have a higher pertinent usage for varieties related to production in these types of goods.[17] In addition, the cost of adapting many of the manufactured varieties related to agricultural and textile production (such as potassic fertilizers, synthetic yarn, respectively) is relatively low. Therefore, it is reasonable to hypothesize that developed country exports of varieties related to production in agricultural and textile sectors are converging towards an upper corner solution, indicating a dominant market power effect (i.e. higher IPRs do not increase high technology agricultural and textile exports to developing countries).

Consider, on the other hand, varieties related to electrical machinery and apparatus for which the potential usage in developing countries is pertinent, but marginal costs of adaptation are relatively higher as a result of limitations to infrastructure in the least developed countries. In this case, there is a greater likelihood that electrical related high technology products have an interior solution and would exhibit a dominant market expansion effect in the presence of stronger IPRs.

Although hypotheses can be made, given the characteristics of the theoretical model, as to which varieties of manufactured goods should exhibit a dominant market power effect versus a dominant market expansion effect, empirical estimation is necessary to confirm these predictions. The next section describes the empirical estimation used in this paper.

[17] This relates to the $\frac{\partial U_{ji}}{\partial j}$ assumption in the previous section.

3.4 Empirical Estimation

This section outlines the estimation procedures and equations used to evaluate bilateral industrialized high technology exports to developing countries for a variety of high technology goods. Of key interest are the results on how IPRs in developing countries impact developed country exports to these countries, if at all. Predictions made in the previous section about which variety of goods have a dominant market expansion or market power effect in the wake of increased IPRs can be confirmed with empirical estimation.

A Tobit estimation procedure is used to estimate bilateral trade flows for each variety of good considered.[18] The Tobit model contains a discrete component, which accounts for differences between zero and positive trade values, as well as a continuous component, which accounts for the distribution among positive trade values. Generally speaking, the Tobit is specified as follows:

$$y_{it}^* = x_{it}'\theta + \epsilon_{it}$$

$$y_{it} = y_{it}^* \text{ if } y_{it}^* > 0$$

$$y_{it} = 0 \text{ if } y_{it}^* = 0.$$

where y_{it} is the dependent variable and x_{it} is the vector of independent variables. IPRs enter as an independent variable. (A complete specification will be discussed later.) A significant and positive coefficient on IPRs means that an increase in developing country IPRs will lead developed countries to increase exports to these countries, or that β_j^* from the theoretical model is increasing. Therefore a positive coefficient on IPRs indicates a dominant market expansion effect. An insignificant coefficient on IPRs means that an increase in developing country IPRs has a statistically insignificant impact on developed country exports. If there is a reason to believe, from the theoretical model, that this statistical insignificance is a result of an upper corner solution, then an increase in IPRs would be hypothesized to have

[18]Estimation using a Probit model was also conducted. The results were similar to those obtained using Tobit estimation.

a dominant market power effect.

3.4.1 The Gravity Model

The gravity model is commonly used to estimate bilateral trade flows as it leads itself to good empirical estimation results. The theoretical basis of the gravity model for trade hinges on the supply and demand forces between two countries. (A review of literature on the gravity model was provided in Section 2.) These supply and demand forces are related to the relative economic size of the two trading countries, adjusting for the distance between them. Often the gravity model for trade accounts for physical, social, and/or cultural distance between trade partners.

Equation (3.10) represents a gravity model for bilateral trade, while a logged transformation in (3.11) presents a basic estimating equation derived from the gravity model.

$$T_{ij} = GM_i^{\theta_1} M_j^{\theta_2} D_{ij}^{-\theta_3} \tag{3.10}$$

and

$$\log(T_{ij}) = \log G + \theta_1 \log(M_i) + \theta_2 \log(M_j) - \theta_3 \log(D_{ij}) \tag{3.11}$$

where T_{ij} is trade flow from country i to country j, M_i is the economic size of country i, M_j is the economic size of country j, D_{ij} is the distance between countries i and j, and G is some constant of gravitation.

Given the success of gravity models in estimating bilateral trade flows, this paper utilizes such a model for empirical estimation. The bilateral trade flows specifically under consideration in this paper are developed country exports of high technology goods to developing countries. Therefore, the dependent variable in the gravity equation is developed country export values to developing countries.[19] Data on bilateral export values was obtained from

[19]Export values, rather than export quantities, are used so to keep the data measurements consistent across countries and commodities. Although the home country originally reports these export values in their current national currency, the UN applies the current dollar exchange rate so that all available export value data is reported in current US dollars. The export values are made consistent by using the consumer price index to adjust export values to constant 2000 US dollars.

the United Nation's Commodity Trade Database (Comtrade) for the years 1970, 1975, 1980, 1985, 1990, 1995 and 2000. Export values from the UN's Comtrade database are reported in terms of "free on board" (fob). This means that the value reported for export data includes the transaction value of the good, the cost to transport the good to the border of the exporting country, and the cost to load the good on the carrier.

The core independent variables used in the gravity equation of this paper include gross domestic product (GDP) in the reporting and parter country, population in the reporting and partner country, the distance between trade partners, and sharing a common border, language, or colonizer. GDP is a measure of economic size that is key to the supply and demand forces for which the gravity model is rooted. More specifically, GDP of the importing country captures the country's capacity to absorb trade, while GDP of the exporting country captures its capacity to produce trade. Therefore, the coefficients on GDP are expected to be positive. Data on GDP were obtained from the World Bank's World Development Indicators.

Including a regressor for population for both trade partners allows for the possibility of scale effects independent of economic size. Traditionally, the coefficients on population have been said to be indeterminant.[20] However, it is possible that for the case of high technology manufactured exports to developing countries, as considered in this paper, the coefficient on population may be expectedly negative. This is because the coefficient on population may be capturing the relationship between *per capita* GDP and exports. Countries with higher populations, likely corresponding to lower levels of per capita GDP, may receive fewer industrialized high technology exports. This would correspond with a negative coefficient for population. Data on population was obtained from the World Bank's World Development Indicators.

The other independent variables included in the gravity equation embody physical, social, and cultural distance-related barriers to trade. Data on these variables was obtained

[20]The general argument for this is two-fold. A more populous country may be better able to diversify and become self sufficient, thereby decreasing trade. On the other hand, countries with greater populations may be better able to engage in economies of scale production, likely increasing export activity.

from CEPII distance database.[21] The first measure of "distance" is physical distance. This is approximated by the geographical distance between the "most important" cities in each trading partner according to population and agglomeration economies. Physical distance is used as a proxy for transportation costs such that the greater physical distance, the greater the costs associated with transporting goods. The sign of the physical distance coefficient is therefore expected to be negative.

Similar social and cultural interactions among countries may also positively impact trade by reducing the "cultural distance" between trade partners. For example, the interactions that lead to trade may be easier if countries share a common language. To account for this possibility, the gravity equation includes the variable *language*, which is a dummy variable that takes the value of one if countries have similar official national languages and a value of zero otherwise. Social and economic similarities may also exist if the countries have colonial ties. Countries with colonial ties are likely to have compatible trade policies as well as a pre-established economic relationship (regardless of distance). Therefore, including a dummy variable, *colony*, that takes the value of one if trading partners have ever had a colonial link and zero otherwise is also included in the gravity equation.[22]

Trade flows are also believed to be impacted by whether or not trading partners share a common border. Contiguous countries have greater ease in the transport of goods (which can been seen as decreasing a barrier to trade). Although this variable is important, it is omitted since no developed-developing country pair in the data set share a common border. This is because the classification of developed countries contains only high income countries and the classification of developing countries contains only the least developed, low income countries. (The classification of countries as developed or developing is discussed in greater detail later in this section.)

To summarize, the specific benchmark gravity equation used in estimation takes the following form:

[21] http://www.cepii.fr/anglaisgraph/bdd/distances.htm

[22] Although there are common links between countries with shared colonial ties and shared languages, both variables are often included in the gravity equation. Empirical test do not show multicollinearity between these two variables and therefore they are both included in the estimating equations with confidence.

$$\log(X_{nit}) = \beta_0 + \beta_1 \log(\text{GDP})_{nt} + \beta_2 \log(\text{GDP})_{it} + \beta_3 \log(\text{pop})_{nt} + \beta_4 \log(\text{pop})_{it} \qquad (3.12)$$
$$+ \beta_5 \log(\text{distance})_{ni} + \beta_6 (\text{colony})_{ni} + \beta_7 (\text{language})_{ni} + \varepsilon_{nit}$$

where the subscript n represents the Northern exporting country and subscript i represents their Southern trade partner. X_{nit} represents country n's exports into country i at time t. All the coefficients are expected to be positive, except for the population and distance variables, as previously explained.

An index of the strength of IPRs in the importing country is included as an additional regressor to test how patent rights in the developing countries impact their receipt of high technology exports from developed countries. The Ginarte-Park IPR Index is used to approximate the strength of patent protection in the importing country.[23] The Ginarte-Park (GP) Index ranges from 0 to 5, with 5 indicating maximum patent protection. The index takes into account; (1) coverage, (2) membership in international treaties, (3) loss of protection, (4) enforcement, and (5) duration of protection. Since its arrival, the GP Index has been accepted as the superior index to be used in empirical IPR analysis. In addition, the GP Index has been expanded to include a larger set of countries and years. For these reasons, the GP Index is used to approximate patent strength in this paper.

As shown in the theory, IPRs have a positive or insignificant effect depending on whether the country is dominated by market expansion or market power effects, respectively. Therefore, interpreting the coefficient on IPRs will be similar. If the coefficient on IPRs is statistically significant and positive, meaning that an increase in developing country IPRs leads to an increase in developed country exports to developing countries, than a dominant market expansion effect can be assumed for the corresponding high technology good. On the other hand, if the coefficient on IPRs is statistically insignificant, meaning that coefficient is not significantly different than zero and therefore that changes in developing country IPRs provide no significant response to export activity in developed countries, than the economy

[23] I would like to thank Walter Park for providing me with the index.

is in a "corner solution" state described in the equation (3.7). Although the two corner solutions cannot be differentiated empirically, one possibility is that there is a dominant market power effect (the upper corner solution). The other possibility is that production costs are so high that the good is not exported to any developing countries (the lower corner solution).

Sector specific value added as a percent of GDP in the previous year is included as a final regressor in the estimating equation. In general, value added for a sector measures total output for a sector net of intermediate inputs. The value added regressor attempts to capture how "pertinent usage," captured by the U_{ji} variable in the theoretical model impacts whether an increase in IPRs leads to a dominant market expansion or market power effect. Recall that U_{ji} refers to the pertinent usage of high technology variety j with a given level of technological advancement i in production processes. Value added as a percent of GDP in the previous year is included as a proxy for pertinent usage in an attempt to capture a country's increased demand for high-technology varieties that have a greater impact on domestic production.

It is assumed that each high technology variety that the developed country exports will be used for production in the receiving developing country in one of the following five categories: (1) Agriculture, (2) Chemicals, (3) Textiles and Clothing, (4) Machinery and Transport Equipment, and (5) Other Manufacturing goods.[24] The "value added" category corresponding to each high technology good is outlined in Table 3.2. (For an explanation as to how each high technology good was assigned a "value added" category, see Appendix B.2.) The greater value added as a percent of GDP in a category in the previous year, the more useful innovations will be that are used in these sectors. Data on value added was

[24] Agricultural value added refers inputs related to forestry, hunting, and fishing, as well as cultivation of crops and livestock production. Other manufacturing refers to inputs used in production of wood and related products, paper and paper-related products, petroleum and related products, basic metals and mineral products, fabricated metal products and professional goods, and other similar industries. Other manufacturing also includes all unallocated data. In general, value added is the sum of gross output minus the value of intermediate inputs used in each specified sector of production.

obtained from the World Bank's World Development Indicators.[25]

Including the IPR and value added regressors yields the following fully specified gravity equation:

$$\begin{aligned} \log(X_{nitj}) =& \beta_0 + \beta_1 \log(\text{GDP})_{nt} + \beta_2 \log(\text{GDP})_{it} + \beta_3 \log(\text{pop})_{nt} + \beta_4 \log(\text{pop})_{it} \\ & + \beta_5 \log(\text{distance})_{ni} + \beta_6 (\text{colony})_{ni} + \beta_7 (\text{language})_{ni} + \beta_8 \log(\text{IPR})_{it} \\ & + \beta_9 (\text{value added})_{ij,t-1} + \varepsilon_{nitj} \end{aligned} \tag{3.13}$$

where j corresponds to the value added category best associated with the high technology group being estimated and X_{nit} represents country n's exports into country i at time t.

Estimation of (3.13) is conducted for each high technology group in Table 3.1. In addition, trade values for each high technology group are considered over the time span 1970 to 2000. Due to limitations of the Ginarte-Park IPR index, full data is available every five years, or 1970, 1975, 1980,..., 2000. Comtrade reports trade values in current US dollars and is therefore converted into constant US dollars using the consumer price index. Year dummy variables are included in the estimation equation to account for year fixed effects.

3.4.2 Country and High Technology Good Specifications

Of primary concern in this paper is how developed country high technology exports to developing countries respond to increases in IPRs in *developing* countries. Only exports to the least developed countries are considered as they best fit the characteristics assumed by the theoretical model. Countries are considered "developing" if they are low income (per capita GNI below \$875) according to the World Bank classifications. Countries are considered "developed" if they are high income (per capita GNI greater than \$10,725) according

[25] Data on Agriculture and Manufacturing value added was available in terms of a percent of GDP. Chemical, textile and clothing, machinery and transport equipment, and other manufacturing value added was available as a percent of total manufacturing. In order to calculate value added as a percent of GDP, each category with a value added as a percent of manufacturing was multiplied by the percent of manufacturing value added as a percent of GDP.

to World Bank classifications.[26]

Classifying a variety as high technology is slightly more difficult. Krugman (1987) defines high technology goods as the goods in which investment in the creation of knowledge makes up a substantial portion of total production costs. Primo Braga and Yeats (1992) identify high technology commodity groups using a more precise classification of high technology goods proposed by Davis (1982). Primo Braga and Yeats (1992) equated "technological intensity" with the amount of research and development expenditures required to produce a certain good in the United States. Based on this definition, they identified a group of goods that could be labeled as "high technology." (For a full explanation of how the following commodity groups were specified as "high technology" groups, refer to Primo Braga and Yeats (1992).) Primo Braga and Fink (1999) later used this classification of high technology goods in their research. It is also the high technology classification used in this paper.[27]

The composition of the high technology aggregate is outlined in Table 3.1. Table 3.2 lists the value added category that corresponds to each high technology variety. For example, developed country exports of inorganic elements (SITC Revision 1 code 513) will likely correspond to value added in chemical related production in the developing country. Therefore, the country specific value added in chemical production (as a percent of GDP) in the previous year for the importing country is used to approximate the relevant usage of imports of inorganic elements in country specific production in the current period. (For a complete explanation as to how the value added categories were assigned, refer to Appendix B.2.)

3.4.3 Results

Equation (3.13) is estimated for each of the high technology variety specified in Table 3.1. The results for each commodity are found in Table 3.3. This table contains a great deal of information. To summarize the key results, when empirically accounting for pertinent usage

[26]These classifications are based on 2005 GNI.

[27]While Primo Braga and Fink considered the impact of IPRs on trade of a high technology aggregate of goods, this paper considers high technology exports at a disaggregated level, so to evaluate the empirical results using the predicted market expansion versus market power effects deduced from the theoretical model.

Table 3.1: Composition of Aggregate High Technology Goods

SITC (Rev. 1)	Description
513	Inorganic elements
514	Other inorganic elements
515	Radioactive Materials
533.1	Coloring Materials
541	Medicinal and pharmaceutical products
541.9	Pharmaceutical goods excluding medicaments
561.3	Potassic fertilizers
571.2	Fuses and detonators
571.4	Hunting and sporting ammunition
581.1	Plastics and products of condensation
581.2	Products of polymerization
651.6	Synthetic fibers
651.7	Yarn and artificial fibers
711.3	Steam engines
711.4	Aircraft engines
711.5	Internal combustion engines
711.6	Gas turbines
711.8	Engines not elsewhere specified
714	Office machinery
724	Telecommunications apparatus
729.3	Transistors, photocell, and so forth
729.7	Electron accelerators
729.9	Electrical machinery and apparatus
734	Aircraft
861	Scientific instruments
862	Photographic supplies
891.1	Tape recorders
891.2	Recorders of sound
894.3	Nonmilitary arms
899.6	Orthopedic appliances

Table 3.2: Value Added Categories

SITC (Rev. 1)	Description	Value Added Category
513	Inorganic elements	Chemical
514	Other inorganic elements	Chemical
515	Radioactive Materials	Chemical
533.1	Coloring Materials	Textile
541	Medicinal and pharmaceutical products	Chemical
541.9	Pharmaceutical goods excluding medicaments	Other
561.3	Potassic fertilizers	Agricultural
571.2	Fuses and detonators	Other
571.4	Hunting and sporting ammunition	Agricultural
581.1	Plastics and products of condensation	Other
581.2	Products of polymerization	Other
651.6	Synthetic fibers	Textile
651.7	Yarn and artificial fibers	Textile
711.3	Steam engines	Machinery and Transport Equip.
711.4	Aircraft engines	Machinery and Transport Equip.
711.5	Internal combustion engines	Machinery and Transport Equip.
711.6	Gas turbines	Machinery and Transport Equip.
711.8	Engines not elsewhere specified	Machinery and Transport Equip.
714	Office machinery	Machinery and Transport Equip.
724	Telecommunications apparatus	Machinery and Transport Equip.
729.3	Transistors, photocell, and so forth	Other
729.7	Electron accelerators	Other
729.9	Electrical machinery and apparatus	Machinery and Transport Equip.
734	Aircraft	Machinery and Transport Equip.
861	Scientific instruments	Other
862	Photographic supplies	Other
891.1	Tape recorders	Other
891.2	Recorders of sound	Other
894.3	Nonmilitary arms	Other
899.6	Orthopedic appliances	Other

of each high technology variety in production (as approximated by the commodity specific value added variable), IPRs have either a positive effect (13 varieties) or no effect (17 varieties) on industrialized high technology exports to developing countries. As noted earlier, those commodity groups that show IPRs having a positive impact on export values suggests a dominant market expansion effect for the corresponding commodity. Those commodity group estimations in which IPRs have no statistically significant impact on developed country exports to developing countries suggest that either: (1) there is a dominant market power effect ($\beta_j^* = \frac{1}{2}$ in the theory) or (2) the marginal cost of production and adaptation is so high that no markets will be supplied ($\beta_j^* = 0$ in the theory), therefore resulting in no significant change in export activity.

For 20 out of 30 varieties, the significance of the IPR variable remains the same for the case when the "value added" variable is included as well as when it is omitted.[28] To complement the theory, the preferred specification includes the value added component.

The results suggest that an increase in IPRs has caused developing countries to experience a dominant market expansion effect for the following high technology goods: inorganic elements not elsewhere specified (514), medicinal goods including medicaments (541), plastics and products of condensation (581.1), products of polymerization (581.2), internal combustion engines (711.5), engines not elsewhere specified (711.8), office machinery (714), telecommunication apparatuses (724), electrical machinery and apparatuses (729.9), scientific instruments (861), photographic supplies (862), tape recorders (891.1), and nonmilitary arms (894.3),

On the other hand, an increase in IPRs has had no significant impact on developed country exports to developing countries for the following high technology goods: oxides, gases, and chemical elements (513), radioactive materials (515), coloring materials (533.1), pharmaceutical goods excluding medicaments (541.9), potassic fertilizers (561.3), fuses and detonators (571.2), hunting and sporting ammunition (571.4), synthetic fibers (651.6), yarn and artificial fibers (651.7), steam engines (711.3), aircraft engines (711.4), gas turbines

[28]Differences occur in the following varieties: 513, 541.9, 571.2, 651.6, 711.4, 711.6, 729.3, 734, 891.2, and 894.3.

(711.6), transistors, photocells and the like (729.3), electron accelerators (729.7), aircrafts (734), recorders of sound (891.2), and orthopedic appliances (899.6). Of these varieties, coloring materials (533.1), potassic fertilizers (561.3), synthetic fibers (651.6), and yarn and artificial fibers (651.7) have relatively low adaptation costs and high pertinent usage in developing countries, and are therefore subject to a dominant market power effect. Notice that these four varieties can best be associated with the textile and agricultural industries and are traditionally critical to production in developing countries. (Also, note that the sign on the IPR coefficient for these four varieties is the same both when empirically accounting for pertinent usage and when omitting it.)

Table 3.3 reveals additional insight into the exports of high technology goods. The value added variable for most varieties has a coefficient of zero or very close to zero. The sign on the agricultural value added coefficient for potassic fertilizers, however, is statistically significant and takes a value of -0.25.[29] This oddly suggests that higher value added to production in the agricultural sector in the previous year will lead to a lower exports of potassic fertilizers in the current period. Although it is unclear from the confines of the regression analysis, perhaps the negative impact of "value added in the previous year" is a result of stockpiling resources or demand shifts resulting from evolving agricultural techniques. For the varieties in which the coefficient on value added is zero or close to zero, (while the coefficient is not always significant) the coefficient suggests the value added in the previous period in the corresponding sector has no to negligible impact on current exports of high technology goods in these sector. This does not necessarily negate the importance of "pertinent usage" in the demand for these goods. It may, however, suggest that pertinent usage is time specific and can not be interpreted across different periods.

The coefficients on the gravity variable in Table 3.3 are largely consistent with expectations. For example, the distance variable is negative in all cases except for tape recorders (891.1).[30] In addition, the colony and language variables take, for the most part, a positive sign. The coefficients on GDP are positive as well, while the coefficients on population are

[29]Potassic fertilizers is one of eight varieties for which the value added coefficient takes a negative sign.

[30]This refers to the regression where the value added variable is omitted.

overwhelmingly negative as postulated. From this we can conclude that the gravity model fits the estimation of disaggregated high-technology bilateral export flows fairly well.

3.5 Conclusion

This paper is unique as it is the first to distinguish between the market power and market expansion effect of IPRs in developing countries by using highly disaggregated data on high technology exports. The impact of developing country IPRs on high technology exports from developed countries is contingent on a combination of variables such as production and adaptation costs and whether the variety of the innovation can readily be used in the domestic production processes. Innovations of high technology varieties such as potassic fertilizers and synthetic, yarn, and artificial fibers are traditionally very pertinent to production in developing countries. As a result, this allows innovating firms to markup prices relatively higher than they could if the purchasing country had limited use for the good. In addition, marginal production and adaptation costs of innovated goods in these categories are expectedly low. Increasing IPRs in developing countries, therefore, does not lead to market expansion of these goods, but rather the market power effect dominates. High technology goods that have relatively higher production and adaptation costs may exhibit dominant market expansion effects in developing countries.

Table 3.3: Developed Country High Tech Exports to Low Income Countries (By Commodity Code)

	513	513	514	514	515	515	533.1	533.1
log(IPR)	1.82***	-0.54	3.27*	3.38***	-1.95	-1.27	0.96	0.37
	(1.78)	(-0.25)	(3.42)	(1.67)	(-0.95)	(-0.29)	(0.75)	(0.14)
log(GDP_{rep})	2.35*	1.93**	3.37*	3.50*	3.61*	2.43	4.72*	4.06*
	(5.55)	(2.47)	(8.31)	(4.66)	(3.82)	(1.50)	(8.20)	(4.52)
log(GDP_{part})	0.71	1.17	2.03*	1.96*	4.22*	6.72*	0.31	1.41
	(1.41)	(1.57)	(4.24)	(2.65)	(2.69)	(3.24)	(0.40)	(1.33)
log(Pop_{rep})	-1.30*	-0.93	-2.16*	-2.37*	-1.86***	-0.83	-3.53*	-3.16*
	(-2.89)	(-1.15)	(-5.05)	(-3.02)	(-1.91)	(-0.52)	(-5.89)	(-3.38)
log(Pop_{part})	0.77	0.33	-0.65	-0.43	-3.49**	-5.82*	0.74	0.00
	(1.43)	(0.41)	(-1.27)	(-0.54)	(-2.14)	(-2.70)	(0.91)	(0.00)
colony	6.85*	4.49*	6.48*	4.42*	6.09*	4.53**	7.30*	6.21*
	(8.69)	(3.63)	(8.63)	(3.67)	(5.15)	(2.52)	(8.13)	(4.53)
log(distance)	-3.93*	-5.67*	-3.61*	-6.08*	-2.75**	-5.85*	-4.08*	-6.55*
	(-7.30)	(-5.88)	(-7.24)	(-6.49)	(-2.30)	(-2.76)	(-5.78)	(-5.33)
language	1.21**	2.17*	0.51	1.17	0.87	1.92	0.75	0.96
	(2.36)	(2.92)	(1.08)	(1.64)	(0.97)	(1.49)	(1.12)	(0.99)
1975	2.10*	0.82	2.48*	1.01	3.83**	1.30	0.64	-1.96
	(2.62)	(0.68)	(3.24)	(0.85)	(2.26)	(0.57)	(0.61)	(-1.34)
1980	4.02*	2.37**	3.35*	1.32	3.04***	1.50	1.27	-1.78
	(4.99)	(1.99)	(4.35)	(1.12)	(1.75)	(0.65)	(1.21)	(-1.20)
1985	3.40*	3.38*	2.84*	2.11***	0.89	-0.18	2.38**	0.33
	(4.22)	(2.84)	(3.67)	(1.81)	(0.51)	(-0.08)	(2.26)	(0.22)
1990	3.79*	3.45*	2.23*	1.32	4.17**	2.41	2.58**	0.75
	(4.62)	(2.82)	(2.82)	(1.09)	(2.33)	(0.99)	(2.37)	(0.49)
1995	2.14**	2.08	0.37	-0.25	4.52**	1.45	1.52	-0.97
	(2.51)	(1.59)	(0.45)	(-0.20)	(2.45)	(0.54)	(1.34)	(-0.58)
2000	0.83	1.63	-0.33	-2.65***	2.40	-1.18	0.85	-1.61
	(0.90)	(1.03)	(-0.37)	(-1.72)	(1.17)	(-0.34)	(0.70)	(-0.76)
chemical		-0.02*		-0.01*		0.01		
		(-4.22)		(-3.26)		(0.68)		
textile								0.00
								(0.89)
Constant	-32.47*	-13.58	-55.22*	-31.87*	-87.26*	-78.24*	-36.15*	-20.06
	(-4.67)	(-1.10)	(-8.21)	(-2.64)	(-4.95)	(-2.97)	(-3.73)	(-1.29)
Observations	3007	1392	3013	1361	1023	541	1943	965

Note: z-statistics are in parenthesis. $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance. Standard errors are corrected using White's correction. The comparison year for the year dummies is 1970.

	541	541	541.9	541.9	561.3	561.3	571.2	571.2
log(IPR)	6.66*	6.13*	2.77*	1.26	1.59	2.26	5.58***	9.16
	(9.37)	(4.13)	(2.80)	(0.66)	(0.49)	(0.66)	(1.88)	(1.47)
log(GDP_{rep})	2.00*	2.11*	2.55*	2.63*	6.07*	3.01	0.28	-0.24
	(7.26)	(4.18)	(6.21)	(3.95)	(3.82)	(1.38)	(0.22)	(-0.11)
log(GDP_{part})	3.80*	3.80*	2.44*	3.19*	2.19	1.54	1.09	-0.16
	(12.20)	(7.81)	(4.68)	(4.34)	(0.91)	(0.59)	(0.51)	(-0.05)
log(Pop_{rep})	-1.13*	-1.44*	-1.52*	-1.86*	-4.54*	-1.50	1.59	2.61
	(-3.79)	(-2.65)	(-3.43)	(-2.69)	(-2.88)	(-0.69)	(1.18)	(1.15)
log(Pop_{part})	-3.22*	-3.10*	-1.58*	-2.13*	-2.33	-1.76	0.25	1.52
	(-9.19)	(-5.70)	(-2.85)	(-2.73)	(-0.88)	(-0.62)	(0.10)	(0.46)
colony	5.16*	3.07*	7.88*	6.57*	2.06	2.11	13.74*	16.09*
	(8.06)	(3.05)	(10.84)	(6.28)	(0.87)	(0.85)	(7.22)	(4.50)
log(distance)	-3.26*	-4.04*	-3.41*	-5.41*	-2.02	-2.76	-3.13***	-1.11
	(-9.69)	(-6.31)	(-6.73)	(-6.34)	(-0.98)	(-1.20)	(-1.77)	(-0.34)
language	1.86*	1.87*	1.44*	1.67*	0.65	0.84	1.63	2.78
	(5.69)	(3.79)	(3.12)	(2.60)	(0.32)	(0.40)	(1.25)	(1.41)
1975	0.86	-0.53	2.17*	1.04	-0.07	-1.42	3.96***	3.75
	(1.61)	(-0.63)	(2.60)	(0.92)	(-0.02)	(-0.52)	(1.81)	(1.17)
1980	1.72*	-0.18	2.94*	2.01***	-2.71	-5.83***	3.66	2.03
	(3.21)	(-0.22)	(3.52)	(1.74)	(-0.97)	(-1.95)	(1.62)	(0.60)
1985	1.82*	1.21	3.69*	3.60*	-1.42	-3.00	2.54	5.77***
	(3.41)	(1.45)	(4.46)	(3.16)	(-0.50)	(-1.02)	(1.12)	(1.74)
1990	1.87*	1.13	5.54*	3.99*	-0.24	-1.50	5.57**	6.83***
	(3.43)	(1.32)	(6.64)	(3.44)	(-0.08)	(-0.49)	(2.37)	(1.94)
1995	1.15**	1.07	3.97*	3.48*	-0.72	-2.80	1.08	0.44
	(2.05)	(1.18)	(4.61)	(2.84)	(-0.24)	(-0.86)	(0.42)	(0.11)
2000	-0.51	-1.12	5.07*	5.12*	-5.53	-7.32**	-2.51	-4.12
	(-0.84)	(-1.03)	(5.52)	(3.55)	(-1.61)	(-2.01)	(-0.87)	(-0.83)
chemical		0.00						
		(1.45)						
agriculture						-0.25**		
						(-2.46)		
other				0.00				0.00
				(0.45)				(0.66)
Constant	-46.55*	-36.55*	-47.11*	-34.07*	-70.37**	-29.36	-52.74**	-69.87***
	(-10.52)	(-4.39)	(-6.54)	(-2.96)	(-2.56)	(-0.92)	(-2.45)	(-1.91)
Observations	4491	1876	2819	1359	700	658	584	335

Note: z-statistics are in parenthesis. $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance. Standard errors are corrected using White's correction. The comparison year for the year dummies is 1970.

	571.4	571.4	581.1	581.1	581.2	581.2	651.6	651.6
log(IPR)	2.61	3.95	2.49*	5.04*	5.67*	7.44*	2.18***	0.25
	(1.37)	(1.11)	(2.65)	(2.76)	(6.75)	(4.62)	(1.83)	(0.10)
log(GDP_{rep})	3.59*	4.55*	2.59*	2.78*	3.17*	2.56*	3.47*	2.51*
	(4.35)	(3.48)	(6.81)	(4.52)	(9.43)	(4.77)	(6.72)	(3.11)
log(GDP_{part})	1.45	3.18***	2.57*	2.94*	1.29*	1.44*	0.43	0.57
	(1.03)	(1.86)	(6.01)	(4.81)	(3.57)	(2.72)	(0.83)	(0.76)
log(Pop_{rep})	-2.66*	-3.52*	-1.60*	-1.74*	-2.25*	-1.71*	-2.25*	-1.81**
	(-3.11)	(-2.71)	(-3.93)	(-2.72)	(-6.22)	(-3.05)	(-4.11)	(-2.16)
log(Pop_{part})	-0.25	-1.62	-1.46*	-1.86*	0.06	0.06	0.17	0.21
	(-0.16)	(-0.92)	(-3.17)	(-2.82)	(0.16)	(0.10)	(0.29)	(0.25)
colony	9.22*	10.18*	6.59*	5.10*	5.51*	3.15*	7.15*	5.99*
	(7.63)	(5.61)	(8.80)	(4.65)	(7.63)	(2.96)	(7.79)	(4.24)
log(distance)	-3.17**	-4.05**	-4.14*	-5.23*	-3.08*	-4.26*	-0.39	-2.05**
	(-2.51)	(-2.06)	(-8.61)	(-6.59)	(-7.64)	(-6.39)	(-0.68)	(-2.05)
language	2.12**	1.12	-0.39	0.29	0.48	1.47**	0.06	-0.46
	(2.01)	(0.73)	(-0.84)	(0.45)	(1.18)	(2.57)	(0.10)	(-0.52)
1975	1.83	0.61	1.35***	0.68	1.09***	-1.02	2.66*	0.64
	(1.27)	(0.32)	(1.83)	(0.65)	(1.66)	(-1.10)	(2.75)	(0.47)
1980	0.46	0.93	2.88*	2.19**	2.99*	1.13	3.42*	2.16
	(0.30)	(0.48)	(3.92)	(2.06)	(4.57)	(1.23)	(3.53)	(1.57)
1985	-1.61	-1.16	2.38*	2.87*	2.51*	2.08**	1.67***	1.49
	(-1.04)	(-0.59)	(3.21)	(2.70)	(3.82)	(2.26)	(1.69)	(1.08)
1990	-2.36	-3.68***	1.79**	1.92***	4.13*	2.84*	1.42	1.49
	(-1.44)	(-1.71)	(2.37)	(1.79)	(6.23)	(3.01)	(1.42)	(1.05)
1995	-2.24	-2.88	3.14*	2.91*	3.18*	2.08**	0.38	0.24
	(-1.32)	(-1.26)	(4.08)	(2.60)	(4.64)	(2.09)	(0.36)	(0.16)
2000	-3.69**	-5.08***	1.93**	1.79	1.04	-0.94	0.06	0.08
	(-1.98)	(-1.83)	(2.32)	(1.32)	(1.41)	-0.79	(0.05)	(0.04)
textile								0.00
								(0.69)
other		0.00		0.00		0.00		
		(0.45)		(0.50)		(0.86)		
Constant	-50.64*	-73.78*	-41.70*	-39.14*	-46.46*	-35.29*	-55.67*	-27.83**
	(-3.41)	(-3.14)	(-6.48)	(-3.67)	(-8.46)	(-3.80)	(-6.75)	(-2.03)
Observations	1100	615	3169	1566	3838	1903	2478	1209

Note: z-statistics are in parenthesis. $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance. Standard errors are corrected using White's correction. The comparison year for the year dummies is 1970.

	651.7	651.7	711.3	711.3	711.4	711.4	711.5	711.5
log(IPR)	2.82	3.11	1.33	3.01	2.58***	1.68	3.68*	4.18**
	(1.55)	(0.83)	(0.75)	(0.76)	(1.71)	(0.49)	(4.79)	(2.47)
log(GDP_{rep})	4.16*	3.24**	3.37*	4.23*	2.05*	2.63**	1.94*	1.50*
	(4.69)	(2.43)	(4.19)	(2.92)	(3.22)	(2.29)	(6.34)	(2.71)
log(GDP_{part})	0.96	0.87	2.16	4.11**	1.61***	1.50	4.55*	4.76*
	(1.14)	(0.79)	(1.52)	(2.10)	(1.85)	(1.13)	(12.76)	(8.44)
log(Pop_{rep})	-2.47*	-1.83	-1.78**	-2.11	-0.80	-1.46	-1.28*	-0.69
	(-2.73)	(-1.35)	(-2.16)	(-1.58)	(-1.20)	(-1.35)	(-3.89)	(-1.27)
log(Pop_{part})	0.05	0.02	-0.53	-2.14	-0.20	0.04	-3.31*	-3.59*
	(0.05)	(0.02)	(-0.36)	(-1.08)	(-0.20)	(0.03)	(-8.59)	(-5.85)
colony	5.03*	3.83**	8.52*	10.10*	8.48*	7.23*	6.58*	5.21*
	(4.10)	(2.06)	(7.26)	(5.20)	(8.16)	(4.27)	(10.02)	(4.68)
log(distance)	-5.00*	-6.05*	-2.53**	-5.26**	-3.18*	-5.52*	-2.91*	-3.76*
	(-5.32)	(-3.74)	(-2.27)	(-2.42)	(-3.82)	(-3.56)	(-7.63)	(-4.84)
language	1.90***	2.43***	-0.18	-0.68	1.60**	3.33*	-1.05*	-0.66
	(1.94)	(1.73)	(-0.18)	(-0.45)	(2.19)	(2.94)	(-2.80)	(-1.11)
1975	-0.69	0.42	3.70**	2.37	3.37*	3.94**	1.61*	1.29
	(-0.50)	(0.22)	(2.52)	(1.13)	(2.79)	(2.11)	(2.75)	(1.34)
1980	-1.76	0.01	4.86*	1.59	1.68	0.04	2.08*	1.86***
	(-1.24)	(0.00)	(3.28)	(0.73)	(1.35)	(0.02)	(3.52)	(1.93)
1985	-2.69***	-0.46	2.03	0.44	2.16***	3.35***	1.20**	1.44
	(-1.88)	(-0.24)	(1.34)	(0.21)	(1.75)	(1.77)	(2.03)	(1.52)
1990	-4.52*	-2.56	2.46	-0.09	3.72*	5.07*	1.52**	0.81
	(-3.02)	(-1.25)	(1.56)	(-0.04)	(2.97)	(2.64)	(2.54)	(0.84)
1995	-5.85*	-5.00**	1.56	-0.57	2.57***	4.14**	0.86	0.99
	(-3.81)	(-2.14)	(0.96)	(-0.24)	(1.96)	(1.99)	(1.38)	(0.96)
2000	-5.78*	-2.89	1.59	-0.02	0.48	2.41	-0.39	0.02
	(-3.52)	(-1.01)	(0.90)	(-0.01)	(0.33)	(0.91)	(-0.59)	(0.01)
textile		0.00						
		(0.70)						
mach. & trans				-0.01		0.00		-0.01**
				(-0.81)		(0.64)		(-2.09)
Constant	-39.93*	-18.71	-81.37*	-95.40*	-52.22*	-35.06	-62.30*	-54.82*
	(-3.04)	(-0.86)	(-5.33)	(-3.46)	(-5.00)	(-1.61)	(-12.17)	(-4.92)
Observations	1341	704	1352	680	1894	896	3870	1550

Note: z-statistics are in parenthesis. $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance. Standard errors are corrected using White's correction. The comparison year for the year dummies is 1970.

	711.6	711.6	711.8	711.8	714	714	724	724
log(IPR)	6.66*	3.01	3.91*	4.58***	4.02*	4.65*	5.28*	5.28*
	(3.91)	(0.84)	(3.22)	(1.82)	(6.02)	(3.08)	(7.43)	(3.40)
log(GDP_{rep})	2.09*	1.56	2.01*	0.33	1.39*	1.15**	1.42*	1.57*
	(2.68)	(1.13)	(3.95)	(0.38)	(5.34)	(2.39)	(5.27)	(3.23)
log(GDP_{part})	2.47***	0.35	3.16*	3.38*	4.95*	5.25*	3.48*	3.65*
	(1.91)	(0.19)	(4.24)	(3.39)	(15.78)	(10.19)	(11.32)	(7.48)
log(Pop_{rep})	0.30	0.69	-0.42	0.98	-0.84*	-0.61	-0.79*	-0.91***
	(0.38)	(0.54)	(-0.78)	(1.21)	(-2.96)	(-1.30)	(-2.68)	(-1.90)
log(Pop_{part})	-1.16	1.49	-2.19*	-2.25**	-4.32*	-4.63*	-2.76*	-3.23*
	(-0.85)	(0.77)	(-2.80)	(-2.15)	(-12.65)	(-8.19)	(-8.08)	(-5.93)
colony	6.93*	7.05*	7.60*	7.31*	4.80*	3.89*	4.90*	3.95*
	(5.98)	(3.94)	(9.09)	(5.45)	(8.12)	(3.78)	(7.65)	(3.66)
log(distance)	-2.33**	-2.25	-3.21*	-2.23**	-2.47*	-3.07*	-0.24	-0.02
	(-2.30)	(-1.26)	(-5.02)	(-1.97)	(-7.93)	(-4.73)	(-0.75)	(-0.03)
language	1.26	1.87	1.24**	0.45	1.38*	1.45*	1.35*	1.05**
	(1.47)	(1.42)	(2.15)	(0.53)	(4.51)	(2.86)	(4.22)	(2.06)
1975	6.32*	6.73*	1.94***	1.86	0.48	-0.37	2.17*	0.29
	(3.66)	(2.77)	(1.92)	(1.31)	(0.94)	(-0.42)	(4.07)	(0.34)
1980	11.23*	11.37*	1.13	1.79	0.87***	0.39	2.60*	1.43***
	(6.70)	(4.73)	(1.10)	(1.24)	(1.69)	(0.45)	(4.84)	(1.65)
1985	11.87*	12.65*	1.95***	1.63	1.32**	1.53***	2.32*	2.04**
	(7.07)	(5.38)	(1.91)	(1.15)	(2.56)	(1.78)	(4.32)	(2.36)
1990	12.55*	13.61*	4.41*	4.03*	2.65*	2.10**	3.15*	1.96**
	(7.29)	(5.60)	(4.27)	(2.81)	(5.09)	(2.44)	(5.77)	(2.27)
1995	6.07*	8.29*	4.86*	5.44*	2.28*	2.69*	3.12*	3.00*
	(3.40)	(3.21)	(4.55)	(3.57)	(4.24)	(2.93)	(5.54)	(3.24)
2000	6.79*	8.85*	3.31*	4.87*	1.86*	2.12***	3.08*	2.06***
	(3.60)	(2.88)	(2.84)	(2.59)	(3.20)	(1.83)	(5.06)	(1.75)
mach. & trans		-0.01		0.00		0.00		-0.01**
		(-1.52)		(0.39)		(1.22)		(-2.30)
Constant	-97.10*	-77.18*	-66.13*	-65.53*	-55.23*	-50.53*	-65.15*	-62.78*
	(-6.69)	(-2.92)	(-6.75)	(-3.78)	(-12.32)	(-5.22)	(-14.19)	(-6.56)
Observations	1519	710	2322	1115	4306	1696	4573	1798

Note: z-statistics are in parenthesis. $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance. Standard errors are corrected using White's correction. The comparison year for the year dummies is 1970.

	729.3	729.3	729.7	729.7	729.9	729.9	734	734
log(IPR)	1.97***	2.95	-4.78	-21.67	4.35*	4.96*	2.50***	1.99
	(1.94)	(1.50)	(-0.36)	(-0.54)	(5.58)	(2.91)	(1.77)	(0.66)
log(GDP_{rep})	2.42*	2.19*	-1.81	-4.58	2.28*	1.90*	2.51*	2.51**
	(5.93)	(3.38)	(-0.37)	(-0.41)	(7.29)	(3.49)	(4.31)	(2.55)
log(GDP_{part})	3.42*	2.75*	3.12	5.34	3.05*	3.35*	2.14**	2.24***
	(6.32)	(3.71)	(0.38)	(0.57)	(7.88)	(5.89)	(2.56)	(1.94)
log(Pop_{rep})	-1.02**	-0.86	2.66	3.52	-1.24*	-0.99***	-1.52**	-1.53
	(-2.33)	(-1.28)	(0.50)	(0.39)	(-3.68)	(-1.86)	(-2.45)	(-1.62)
log(Pop_{part})	-2.06*	-1.13	-2.26	-4.93	-2.11*	-2.75*	-0.88	-1.07
	(-3.53)	(-1.41)	(-0.24)	(-0.46)	(-5.04)	(-4.42)	(-0.98)	(-0.86)
colony	6.68*	4.87*	1.01	-2.77	5.97*	4.79*	3.93*	0.65
	(9.03)	(4.42)	(0.18)	(-0.36)	(9.13)	(4.39)	(3.82)	(0.39)
log(distance)	-2.90*	-3.68*	-0.09	-9.46	-1.80*	-2.77*	-2.37*	-2.47***
	(-5.81)	(-4.48)	(-0.01)	(-0.77)	(-4.71)	(-3.79)	(-3.30)	(-1.91)
language	1.97*	2.26*	2.97	10.81	0.51	0.57	2.89*	3.76*
	(4.26)	(3.50)	(0.61)	(1.31)	(1.40)	(1.03)	(4.65)	(4.00)
1975	2.55*	1.64	1.45	-3.87	2.39*	1.79***	2.74**	1.17
	(3.01)	(1.41)	(0.25)	(-0.46)	(3.95)	(1.93)	(2.53)	(0.73)
1980	3.24*	1.77	2.10	1.98	3.11*	1.75***	3.56*	2.68***
	(3.82)	(1.49)	(0.36)	(0.22)	(5.10)	(1.85)	(3.26)	(1.66)
1985	2.97*	2.66**	-9.12	-9.63	2.19*	1.32	2.20**	1.71
	(3.50)	(2.26)	(-1.19)	(-0.83)	(3.54)	(1.40)	(1.99)	(1.06)
1990	4.64*	4.70*	-4.82	-7.33	2.67*	1.79***	1.19	0.71
	(5.44)	(3.95)	(-0.68)	(-0.65)	(4.25)	(1.89)	(1.04)	(0.44)
1995	4.42*	3.73*	-3.15	-2.4	2.26*	2.08**	1.95***	1.99
	(5.01)	(2.96)	(0.42)	(0.19)	(3.49)	(2.06)	(1.67)	(1.14)
2000	4.88*	4.72*	10.67	15.05	1.50**	1.25	1.11	1.37
	(5.15)	(3.15)	(1.12)	(0.58)	(2.13)	(0.97)	(0.86)	(0.62)
mach. & trans						0.00		-0.01
						(1.22)		(-1.18)
other		0.00		0.03				
		(1.09)		(0.76)				
Constant	-74.41*	-63.55*	-60.24	54.55	-63.32*	-46.56*	-59.08*	-55.03*
	(-10.36)	(-5.49)	(-0.61)	(0.24)	(-11.55)	(-4.22)	(-5.59)	(-2.86)
Observations	2923	1477	158	125	3697	1543	2554	1174

Note: z-statistics are in parenthesis. $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance. Standard errors are corrected using White's correction. The comparison year for the year dummies is 1970.

	861	861	862	862	891.1	891.1
log(IPR)	5.24*	6.14*	2.77*	3.62***	3.34*	4.02**
	(8.46)	(5.07)	(2.89)	(1.96)	(3.91)	(2.49)
log(GDP_{rep})	1.79*	1.55*	2.27*	1.96*	1.73*	2.03*
	(7.42)	(3.97)	(5.84)	(3.14)	(5.06)	(3.71)
log(GDP_{part})	4.96*	5.28*	1.89*	2.56*	2.84*	3.16*
	(18.04)	(13.10)	(4.19)	(3.95)	(7.01)	(5.52)
log(Pop_{rep})	-1.10*	-1.08*	-1.47*	-1.27***	-0.97*	-1.40**
	(-4.21)	(-2.61)	(-3.51)	(-1.94)	(-2.61)	(-2.44)
log(Pop_{part})	-4.30*	-4.61*	-0.80	-1.23***	-2.28*	-2.55*
	(-14.17)	(-10.26)	(-1.64)	(-1.74)	(-5.18)	(-4.09)
colony	4.52*	3.00*	6.66*	5.28*	6.81*	5.05*
	(7.93)	(3.53)	(9.10)	(4.91)	(9.91)	(5.06)
log(distance)	-1.77*	-2.32*	-3.12*	-3.88*	0.07	-1.69**
	(-6.17)	(-4.73)	(-6.58)	(-4.79)	(0.16)	(-2.43)
language	0.87*	1.22*	0.95**	1.53**	1.27*	1.61*
	(3.04)	(2.97)	(2.03)	(2.38)	(3.25)	(2.90)
1975	1.64*	0.63	2.00*	1.09	2.86*	1.99**
	(3.51)	(0.93)	(2.62)	(1.02)	(4.21)	(2.08)
1980	1.97*	0.74	3.75*	2.65**	3.78*	3.14*
	(4.20)	(1.07)	(4.93)	(2.45)	(5.55)	(3.26)
1985	1.43*	1.21***	2.34*	2.34**	3.28*	3.36*
	(3.02)	(1.73)	(3.07)	(2.17)	(4.81)	(3.48)
1990	1.93*	1.20***	3.57*	2.46**	2.73*	2.54**
	(4.05)	(1.69)	(4.61)	(2.21)	(3.91)	(2.53)
1995	1.51*	1.17	2.57*	2.15***	2.11*	2.46**
	(3.06)	(1.57)	(3.21)	(1.83)	(2.93)	(2.35)
2000	0.41	-0.79	1.09	-0.42	0.89	0.27
	(0.77)	(-0.89)	(1.26)	(-0.30)	(1.14)	(0.22)
other		0.00		0.00		0.00
		(0.75)		(0.48)		(1.39)
Constant	-66.25*	-59.61*	-39.90*	-40.74*	-64.88*	-53.32*
	(-15.94)	(-8.55)	(-5.93)	(-3.71)	(-10.91)	(-5.46)
Observations	4615	2191	2967	1468	3262	1591

Note: z-statistics are in parenthesis. $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance. Standard errors are corrected using White's correction. The comparison year for the year dummies is 1970.

	891.2	891.2	894.3	894.3	899.6	899.6
log(IPR)	1.83**	2.76	4.52*	4.72***	0.08	-1.14
	(1.99)	(1.58)	(3.21)	(1.72)	(0.06)	(-0.46)
log(GDP_{rep})	2.38*	1.97*	1.97*	1.10	4.24*	3.52*
	(6.51)	(3.41)	(3.14)	(1.05)	(7.50)	(4.14)
log(GDP_{part})	1.34*	1.81*	-0.46	-1.34	3.55*	4.50*
	(3.09)	(2.91)	(-0.56)	(-1.24)	(4.54)	(4.44)
log(Pop_{rep})	-1.48*	-1.02***	-1.30**	-0.64	-2.78*	-2.36*
	(-3.73)	(-1.67)	(-1.97)	(-0.60)	(-4.66)	(-2.71)
log(Pop_{part})	-0.25	-0.39	1.77**	2.92**	-3.28*	-4.37*
	(-0.51)	(-0.57)	(1.98)	(2.47)	(-4.04)	(-4.20)
colony	6.77*	5.39*	6.60*	5.42*	6.71*	6.33*
	(9.59)	(5.23)	(6.59)	(3.72)	(7.90)	(5.39)
log(distance)	-0.28	-1.61**	-3.24*	-4.40*	-4.15*	-4.53*
	(-0.67)	(-2.26)	(-3.91)	(-3.23)	(-5.62)	(-3.89)
language	1.76*	1.67*	1.00	1.46	1.96*	1.79**
	(4.32)	(2.92)	(1.21)	(1.27)	(3.18)	(2.21)
1975	2.92*	2.25**	-0.33	-0.54	2.13***	1.69
	(3.83)	(2.10)	(-0.30)	(-0.35)	(1.94)	(1.18)
1980	3.78*	3.37*	0.71	0.31	4.50*	4.18*
	(4.95)	(3.11)	(0.64)	(0.19)	(4.15)	(2.93)
1985	3.83*	3.94*	-0.92	0.21	4.13*	4.09*
	(5.03)	(3.61)	(-0.81)	(0.13)	(3.80)	(2.88)
1990	6.90*	6.09*	-2.48**	-1.24	4.55*	5.37*
	(9.02)	(5.52)	(-2.06)	(-0.74)	(4.11)	(3.72)
1995	7.29*	7.79*	-1.66	-0.35	4.79*	4.63*
	(9.24)	(6.75)	(-1.35)	(-0.20)	(4.21)	(2.99)
2000	7.48*	7.64*	-4.11*	-2.35	4.13*	5.25*
	(8.82)	(5.66)	(-3.02)	(-1.12)	(3.35)	(2.83)
other		0.00		0.00***		0.00
		(0.68)		(1.69)		(0.25)
Constant	-64.54*	-62.12*	-18.49***	1.63	-58.68*	-51.67*
	(-10.51)	(-6.13)	(-1.76)	(0.10)	(-5.75)	(-3.44)
Observations	3377	1660	1448	786	1872	992

Note: z-statistics are in parenthesis. $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance. Standard errors are corrected using White's correction. The comparison year for the year dummies is 1970.

Chapter 4

Do Intellectual Property Rights Increase Export Activity in Developing Countries?

4.1 Introduction

Development policies centered on export promotion have become increasingly popular strategies for stimulating economic growth in developing countries. At the same time, many developing countries have begun to implement intellectual property rights (IPRs), often upon the suggestion of the industrialized world. This paper examines the link between these two policies by examining the role that patent policies have on export activity in developing countries. While past research in the area of IPRs and trade focused on the role that domestic IPRs play in attracting imports, the focus of this paper lies in the role of domestic IPRs in *creating* exports.

There is some sector specific evidence that domestic IPRs do play a role in increasing export activity in developing countries. For example, domestic generic pharmaceutical firms in Jordan (a lower-middle income country according to the World Bank's classification) attribute the thirty percent increase in export activity between 1999 and 2002 to a national strengthening of IPRs during this period (Holden 2006). This paper provides more macroeconomic and empirical support for the notion that stronger domestic IPRs increase exports in developing countries.

The theoretical model presented in this paper suggests that the increase in total exports resulting from stronger domestic IPRs is a consequence of increased exports of newly innovated goods as well as greater exports of existing goods that have become more efficient to produce as a result of increased technological spillovers from greater level of inward FDI. Empirical analysis supports the theoretical model that IPR policies serve as an effective path to achieve export led development.

Section 2 will provide a brief discussion of related literature. The theoretical model will be introduced in Section 3. Section 4 discusses the data, methodology, and key empirical results. Sections 5 concludes.

4.2 Relevant Literature

Literature on the relationship between bilateral trade and IPRs has focused on whether domestic IPRs *attract* imports. Primo Braga and Fink (1999, 2005) found that stronger domestic IPRs increase imports of non-fuel goods. Maskus and Penubarti (1995) found similar results and concluded that domestic IPRs increase manufacturing imports into both small and large developing countries. Smith (2002) narrowed the analysis and looked at how foreign IPRs affected exports of pharmaceutical goods from the United States. Smith concluded that foreign IPRs increase US exports of pharmaceutical goods only if the trade partner has strong imitative abilities. Yang and Woo (2006) found that domestic IPRs have no impact on agricultural imports. Briggs (2008b) considers developing-country imports of a variety of high technology goods from developed countries and finds that IPRs have a significant impact on attracting high technology imports if and only if the marginal cost of adapting and producing the good is adequately below the mark-up in price.

While these articles look at the role domestic IPRs play in attracting imports, the relationship between domestic IPRs and export platforms has received little attention. Instead, most research has focused on the relationship between *innovation* and export activity. The impact of innovation on export behavior is central to the product life cycle models seen in papers such as Vernon (1966), Krugman (1979), and Dollar (1986). Such product life cycle models postulate that innovation is the driving force behind export activity of developed countries. These models, however, consider innovation to be an exogenous influence on exports.

More recent explorations of the link between innovation and export activity consider the possibility that innovation and export activity are endogenous. While innovation may lead to more exports, it is also possible that those countries and firms that engage in exportation embody qualities that lead them to innovate. Such endogeneity was incorporated by Grossman and Helpman (1989, 1991), Young (1991), Smith et. al. (2002), and Lachenmaier and Wossmann (2006). The general conclusion is that innovation stimulates export activity in *industrialized* countries. More pertinent to the focus of this paper, however, is research that considers innovation and export activity in *developing* countries.

Young (1991) finds that when engaged in less restricted trade, less developed countries (LDCs) experience rates of technological progress at or below levels they would expect to achieve in autarky. He attributes this to the belief that, in the presence of free trade, LDCs specialize in the production of lower technology goods in which "learning by doing" has already been exhausted. In the absence of free trade more laborers work in "advanced" domestic industries ("advanced by LDC standards") therefore leading to greater levels of technological advancement via learning by doing. Young acknowledges that static gains from trade that occur when countries utilize their comparative advantages may still result in trade being welfare-improving.

Other literature related to the IPR-innovation-export triad includes research examining the relationship between IPRs and innovation. Empirical investigation by Schneider (2005) led her to conclude that IPRs do in fact increase innovation, although the effect is larger in developed countries. A partial equilibrium model developed by Chen and Puttitanun (2005) confirms Schneider's empirical findings that there is a positive relationship between IPRs and innovation, which may increase as a country develops.[1]

[1]Literature on optimal patent policy often explores the relationship between innovation and IPRs. Literature on optimal patent breadth and length examines the optimal level of patent protection given the subsequent benefits from innovation versus the costs to producers and consumers. IPRs provide firms with incentives to innovate by protecting against the pirating of innovated technologies likely developed as a consequence of significant research and development costs. Stronger IPRs, however, do not necessarily translate into higher welfare for countries as a whole. Welfare maximization and cost minimization models are often used to analyze optimal patent policies. William Nordhaus (1969, 1972), Gilbert and Shapiro (1990), Klem-

To summarize, although research exists linking IPRs and innovation, and innovation and exports, there is little literature examining the link between IPRs and exports. This paper will attempt to answer whether IPRs play a role in generating export platforms in developing countries, either directly or indirectly. Many developing countries embrace the idea of export led growth, so it is worthwhile to examine whether stronger IPRs help create an environment that enables them to achieve increased export activity. In the next section, a theoretical model is established to explore these issues.

4.3 Theoretical Model

It is assumed that the domestic market in developing countries is composed of two types of firms, (1) innovating firms that produce and sell new goods and (2) firms that produce and sell an existing good. As a consequence, total developing country exports are comprised of these two types of goods.

$$X^{total} = X^{new} + X^{existing} \tag{4.1}$$

The impact of intellectual property rights on the exports of newly innovated goods and existing goods will first be discussed separately, and then brought together to assess the impact of IPRs on total exports as represented by (4.1).

4.3.1 Exports of Newly Innovated Goods

The volume of domestic exports of newly innovated goods is a linear function of the number of new domestic products sold on the foreign market.

$$X^{new} = MI(\beta) \tag{4.2}$$

perer (1990), Hopenhayn and Mitchell (2001), and Gallini (1992) examined the theory behind optimal patent choice. Nordhaus (1972), Hopenhayn and Mitchell, and Gallini paid particular attention to how spillover effects impact innovation, and ultimately the optimal choice of IPRs. Although this paper does not examine the optimal choice in IPRs (and instead takes IPRs as exogenously given), the models of optimal patent policy are important as they underscore the idea that various levels of IPRs do in fact impact a country's innovation in a variety of ways.

where I is the number of newly innovated products sold on the foreign market, β is the level of domestic IPRs, and M is the quantity of each product that is imported by a foreign market.[2] Stronger IPRs lead to increased innovation and, therefore, a greater number of innovated goods sold on the foreign market, or $I'(\beta) > 0$.[3] (Chen and Puttitanun (2005) have provided theoretical evidence to support this assertion.) M is related to the size of the importing country. The larger the economy of the trade partner, the more of each innovated good that will be exported.

The impact of a change in IPRs on exports of new goods is positive. This fact is demonstrated in (4.3)

$$X_{\beta}^{new} = MI'(\beta) > 0 \tag{4.3}$$

where

X^{new} is exports of newly innovated goods,

M is the quantity of each product that is imported by a foreign market (M is related to the size of the importing market),

I is the number of newly innovated goods appropriate for sale on the foreign market,

β is the level of domestic IPRs.

It may seem difficult to find a good estimate for the number of new products a country sells on the foreign market to use in empirical analysis. However, a common estimate of total innovation, patent counts, is well suited to approximate such "foreign market appropriate" newly innovated goods. Patent counts are increasingly used to approximate a country's innovative achievements (Jaffe and Trajtenberg, 2002). However, using *domestic* patent count data is problematic as (1) less-developed countries often lack sufficient data on domestic patents and (2) collecting data on patent counts from individual country data

[2] The number of newly innovated products refers to the number of different types of newly innovated goods. This is distinctly different from the total volume of newly innovated products sold on the foreign market.

[3] The influences of other factors that impact innovation such as institutional quality and human capital are assumed away as they bring no additional information in assessing the relationship between IPRs and exports in the theoretical model.

sources may not be comparable as individual legal standards such as patent breadth may vary across countries. To ensure standardized data, patent count data reported by the United States Patent and Trademark Office (USPTO), European Patent Office (EPO), or Japanese Patent Office (JPO) are often used. The USPTO, EPO, JPO are the three patent offices receiving the greatest number of filings both domestically an internationally (OECD, 2004). Therefore, countries have the greatest likelihood of applying for a patent in one of these three countries.

Patent counts reported by organizations such as the USPTO may be an insufficient measure of innovation in a country as innovators in foreign countries are not likely to apply to patent all domestic innovations for protection on the US market. This is because some domestic innovations likely have more domestic appeal than foreign appeal. This might occur because inventions have little use in industrialized, foreign markets or because individuals/firms are not familiar with processes to receive international patents. (Further discussion on the use of patent counts to estimate innovation is explored in Appendix C.1.)

Although USPTO patent counts are a flawed measure of innovative achievements in a country, they are better used to approximate innovation of goods that have potential use abroad. And, if an innovation has a use abroad, it is also a good candidate for export from the domestic innovating country. Therefore, this paper assumes that a country's exports of newly innovated goods is a linear function of the number of patents granted to them by the USPTO. As a consequence, data on USPTO patent grants are used to approximate the number of newly innovated products that are sold in foreign markets, I, in later empirical analysis.

4.3.2 Exports of Existing Goods

The influence of developing country IPRs on exports of existing goods can be modeled using a profit maximization equation for a representative (perfectly competitive) firm that chooses the quantity of goods to produce for the domestic (developing country) market as well as the quantity to produce for the foreign market. The general structure of this component of the theoretical model resembles that used by Aitken, Hanson, and Harrison

(1997). (Aitken, et.al. did not include IPRs or innovation in their model, but they did create a general model for a representative firm's choice in export quantity.)

It is assumed that N firms are identical to one another, so that the impact of an increase in IPRs on the decision making of one representative firm is the same as the impact on the entire country. The quantities the representative firm produces for each market, domestic and foreign, are determined from a profit maximizing equation. Although multiple export markets are likely, for simplicity exporting to the foreign market is considered a single decision.

The profit maximizing equation includes both total costs and total revenues. Total costs for each firm are comprised of firm level production and distribution costs. The equation representing total costs is as follows:

$$h(q_d + q_f, F, A) + m_d(q_d) + m_f(q_f) \tag{4.4}$$

where d represents the domestic market, f represents the foreign market, *h()* is the common function for production costs regardless of the intended market, $m_d()$ is the cost function for distributing the good to the domestic market, $m_f()$ is the cost function for distributing the good to the foreign market, F is a function of fixed production costs that enter additively into the cost function, and A is fixed economy-wide FDI acquisition costs. Since each of the N identical firms acquires an equal proportion of inward FDI, the fixed cost to this acquisition is $\frac{1}{N}$th of total FDI acquisition costs, $A(\theta)$, where θ is total domestic inward FDI. Economy wide inward FDI is assumed to be exogenous, such that each individual firm cannot choose its level of inward FDI.

Total domestic inward FDI is assumed to result in technology transfer to domestic firms, which will make domestic capital more efficient. With more efficient capital, the unit cost of production is lower. Let $k\theta$ represent the reduction in cost due to the technological transfer to the domestic firm that results from inward FDI.

A change in domestic IPRs will cause a chain reaction throughout the domestic economy. An increase in domestic IPRs will reduce imitation in the sector specific to the innovated good. Imitation allows for a more competitive market. Therefore, a reduction in imitation in a given industry corresponds to a social cost associated with moving away from a perfectly competitive market. The reduction in imitation, however, will have a welfare improving effect as foreign firms find it more attractive to invest in the domestic market. Sector specific increases in FDI will generate an increase in economy wide technology transfer to domestic firms, as elements of sector specific FDI can be applied in other sectors where imitation is not a concern to the foreign firm. For example, FDI in one sector may introduce management and production techniques that can be used in a variety of sectors.

It is assumed that the economy wide externalities from an increase in IPRs exceed the social sector-specific costs of moving towards a less competitive market. Theoretically, the overriding positive economy wide effect is captured by the assumption that $\theta'(\beta) > 0$, indicating that strengthening domestic IPRs lead to an increase in inward FDI and a net benefit via technology transfer.

Simple functional forms of the cost functions provide an optimizing equation for exports that leads itself to empirical estimation. The functional form of production costs is detailed in (4.5) and the functional form for distribution costs to the domestic and foreign markets are found in equations (4.6) and (4.7), respectively. These functional forms resemble those used by Aitken, et.al. (1997) and lead to a manageable profit maximization equation.

$$h(q_d + q_f, F) = \frac{a}{2}(q_d + q_f)^2 - k\theta(q_d + q_f) + F + \frac{1}{N}A(\theta) \tag{4.5}$$

$$m_d(q_d) = \frac{b_d}{2}q_d^2 + c_d q_d \tag{4.6}$$

$$m_f(q_f) = \frac{b_f}{2}q_f^2 + c_f q_f \tag{4.7}$$

where k, a, b_d, b_f c_d, and c_f are scalar parameters;

$h(q_d + q_f, F)$ is production costs;

$m_d(q_d)$ is distribution costs to the domestic market;

$m_f(q_f)$ is distribution costs to the foreign market;

F is a function of fixed production costs

A is total FDI acquisition costs for the domestic country

N is the number of (identical) firms in the domestic economy that enter additively;

θ is FDI.

.

The representative firm maximizes profit by choosing the quantity to produce for the domestic market (q_d) and the foreign market (q_f). The profit function in (4.8) embodies total revenue minus total cost for the representative firm.

$$\underbrace{\max}_{q_d, q_f} \pi = P_d q_d + P_f q_f - \frac{a}{2}(q_d + q_f)^2 + k\theta(q_d + q_f) - F - \frac{1}{N}A(\theta) - \frac{b_d}{2}q_d^2 - c_d q_d - \frac{b_f}{2}q_f^2 - c_f q_f \quad (4.8)$$

where P_d and P_f are the price of the (existing) good on the domestic and foreign market, respectively.

Maximization of (4.8) yields the following first order conditions:

$$\frac{\partial \pi}{\partial q_d} : P_d - a(q_d + q_f) + k\theta - b_d q_d - c_d = 0 \quad (4.9)$$

$$\frac{\partial \pi}{\partial q_f} : P_f - a(q_d + q_f) + k\theta - b_f q_f - c_f = 0 \quad (4.10)$$

From the first order conditions shown in (4.9) and (4.10), the implicit function theorem can be used to determine the impact that a change in IPRs will have on the quantity produced for the foreign market.

$$\begin{pmatrix} -a - b_d & -a \\ -a & -a - b_f \end{pmatrix} \begin{pmatrix} \frac{\partial q_d}{\partial \beta} \\ \frac{\partial q_f}{\partial \beta} \end{pmatrix} = - \begin{pmatrix} k\theta_\beta \\ k\theta_\beta \end{pmatrix} \quad (4.11)$$

The Hessian in (4.11) is positive definite. This is demonstrated below in (4.12).

$$
\begin{aligned}
H =&(-a - b_d)(-a - b_f) - (a)^2 \\
=&a^2 + ab_d + ab_f - a^2 \\
=&ab_d + ab_f
\end{aligned}
\tag{4.12}
$$

Since each component of the above equation is positive, it can be concluded that $|H| > 0$.

The implicit function theorem can now be utilized to find the sign of $\frac{\partial q_f}{\partial \beta}$.

$$
\frac{\begin{vmatrix} -a - b_d & -k\theta_\beta \\ -a & -k\theta_\beta \end{vmatrix}}{|H|}
\tag{4.13}
$$

It has already been shown that $|H| > 0$. Therefore, the entire sign of (4.13) will take the sign of the numerator. The numerator is equal to $b_d k\theta_\beta > 0$ indicating that $\frac{\partial q_f}{\partial \beta} > 0$. This implies that stronger IPRs will increase exports of existing goods by each representative firm. Since the representative firm is assumed to be identical to all other firms producing existing goods, exports of existing goods from the domestic economy, $X^{existing} = Nq_f$, where N is the number of firms in the domestic market producing existing goods. It should, therefore, also be noted that $X_\beta^{existing} = N\frac{\partial q_f}{\partial \beta} > 0$.

4.3.3 Total Export Activity

As revealed in equation (4.1), total domestic exports are a linear combination of exports of newly innovated goods and exports of existing goods. Given the linear structure of total exports, the impact of IPRs on total exports is also a linear combination of the impact of IPRs on exports of newly innovated goods and the impact of IPRs on exports of existing goods. As a consequence, the impact of IPRs on total exports is theoretically positive.

$$
X^{total} = X^{new} + X^{existing} \Rightarrow X_\beta^{total} = X_\beta^{new} + X_\beta^{existing} > 0 \tag{4.14}
$$

Given the above theory, there is reason to believe that higher IPRs in developing countries will generate greater export activity. The next step is to explore whether there is empirical evidence of this hypothesis.

4.4 Empirical Estimation

This section first discusses the estimating equation for bilateral exports as derived from the theoretical model. Endogeneity problems and estimation techniques are then explored, and empirical results reported.

4.4.1 Estimating Equation for Exports

The estimating equation for bilateral exports used in this paper models the components of X_β^{total}. This includes components from equation (4.3)

$$X_\beta^{new} = MI'(\beta)$$

and equation (4.13)

$$X_\beta^{existing} = N\frac{\partial q_f}{\partial \beta} = N\frac{b_d k \theta_\beta}{ab_d + ab_f}.$$

When combined, the following equation is obtained:

$$\begin{aligned} X_\beta^{total} =& X_\beta^{new} + X_\beta^{existing} \\ =& MI'(\beta) + N\frac{b_d k \theta_\beta}{ab_d + ab_f}. \end{aligned} \tag{4.15}$$

where

a, b_d, b_f, and k are scalar parameters in the production and distribution costs functions,

θ is FDI,

N is the number of firms in the domestic market producing existing goods

M is a linear function (related to the size of the importing market) that determines how many of each newly innovated good will be exported,

I is the number of newly innovated goods appropriate for sale on the foreign market,

β is the level of domestic IPRs.

While it is not practical to estimate (4.15) directly, the estimating equation for bilateral exports used in this paper approximates (4.15). This estimating equation is as follows:

$$\begin{aligned} \log X_{dft} =& \alpha_0 + \alpha_1 \log(\text{GDP})_{dt} + \alpha_2 \log(\text{GDP})_{ft} + \alpha_3 \log(\widehat{\text{Innovation}})_{dt} \\ &+ \alpha_4 \log(\widehat{\text{FDI}})_{dt} + \alpha_5 \log(\text{IPR})_{dt} - \alpha_6 \log(\text{distance})_{df} + \varepsilon_{dft} + \mu_d + \eta_t. \end{aligned} \tag{4.16}$$

where d denotes the domestic country, f denotes the foreign country, and X_{dft} is the value of exports from country d arriving in country f at time t.[4] The estimating equation in (4.16) resembles the logged transformation of the gravity model for bilateral trade flows, which has proven to be successful in estimating bilateral trade flows.[5] (The theoretical basis of the gravity model for trade hinges on the supply and demand forces between two countries. These supply and demand forces are related to the relative economic size of the two trading countries, adjusting for the distance between them.)

Each variable included as a regressor in (4.16) can be linked to a component of equation (4.15) in the theoretical model. Domestic and foreign GDP capture the relative size of the exporting and importing markets and are used to approximate the information embodied in N and M, respectively. A measure of innovation is included to capture the effects of I in (4.15). A measure of inward FDI is included as a regressor to approximate the impact of θ on bilateral exports. The variable for physical distance between trade partners is included to capture the effect b_d and b_f, which are scalars in the cost function for distributing goods.

[4] The estimating equations for $\widehat{\text{Innovation}}$ and $\widehat{\text{FDI}}$ will be discussed in more detail later.

[5] See Anderson (1979), Bergstrand (1985, 1989), Deardorff (1995), Feenstra et. al. (2001) and Eaton and Kortum (2002).

Notice that the sign on the distance equation is negative, signaling that distribution costs will be higher the greater the distance between trading partners, which will have an expectedly negative impact on bilateral exports. Lastly, a measure for IPRs, β, is also included in the regressor to capture the effect that IPRs on export activity.

A Tobit model is used to estimate bilateral trade flows as it accounts for the possibility of zero trade. The Tobit model contains a discrete component, which accounts for differences between zero and positive trade values, as well as a continuous component, which accounts for the distribution among positive trade values. Generally speaking, the Tobit is specified as follows:

$$y^*_{it} = x'_{it}\beta + \epsilon_{it}$$

$$y_{it} = y^*_{it} \text{ if } y^*_{it} > 0$$

$$y_{it} = 0 \text{ if } y^*_{it} = 0.$$

where y_{it} is the dependent variable and x_{it} is the vector of independent variables.

4.4.2 Problems with Endogeneity

From the theoretical model, it has been established that both innovation and foreign direct investment are functions of IPRs in a given period. As a result some of the regressors in equation (4.16) are correlated with the error term. Estimating (4.16) using OLS would, therefore, lead to inconsistent and biased results. An instrumental variables approach is instead used to mitigate endogeneity among regressors.

The estimating equation in (4.16) contains two endogenous variables. Therefore, in order to utilize instrumental variable estimation, at least two variables must be identified that are correlated with FDI and/or innovation, but uncorrelated with the error term in the export equation. These excluded exogenous variables will serve as instruments in the empirical estimation of bilateral exports.

In order to identify instruments, it is first important to identify which variables are correlated with the two endogenous variables. In doing so, the estimating equation for innovation is first explored, followed by the estimating equation for FDI.

Estimating Innovation

Chen and Puttitanun (2005) model innovative output as a function of IPRs, per capita GDP, tertiary school enrollment rates, economic freedom, and population. Schneider (2005) estimated innovation as a function of IPRs, human capital stock, high technology imports, research and development, GDP, FDI, and infrastructure. The production function for innovation used in this paper is assumed to take a Cobb-Douglas form with inputs that closely resemble those used by Chen and Puttitanun.

Innovation is assumed to be a function of domestic IPRs, domestic GDP, tertiary school enrollment rates, business environment, population, and R&D expenditures. Each α coefficient in the estimating equation can be interpreted as the elasticity of that variable with respect to innovation. In most research where innovation is the dependent variable,[6] each explanatory variable is assumed to have a constant elasticity such that a change in the explanatory variable will have the same change in innovation, regardless of the initial value of the variable. The constant elasticity of the explanatory variables is captured by the fact that each explanatory variable enters into log form in equation (4.17), below.

$$\begin{aligned}\log(\text{Innovation})_{it} =& \alpha_0 + \alpha_1 \log(\text{IPR})_{it} + \alpha_2 \log(\text{R\&D})_{it} + \alpha_3 \log(\text{GDP})_{it} \\ &+ \alpha_4 \log(\text{tertiary school enrollment})_{it} + \alpha_5 \log(\text{business environment})_{it} \\ &+ \alpha_6 \log(\text{population})_{it} + \varepsilon_{it} + \mu_i + \eta_t.\end{aligned} \tag{4.17}$$

Innovation is expected to have a positive relationship with all of the above variables. A more sound business environment creates an economic environment capable of effectively utilizing innovation. Population is included as a regressor so to control for possible scale effects that may arise from the assumption that countries with larger populations will likely

[6] See Smith (2005), Chen and Puttitanun (2005), Hausman, Hall, and Griliches (1984, 1986).

have a larger number of innovations (or patent counts) simply because they are more populous. Chen and Puttitanun (2005) provided theoretical support for the expected positive relationship between IPRs and innovation; in other words, they found theoretical support for the previously assumed notion that $I'(\beta) > 0$. This assumption arises from the belief that stronger IPRs support an environment conducive to innovation. Chen and Puttitanun also provided theoretical support for the positive relationship between innovation and output concluding that innovation will be greater in more developed countries.

A discussion of the specific data used to estimate (4.17) will take place later in the paper. Before doing so, however, an estimation equation for the second endogenous variable, inward FDI, is discussed.

Estimating Inward FDI

There are many components that impact inward FDI in a country. It is assumed that:

$$\text{Inward FDI} = f(\text{IPRs, business environment, GDP, population, K in the previous period}) \quad (4.18)$$

Each of the variables in (4.18) is expected to have a positive impact on FDI. Stronger IPRs in country i should attract more inward FDI into this country. In addition, a more sound business environment will also attract more FDI. The larger a country, as approximated by GDP, the greater the capacity for inward FDI. Similarly, the more populous a country, the greater the opportunity for domestic labor to support inward FDI. Lastly, capital stock in the previous period is related to how attractive foreign investors may find the market in the current period. In the context of developing countries, higher levels of capital stock in the previous period suggest that the domestic economy may be able to support further capital investments, therefore making the domestic market more attractive to inward FDI. This contrasts with the possible effect that higher levels of capital in the previous period signal a saturated market, which is better suited for developed countries.

As with the production function for innovation, the production function for FDI is assumed to be Cobb-Douglas in form. Such a Cobb-Douglas form lends itself to an estimation equation for FDI that is linear in logs. The specific estimating equation for inward FDI is as follows:

$$
\begin{aligned}
\log(\text{Inward FDI})_{it} =& \theta_0 + \theta_1 \log(\text{IPRs})_{it} + \theta_2 \log(\text{business environment})_{it} \\
&+\theta_3 \log(\text{GDP})_{it} + \theta_4 \log(\text{population})_{it} + \theta_5 \log(K)_{i,t-5} + \varepsilon_{it} + \mu_i + \eta_t
\end{aligned}
\tag{4.19}
$$

where $t-5$ represents the previous period for which there is complete data. (Data on the IPR Index is available every fifth year.)

Empirical estimation of the innovation and FDI equations support that the specified independent variables are in fact statistically significant in explaining innovation and inward FDI, respectively.

Identification

Given the explanatory variables for innovation and inward FDI listed in (4.17) and (4.19), respectively, the bilateral export equation is over-identified. The number of excluded exogenous variables in the innovation equation (R&D expenditures, tertiary school enrollment, business environment, population of the domestic economy, and capital in the previous period) exceeds the number of included endogenous variables in the bilateral export equation (innovation and inward FDI). Over or exact-identification is a necessary condition for two stage, instrumental variables estimation.

Empirical tests indicate that the above excluded exogenous variables are valid instruments in that they are not correlated with the error term in the export equation. To test this, tertiary school enrollment, business environment, and physical capital in the previous period are included in the estimation equation for bilateral exports, leaving R&D expenditures and population in the domestic economy to serve as instruments in the two-stage estimation.

A joint F-test supports that tertiary school enrollment, business environment, and capital in the previous period are jointly insignificant in determining bilateral exports. Then, R&D expenditures and population in the domestic economy are included in the estimation equation for bilateral exports leaving tertiary school enrollment, business environment, and capital in the previous period to serve as instruments in the two-stage estimation. Again, a joint F-test supports that R&D expenditures and population in the domestic economy are jointly insignificant in determining bilateral exports.

4.4.3 Data Description

In order to estimate exports from developing countries, criteria for "developing" must first be established. A country is considered "developing" if it is a low or lower-middle income country. Country classifications were obtained from the World Bank. A country is considered low income if 2005 per capita GNI is below $875, while a country is considered lower-middle income if 2005 per capita GNI is between $876 and $3,465.

The dependent variable in the export equation is bilateral exports from developing countries. Data on bilateral trade flows were obtained from the United Nation's Commodity Trade Database (Comtrade). Trade values for imports from the UN's Comtrade database are stated in "free on board" (fob) terms. This means the value reported for export data includes the transaction value of the good and the cost to transport the good to the border of the exporting country, as well as loading costs. Trade values, rather than trade quantities, are used so to keep the data measurements consistent across countries and commodities.[7]

Independent variables in the bilateral export equation include GDP for the reporting and partner country, and inward FDI, innovation, and IPRs in the reporting country. Data on GDP were obtained from the World Development Indicators database. Data on inward FDI flows as reported on the country's balance of payments were also obtained from the World Development Indicators database. FDI flows are reported in current US dollars. However,

[7] Although the home country originally reports these trade values in their current national currency, the UN applies the current dollar exchange rate so that all available trade value data is reported in current US dollars. The trade values are made consistent by using the consumer price index to adjust trade values to constant 2000 US dollars.

the US consumer price index was used to convert inward FDI flows into constant 2000 US dollars, so that multi-period analysis can accurately be interpreted.

As previously discussed, US patent grants are used to approximate innovation in each country. This data is available from the United States Patent and Trademark Office (USPTO). Countries will likely apply for a patent in the United States if the innovation is significant and, particularly, if the innovation is "valuable" internationally. In addition, collecting patent grants from a standardized source, such as the USPTO, is critical as different countries have different patent regimes in place.[8] Historical data on USPTO patent counts were obtained from the World Bank database created by Lederman and Saenz (2005).[9]

The *distance* variable accounts for the geographical distance between the "most important" cities in each trading partner according to population and agglomeration economies. Physical distance is used as a proxy for transportation costs such that the greater physical distance, the greater the costs associated with transporting goods. The sign of the physical distance coefficient is therefore expected to be negative. Data on these variables was obtained from CEPII distance database.[10]

Data were collected for the years 1975, 1980, 1985, 1990, 1995, and 2000. The sample was limited to every fifth year as the index of IPRs used is only available every five years. The Ginarte-Park Index for IPRs is currently the most widely accepted index to approximate patent protection in a country. The index ranges from zero to five, with five being the highest possible level of patent protection. The index is comprised of a series of scores stemming from five different areas of patent protection. These areas include: (1) coverage of certain innovative areas, (2) country membership in international treaties, (3) safeguards against loss of protection, (4) enforcement of patent laws, and (5) duration of protection. In general, the index captures the strength of patent rights in a given country.

[8]For example, the patent system in Japan is set up so that many patents are needed to achieve the same level of breadth of coverage that can be achieved with a single US patent. The breadth of the Japanese patent system widened in 1988 at the onset of a new patent system, so to more resemble that of the United States. Nonetheless, patent breadth remains narrower in Japan compared to the US.

[9]Lederman and Saenz compiled a data set of various patent and R&D variables, which is discussed in their 2005 work. The data set is available at http://go.worldbank.org/NNIBBIHTA0.

[10]http://www.cepii.fr/anglaisgraph/bdd/distances.htm

Recall, the excluded exogenous variables are R&D expenditures, tertiary school enrollment, business environment, population of the domestic economy, and capital in the previous period. Data on *R&D* expenditures as a percent of GDP was obtained from the Lederman and Saenz (2005) data, and were converted to stock *R&D* expenditures by multiplying *R&D* expenditures as a percent of GDP with GDP in constant 2000 US dollars.[11] It is important to use *R&D* expenditures rather than *R&D* expenditures as a percent of GDP as GDP is included as a regressor, and including a measure of *R&D* that is weighted by GDP would create endogeneity among the data.

Data on tertiary school enrollment rates were obtained directly from the UNESCO web site.[12] Data on total population were obtained from the World Bank's World Development Indicators. The a subindex of the *Economic Freedom of the World Index* that captures the "regulation of credit, labor, and business" is used to measure a country's business environment.

Finally, data on physical capital stock between 1960 and 1990 was obtained from Nehru and Dhareshwar (1995). This data is provided in the domestic country's currency in constant 1987 prices. In order to make cross-country comparisons of capital stock, the Nehru and Dhareshwar data was converted into constant 1987 US dollars by using the average period market exchange rate obtained from the IMF's *International Financial Statistics* database. In addition, capital stock for the years since 1990 (for which Nehru and Dhareshwar data is unavailable) was estimated using gross capital formation data as provided by the World Bank's WDI database.[13]

[11] Lederman and Saenz compiled data on *R&D* expenditures using UNESCO yearbooks.

[12] While data for tertiary school enrollment rates was already available in a downloadable, panel form, data for R&D was not, which is why R&D data was obtained from Lederman and Saenz. The web site for which historical school enrollment data is listed is http://www.uis.unesco.org/en/stats/statistics/indicators/i_pages/indic_5.htm.

[13] The first step in expanding the capital stock data is to convert gross capital formation into constant 1987 US dollars by using the GDP deflator. Data on gross capital formation in constant local currency units as well as the GDP deflator was obtained from the WDI database. After compatible data on gross capital formation was calculated, the capital stock was expanded using the following equation for the evolution of capital stock: $K_{i,t+1} = K_{i,t}(1-\delta_i) + \text{Gross Capital Formation}_{i,t+1}$ where δ_i represents the average capital depreciation rate specific to each country. This country specific capital depreciation rate corresponds to the ten-year average rate of capital depreciation in a specific country for the years 1981 to 1990 (i.e. the last ten years for which capital stock data from Nehru and Dhareshwar was available). This ten year average was

Descriptive statistics for (non-dummy) data used in the estimation equations, as described above, can be found in Table 4.1.

Table 4.1: Descriptive Statistics: Low & Lower-Middle Income Countries
(Panel Data, 1975, 1980, 1985,..., 2000)

	Obs.	Mean	Std. Dev.	Min.	Max
log(IPR Index)	23335	0.747	0.421	-1.109	1.311
log(Value of Bilateral Exports)	24055	9.711	6.829	0	24.678
log(USPTO Patent Grants)	24055	0.503	1.041	0	4.875
log(FDI inflows)	21950	22.301	2.552	13.693	28.976
log(Distance)	23254	8.713	0.784	4.656	9.892
log(GDP partner country)	49573	23.890	2.157	18.612	29.910
log(GDP reporting country)	23883	23.282	1.635	19.940	27.812
log(Population)	23983	16.695	1.533	13.264	20.956
log(R&D expenditures)	5516	23.667	2.136	18.918	27.812
log(Tertiary School Enrollment)	22842	1.691	1.120	-2.303	3.902
log(Business Environment)	19803	1.619	0.203	0.993	1.932
log(Lagged K Stock)	19498	25.460	4.118	20.756	42.739

Note: In order to account for zero trade values, a Tobit regression procedure is used to estimate bilateral exports. Thus, a trade value of zero also assumes a logged value equal to zero. Similarly, zero USPTO patent grants assumes a logged value equal to zero.

4.4.4 Empirical Results

Bilateral exports originating in low and lower-middle income countries (to all countries) are estimated in Table 4.2, using the two-stage, instrumental variable approach previously described. The two-stage Tobit model can be calculated using one of the two estimating procedures: (1) Newey's efficient two-step estimator or (2) maximum likelihood estimation. Although maximum likelihood estimation is commonly used in instrumental variables, this paper utilizes Newey's two-step estimator. The benefit of the Newey two-step estimator is that it does not require convergence to determine the initial values, which proved to be difficult in practice. Difficulty with convergence, however, may signal that the first stage is misspecified. To verify that this is not the case, joint significance of the exogenous variables in the innovation and inward FDI equations is tested in the first stage. In doing so,

calculated using capital stock data from Nehru and Dhareshwar (1995) and gross capital formation from the WDI database.

it is confirmed that the exogenous variables are jointly statistically significant in determining innovation and inward FDI. Therefore, the Newey two-step estimator is the preferred estimation method for all instrumental variable, Tobit regressions.

When accounting for endogeneity of innovation and FDI in the benchmark instrumental variable equation, innovation and inward FDI each have a positive impact on bilateral exports in developing countries, as previously suggested by the theory. Neither innovation or FDI, however, is statistically significant.

Of particular interest for this paper is the positive sign and significance of the IPR variable. While IPRs may have a direct effect on export activity, the full impact of IPRs is not captured by the IPR variable in column I of Table 4.2.[14] This is because there are indirect effects of IPRs on exports via increased innovation and FDI. Because of the non-linear nature of the two-stage instrumental variable estimation, in order to evaluate the total effect of IPRs on export behavior, exports should be estimated using a reduced form equation that includes all exogenous variables.[15]

The reduced form results reported in column II of Table 4.2 enables the complete impact of IPRs on export activity to be better interpreted. This complete impact includes the impact that IPRs directly has on export activity as well as the indirect impact IPRs have on export activity via innovation and FDI. The reduced form estimation reveals that the total effect of IPRs is both positive and statistically significant in impacting developing country exports. This result suggests that IPR policies increase export activity in developing countries.

An Alternate Specification

An alternate specification to the benchmark equation is explored in Table 4.3. The estimation specification used to derive the results in Table 4.3 account for the possibility

[14]The first stage results for innovation and inward FDI are reported in Appendix $C.2$.

[15]An alternate approach to estimating the direct effect of IPRs on developing country export activity is to estimate a structural model. One downside to this approach is that misspecification would lead to biased results. A reduced form equation for which all variables are exogenous eliminates problems with misspecification bias. Nonetheless, estimation of a structural model is a worthwhile avenue to explore in future research.

Table 4.2: Bilateral Exports with Inward FDI in Current Period
(Low & Lower-Middle Income Countries)

	I	II
	Instrumental Estimation	Reduced Form Estimation
log(IPRs)	2.20*	4.05*
	(3.55)	(4.91)
log(Inward FDI)	0.13	
	(0.50)	
log(Innovation)	1.06	
	(1.14)	
log($GDP_{partner}$)	1.51*	1.54*
	(35.52)	(36.71)
log($GDP_{reporter}$)	1.08	2.14**
	(0.96)	(1.96)
log(Distance)	-3.06*	-3.15*
	(-22.56)	(-23.62)
1980	1.30***	-0.06
	(1.95)	(-0.06)
1985	2.03***	-1.12
	(1.94)	(-0.72)
1990	0.22	-2.15
	(0.27)	(-1.04)
1995	1.58	-0.72
	(1.11)	(-0.28)
2000	0.40	-2.26
	(0.19)	(-0.75)
log(R&D Expenditures)		0.16
		(0.44)
log(Business Environment)		-3.71**
		(-2.13)
log(K in previous period)		-1.17
		(-1.18)
log($Population_{reporting}$)		9.92**
		(2.09)
log(Tertiary School Enrollment)		0.08
		(0.11)
Constant	-29.97	-170.71**
	(-1.29)	(-2.14)
Observations	3836	4366

Note: z-statistics are in parenthesis in column I. t-statistics are in parenthesis in column II. Instrumental variable Tobit estimation was conducted using Newey's efficient two-step estimation procedure. $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance. The comparison year is 1975. Country fixed effects are also found in empirical estimation, but not reported. The difference in observation between columns I and II is a result of the limited number of observations with inward FDI data in 1975. This discrepancy in the number of observations does not appear when dealing with lagged data, as in Table 4.3.

Table 4.3: Bilateral Exports with Lagged Inward FDI
(Low & Lower-Middle Income Countries)

	I	II
	Instrumental Estimation	Reduced Form Estimation
log(IPRs)	0.40	2.55**
	(0.48)	(2.06)
log(Lagged Inward FDI)	-0.20**	-0.02
	(-1.99)	(-0.20)
log(Innovation)	-2.23*	
	(-3.42)	
log($GDP_{partner}$)	1.48*	1.48*
	(35.89)	(35.96)
log($GDP_{reporter}$)	3.07*	1.64***
	(3.40)	(1.81)
log(Distance)	-3.03*	-3.03*
	(-23.47)	(-23.52)
1980	0.20	-0.76
	(0.39)	(-0.88)
1985	0.07	-2.10
	(0.12)	(-1.45)
1990	2.05*	-3.99**
	(2.83)	(-2.08)
1995	5.33*	-2.71
	(5.71)	(-1.13)
2000	6.74*	-3.76
	(4.71)	(-1.28)
log(R&D Expenditures)		0.06
		(0.15)
log($Population_{reporting}$)		14.47*
		(3.02)
log(Business Environment)		-1.92
		(-0.96)
log(Tertiary School Enrollment)		-1.28
		(-1.30)
Constant	-65.13*	-331.79*
	(-2.90)	(-3.09)
Observations	4198	4198

Note: z-statistics are in parenthesis in column I. t-statistics are in parenthesis in column II. Instrumental variable Tobit estimation was conducted using Newey's efficient two-step estimation procedure. $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance. The comparison year is 1975. Country fixed effects are also found in empirical estimation, but not reported.

that FDI will not impact export activity immediately, but rather after some fixed amount of time has passed. Therefore, the possibility that FDI has a lagged effect on exports is tested by substituting a lagged value for inward FDI in the benchmark equation. Since complete data is available every five years, it is assumed that the lagged impact of FDI on export activity occurs after five years.

Assuming that lagged FDI impacts export activity, rather than FDI in the current period, mitigates concerns that inward FDI is endogenous with export activity. Therefore, lagged FDI is assumed exogenous in Table 4.3. This also means that the instruments used in the first stage no longer include a measure for lagged capital stock, as this appeared only in the estimating equation for inward FDI.

When lagged FDI is considered, the overall results of the instrumental variables estimation appear less convincing. This is largely because the coefficients on innovation and lagged inward FDI are significantly negative, which goes against intuitive expectations about the sign of these variables. This non-intuitive result may stem from the fact that FDI is lagged by five years, which could be too long of time lag to have an impact on export activity. Data restrictions prohibit estimation using a shorter period.

Regardless of these potential problems in the estimation, the sign of the IPR variable remains positive. It is not, however, statistically significant. In the reduced form estimation in column II, which accounts for total impact of IPRs (including the indirect effect of IPRs via innovation), IPRs are statistically significant. This is a critical result, as it mirrors those results found in the original specification presented in Table 4.2.

The overriding result in both Table 4.2 and Table 4.3 is that IPRs have a significant and positive impact on bilateral exports. This suggests that IPR policies may, in fact, go hand in hand with export promotion policies in developing countries.

Comparison to Developed Country Exports

So far, the impact of IPRs on export activity of developing (low and lower-middle income) countries has been explored. It is of interest, however, to see how these results compare with the export activity of developed countries.[16] Given the outlined theoretical model, there is no reason to believe that the effect of developed country exports should be any different than that of developing countries.

Developed countries are classified using the World Bank's classification of high-income countries. Countries are considered high-income if they have 2005 per capita GNI greater than $10,725. Descriptive statistics for these high income countries can be found in Table 4.4.

Table 4.4: Descriptive Statistics: High Income Countries Only
(Panel Data, 1975, 1980, 1985,..., 2000)

	Obs.	Mean	Std. Dev.	Min.	Max
log(IPR Index)	18858	1.185	0.252	0.637	1.609
log(Value of Bilateral Exports)	18858	13.902	6.399	-0.064	26.204
log(USPTO Patent Grants)	17617	5.354	2.559	0	11.351
log(FDI inflows)	15987	25.417	2.393	19.475	31.101
log(Distance)	17846	8.686	0.814	4.088	9.891
log(GDP partner country)	17457	23.671	2.140	18.612	29.910
log(GDP reporting country)	18858	25.702	1.756	20.662	29.910
log(Population)	18858	16.086	1.560	12.292	19.458
log(R&D expenditures)	11208	26.723	1.925	19.519	30.902
log(Tertiary School Enrollment)	18275	3.372	0.625	1.163	4.551
log(Business Environment)	18274	1.786	0.170	1.194	2.175
log(Lagged K Stock)	14671	27.752	2.902	21.660	36.125

Note: Zero USPTO patent grants assume a logged value equal to zero.

Table 4.5 presents results for bilateral exports from high income countries. Estimation procedures for Table 4.5 are identical to those used to estimate Table 4.2. Unlike the results found in Table 4.2 and Table 4.3, which focused on developing countries, IPR policies do not have a statistically significant impact on the export activity in developed countries. This suggests that bilateral exports in developed countries are not significantly impacted by the level of domestic IPRs in these countries.

One explanation for the contrasting insignificant impact of domestic IPRs on developed country exports could be that innovation and inward FDI in developed countries is less dependent on the level of IPRs than it may be in developing countries. This would be con-

[16] The question of how IPRs impact the export activity of developed countries was asked in Briggs (2008b). Briggs (2008b), however, considered the impact of foreign IPRs on developed country high technology exports specifically to developing countries, which is a more narrow question than what is preliminarily explored here.

Table 4.5: Bilateral Exports (High Income Countries)

	I	II
	Instrumental Estimation	Reduced Form Estimation
log(IPRs)	0.83	1.02
	(0.79)	(0.98)
log(Inward FDI)	-0.02	
	(-0.10)	
log(Innovation)	-0.09	
	(-0.16)	
log($GDP_{partner}$)	0.95*	0.94*
	(34.97)	(35.16)
log($GDP_{reporter}$)	2.95	3.28**
	(1.17)	(2.39)
log(Distance)	-0.55*	-0.57*
	(-6.74)	(-7.24)
1980	0.91***	0.95*
	(1.73)	(3.33)
1985	0.56	0.62**
	(0.87)	(2.17)
1990	0.06	0.07
	(0.06)	(0.19)
1995	1.38	1.57*
	(1.10)	(2.78)
2000	1.58	1.82*
	(1.01)	(2.70)
log(R&D Expenditures)		0.05
		(0.12)
log(Business Environment)		-1.81
		(-1.44)
log(K in previous period)		-1.50**
		(-1.93)
log($Population_{reporting}$)		2.74
		(1.22)
log(Tertiary School Enrollment)		0.59
		(1.32)
Constant	-81.01	-106.72*
	(-1.34)	(-1.92)
Observations	7883	8278

Note: z-statistics are in parenthesis in column I. t-statistics are in parenthesis in column II. Instrumental variable Tobit estimation was conducted using Newey's efficient two-step estimation procedure. $* = 99\%$ significance, $** = 95\%$ significance, $*** = 90\%$ significance. The comparison year is 1975. Country fixed effects are also found in empirical estimation, but not reported. The difference in observation between columns I and II is a result of the limited number of observations with inward FDI data in 1975. This discrepancy in the number of observations does not appear when dealing with lagged data, as in Table 4.3.

sistent with the belief that innovation in developed countries occurs so rapidly and becomes outdated so quickly that stronger patent protection brings relatively less in the way of extra incentives to innovate compared to that in developing countries. The prevalence of new goods available to export in developed countries is consistently present. In addition, inward FDI in developed countries may be less dependent on the strength of IPRs in developed countries and more on cyclical market confidence and macroeconomic stability.

While this paper does not provide a thorough analysis of total export activity in developed countries, it provides a preliminary comparison to the impact of domestic IPRs on total exports in developing countries, which is more thoroughly explored in this paper.

4.5 Conclusion

In theory, the implementation of domestic IPRs should increase export activity in countries. Empirical evidence also shows that domestic IPRs have a positive, statistically significant impact on developing country exports. IPRs impact export activity directly as well as indirectly through innovation and FDI. Similar preliminary evaluation of the impact of IPRs on export activity in developed countries fails to exhibit this same statistically significant effect. The results linking stronger IPRs to increased export activity in developing countries suggest that IPR policies and outward oriented development policies in this countries countries may be positively linked. This is something that proponents of IPRs in developing countries have been proclaiming for a while, and this paper provides some evidence in support of this claim.

Appendix A

Appendix for Essay One

A.1 Summary of Empirical Results from Past Literature

Table A.1: IPR Regression Results from Past Literature

Variable	GP OLS	Maskus (1) OLS	Maskus (2) OLS	CP (1) OLS	CP with time dummies OLS
per capita GDP	0.23*	-3.38*	-2.58*	-0.27*	-0.22**
	(0.03)	(2.09)	(0.64)	(0.11)	(0.12)
per capita GDP squared		0.22*	0.17*	0.02*	-0.02*
		(0.03)	(0.40)	(0.01)	(0.01)
School Enrollment Ratio			-0.01	0.02	-0.01
			(0.08)	(0.03)	(0.03)
Openness			0.06	-0.04	-0.05
			(0.08)	(0.03)	(0.03)
Economic Freedom				0.14	0.11
				(0.01)	(0.11)
GDP			-0.01		
			(-0.67)		
(scientists + engineers)/LF			0.08*		
			(0.03)		
Former UK colony			0.23*		
			(0.07)		
Former French colony			0.33*		
			(0.13)		
WTO				0.11*	0.10
				(0.05)	(0.10)
constant	-1.06*	13.61*	10.76*	not reported	not reported
	(0.20)	(2.09)	(2.47)		
No. of Observations	192	144	144	211	211
Adjusted R squared	0.31	0.33	0.37	not reported	not reported

Note: Standard errors are in parenthesis. $*$ indicates more than 95% significance. $**$ indicates 94% significance. All variables are logged except for colony, time and WTO dummies. Years covered by Ginarte-Park (GP) are 1965, 1975, 1985, and 1990; by Maskus are 1985 and 1990; by Chen-Puttitanun (CP) are 1985, 1990, 1995, and 2000. CP results are for developing countries only, while GP and Maskus use data for both developed and developing countries. LF=Labor Force.

The above table reports the regression results for IPRs from Ginarte and Park (GP) (1997), Maskus (2000), and Chen and Puttitanun (CP) (2005), as discussed in the above lit-

erature review. The two-stage model specification for CP is as follows: IPRs = f(per capita GDP, per capita G
for IPRs and INNOVATION = f(IPRs, per capita GDP, tertiary school enrollment, economic freedom, popu
for innovation, where the estimated innovation results are used in the IPR equation.

The results in Table A.1 indicate that standard OLS analysis of panel data on IPRs and per capita income yeild a U-shape link between the two variables. Similar results are found using the updated GP Index and per capita GDP (in constant US dollars). These results are presented in Table A.2.

Table A.2: Preliminary Results for IPR Choice

	Linear	Quadratic
logged per capita GDP	0.25*	-1.65*
	(13.72)	(-8.59)
logged per capita GDP squared		0.13*
		(10.11)
constant	0.72*	7.62*
	(5.13)	(10.48)
N	839	839
R^2	0.1980	0.3092

Note: t-statistics are in parenthesis. $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance. Standard errors have been adjusted using White's correction.

According to the results in Table A.2 the U-curve reaches a minimum at approximately $\log(GDP) = 6.67$, which translates into a per capita income of US$785 (in 2000 US dollars).[1] This simplistic estimation procedure does not provide evidence as to whether the U-shape relationship is driven by longitudinal or cross-sectional forces, but it does confirm that preliminary results using the updated GP Index are similar to those found in past literature.

[1]Calculations were made using data expanded to five decimal places.

A.2 Ginarte-Park Index of Patent Rights

Table A.3: Ginarte-Park Index of Patent Rights: Categories and Calculations

(1) Coverage		
	Available	**Not Available**
Patentability of pharmaceuticals	1/7	0
Patentability of chemicals	1/7	0
Patentability of food	1/7	0
Patentability of plant and animal varieties	1/7	0
Patentability of surgical products	1/7	0
Patentability of microorganisms	1/7	0
Patentability of utility models	1/7	0
(2) Membership in International Treaties		
	Available	**Not Available**
Paris Convention and Revisions	1/3	0
Patent Cooperation Treaty	1/3	0
Protection of New Plant Varieties (UPOV)	1/3	0
(3) Protection Against Losses Arising from:		
	Available	**Not Available**
"Working" Requirements	1/3	0
Compulsory Licensing	1/3	0
Revocation of Patents	1/3	0
(4) Enforcement		
	Available	**Not Available**
Preliminary Injunctions	1/3	0
Contributory Infringement	1/3	0
Burden-of-Proof Reversal	1/3	0
(5) Duration of Protection		
	Full*	**Partial* or No Protection**
	1	f/(full protection)

*Note**: Full duration of protection is 20 years from the date of application or 17 years from the date of grant (depending on whether the country has an application or grant based system). The duration of protection as a fraction of full protection is equal to f/(full protection) such that f/(full protection) is between zero and one. Note 1: Each category is scored between 0 and 1. The index is comprised by adding the score for each category. Note 2: The composition of the GP Index as described in the above table resembles that found in Appendix A of Ginarte and Park (1997) as well as *Economic Freedom of the World* 2001 Annual Report.

A.3 Identifying the "Critical" Cross-Sectional Year

Table A.4: Specification for the 'Critical" Cross-Sectional Year

Country	Year Joined Paris Convention	Rounded Year	IPR in Rounded Year	Logged per capita GDP in Rounded Year
Algeria	1966	1970	3.38	7.243078
Argentina	1967	1970	1.93	8.797403
Australia	1925	1965	2.90	9.207758
Austria	1909	1965	3.38	9.105095
Bangladesh	1991	1995	2.32	5.714601
Belgium	1884	1965	3.38	9.112437
Benin	1967	1970	2.52	5.684398
Bolivia	1993	1995	2.31	6.854131
Botswana	1998	2000	2.24	8.004244
Brazil	1884	1965	1.64	7.26867
Burkina Faso	1963	1965	2.10	5.100389
Burundi	1977	1980	2.86	4.839107
Cameroon	1964	1965	2.10	6.154122
Canada	1925	1965	2.76	9.311739
Central African Rep.	1963	1965	2.10	5.787224
Chad	1963	1965	2.38	5.458616
Chile	1991	1995	3.07	8.365095
Congo, Dem. Rep.	1975	1975	2.86	5.759536
Congo, Rep.	1963	1965	2.10	6.458126
Costa Rica	1995	1995	1.80	8.19082
Cote d'Ivoire	1963	1965	2.38	6.516385
Czech Republic	1993	1995	3.19	8.520643
Denmark	1894	1965	2.66	9.654785
Dominican Republic	1890	1965	2.26	6.619038
Ecuador	1999	2000	3.57	7.16664
Egypt	1951	1965	1.99	6.306225
El Salvador	1994	1995	2.86	7.59751
Finland	1921	1965	1.99	9.097638
France	1884	1965	3.10	9.164486
Gabon	1964	1965	2.10	7.774975

Country	Year Joined Paris Convention	Rounded Year	IPR in Rounded Year	Logged per capita GDP in Rounded Year
Ghana	1976	1980	2.57	5.4534
Greece	1924	1965	2.46	8.384
Grenada	1998	2000	2.51	8.305833
Guatemala	1998	2000	1.56	7.454464
Guyana	1994	1995	1.42	6.745617
Haiti	1958	1965	3.19	6.532083
Honduras	1994	1995	2.10	6.81621
Hong Kong	1997	2000	3.05	10.119
Iceland	1962	1965	2.12	9.416005
India	1998	2000	2.18	6.109697
Ireland	1925	1965	2.56	8.664925
Israel	1950	1965	3.37	8.892984
Italy	1884	1965	3.32	8.895614
Jamaica	1999	2000	3.22	8.039177
Japan	1899	1965	3.18	9.27008
Jordan	1972	1975	1.86	7.019552
Kenya	1965	1965	2.04	5.565759
Korea, Rep.	1980	1980	3.28	8.077585
Liberia	1994	1995	2.86	4.034598
Lithuania	1994	1995	2.90	7.844923
Luxembourg	1922	1965	2.29	9.543539
Madagascar	1963	1965	1.05	5.905131
Malawi	1964	1965	2.70	4.691645
Malaysia	1989	1990	2.70	7.842833
Mali	1983	1985	2.57	5.149384
Malta	1967	1970	1.89	7.502462
Mauritania	1965	1965	2.10	5.827742
Mauritius	1976	1980	2.89	7.355027
Mexico	1903	1965	1.70	8.03862
Morocco	1917	1965	2.38	6.426567
Nepal	2001	2000	3.19	5.415621
Netherlands	1884	1965	3.29	9.259804
New Zealand	1931	1965	3.18	9.159622
Nicaragua	1996	2000	1.59	6.676875
Niger	1964	1965	2.10	5.84994

Country	Year Joined Paris Convention	Rounded Year	IPR in Rounded Year	Logged per capita GDP in Rounded Year
Nigeria	1963	1965	3.05	5.775947
Norway	1885	1965	2.66	9.434578
Pakistan	2004	2000	1.99	6.274768
Panama	1996	2000	3.53	8.278739
Paraguay	1994	1995	2.80	7.341485
Peru	1995	1995	2.71	7.586815
Philippines	1965	1965	2.52	6.517182
Portugal	1884	1965	1.98	8.001512
Rwanda	1984	1985	2.86	5.611012
Saudi Arabia	2004	2000	2.05	9.079221
Senegal	1963	1965	2.10	6.146386
Sierra Leone	1997	2000	3.00	4.94564
Singapore	1995	1995	3.90	9.860181
Slovak Republic	1993	1995	3.19	8.053965
South Africa	1947	1965	3.37	7.897295
Spain	1884	1965	3.29	8.590518
Sri Lanka	1952	1965	2.60	5.642336
Sudan	1984	1985	3.52	5.489991
Swaziland	1991	1995	2.86	7.178594
Sweden	1885	1965	2.66	9.531565
Switzerland	1884	1965	2.71	9.993171
Syria	1924	1965	2.46	6.306041
Togo	1967	1970	2.24	5.694402
Trinidad & Tobago	1964	1965	3.01	8.344262
Tunisia	1884	1965	1.90	6.5935
Ukraine	1991	1995	3.05	6.508002
United Kingdom	1884	1965	3.04	9.363698
United States	1887	1965	3.86	9.706059
Uruguay	1967	1970	2.26	8.311857
Venezuela,	1995	1995	2.76	8.540833
Zambia	1965	1965	3.52	6.404285
Zimbabwe	1980	1980	2.90	6.394734

A.4 Stage One Results for the Fully Specified Model

Table A.5: Stage One Results: log(Per Capita GDP)

	Stage One for columns I and II of Table 2.5	Stage One for columns III and IV of Table 2.5
log(Capital Stock)	0.06*	0.06*
	(4.23)	(3.86)
log(Population)	-0.33*	-0.26*
	(-10.43)	(-9.08)
log(Tertiary School Enrollment)	0.90*	0.75*
	(18.82)	(13.76)
Sub-Saharan Africa	-0.40*	-0.43*
	(-3.21)	(-3.49)
Latin America	-0.78*	-0.36*
	(-9.61)	(-4.31)
Transitional Economies	0.63*	0.50*
	(4.70)	(3.90)
log(Openness)		0.40*
		(2.88)
log(Institutional Quality)		1.26*
		(5.76)
Uncentered R^2	0.9914	0.9938
N	513	425

Note: The above results reflect the first stage results for the two-stage least squares, instrumental variables approach estimated in Table 2.5. Year dummy variables are also included in the estimation procedure of each of the above regressions. t-statistics are in parenthesis. $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance.

A.5 Cross-Sectional Results Accounting for Regional Effects

Table A.6: Cross-Sectional Results by Year, Including Regional Dummy Variables

	1965	1970	1975	1980	1985	1990	1995	2000
$log(pcGDP)$	-0.28	-0.66	-0.87**	-1.25**	-0.68	-0.90	-1.05***	-0.80
	(-0.52)	(-1.33)	(-2.06)	(-2.12)	(-0.85)	(-1.20)	(-1.89)	(-1.63)
$log(pcGDP)^2$	0.04	0.06***	0.07*	0.10*	0.07	0.08***	0.09*	0.07**
	(0.98)	(1.91)	(2.67)	(2.73)	(1.34)	(1.72)	(2.70)	(2.41)
sub Saharan Africa	0.32	0.43**	0.41**	0.41***	0.48***	0.48***	0.55**	0.51**
	(1.54)	(2.10)	(2.08)	(1.83)	(1.98)	(1.88)	(2.56)	(2.20)
Latin America	-0.35***	-0.32	-0.29	-0.38***	-0.44**	-0.39***	-0.02	0.09
	(-1.89)	(-1.62)	(-1.55)	(-1.94)	(-2.03)	(-1.77)	(-0.13)	(0.47)
Transitional							0.40***	0.49*
							(1.85)	(2.68)
Constant	2.38	3.63***	4.46*	5.68**	3.50	4.36	4.88**	4.52**
	(1.20)	(1.95)	(2.84)	(2.55)	(1.14)	(1.51)	(2.28)	(2.37)
Observations	91	96	100	104	106	106	119	118
R^2	0.3014	0.3617	0.3548	0.4091	0.3821	0.3904	0.4246	0.3923

Note: t-statistics are in parenthesis. $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance. Standard errors have been adjusted using White's correction.

Appendix B

Appendix for Essay Two

B.1 Explanations Proposed by Primo Braga & Fink

Primo Braga and Fink (1999) have proposed some possible reasons for finding IPRs to have an insignificant impact on developing country high technology imports, while having a significant impact on total and non-fuel imports. The reasons provided are, again, as follows: (1) Market power effects are particularly strong for high-technology goods and may offset positive market expansion effects, (2) Stronger IPRs may result in FDI by high-tech firms rather than increased trade, (3) The Ginarte-Park IPR Index inappropriately captures IPR strength, (4) The availability of the high-technology imports considered may be insensitive to the domestic country's IPR regime, and (5) Specification error, such as the exclusion of variables for tariff and non-tariff trade barriers, may bias the results.

Justification for the first reason has been provided in this paper. Let us now briefly discuss the other possible reasons mentioned.

The possibility that strong IPRs in developing countries result in increased FDI rather than increased trade in high-technology goods, *Reason 2*, is a possibility worth exploring in future research. The impact of IPRs on FDI was not considered in this paper. A preliminary empirical investigation of whether stronger IPRs increase bilateral inflows of FDI was conducted using a gravity model type approach, similar to that used for bilateral trade flows. The preliminary results are indeterminate. Too many impervious empirical obstacles exist to have an adequate empirical investigation. For example, bilateral FDI data is scarce[1] and the empirical breakout of bilateral FDI flows by sector is next to impossible.

[1] Data on bilateral FDI inflows are obtained from two sources: (1) Source OECD bilateral FDI data and (2) UNCTAD's World Investment Directory (WID) on-line. Source OECD provides the most complete set of bilateral FDI data, while UNCTAD's WID filled in some gaps for the 2000 data. Also, note that UNCTAD

As a result, it is empirically difficult to decipher whether the FDI is truly allocated to high-technology production, thereby replacing trade of high-technology goods.

The appropriateness of the Ginarte-Park IPR Index in capturing IPR strength *Reason 3* is not easily testable. Of course, some subjectivity will always enter into the process of creating an index. Nonetheless, the Ginarte-Park Index remains the common measure of choice in similar analysis.

The fourth reason, that the availability of the high-technology exports to developing countries may be insensitive to the domestic country's IPR regime is the obvious and straight forward interpretation of an insignificant IPR coefficient on an aggregate technology regression such as that in Primo Braga and Fink (1999). However, this is a very general assumption that does not consider the wide variety of goods that comprise a high technology aggregate. This paper, on the other hand, examines exports of high technology goods at a disaggregated level.

Reason 5, which argues the possible existence of specification errors could be analyzed by altering the variables used in the estimation equations. However, the robustness of gravity equations has been tested in previous papers (Baxter and Kouparitsas, 2006) and so we will maintain that the equation specification used in this paper is sufficient.

B.2 Determining "Value Added" Categories

Value added data was obtained from the World Bank's World Development Indicators (WDI). Value added is the net output of a sector, after intermediate inputs are subtracted from outputs. Value added as a percent of GDP is available from WDI for agriculture and manufacturing. Value added as a percent of total manufacturing is available for chemicals, machinery and transport, textiles, and other manufacturing. Chemicals are comprised of ISIC groups 351 and 352. Machinery and transport equipment comprise ISIC groups 382-84. Textiles and clothing comprise ISIC division 32. Other manufacturing includes wood and related products (division 33), paper and paper-related products (division 34), petroleum

WID data is unavailable for 1985 and can be used to supplement data for the year 2000 only.

and related products (groups 353-356), basic metals and mineral products (divisions 36 and 37), fabricated metal products and professional goods (groups 381 and 385), and other industries (group 390). Multiplying value added as a percent of total manufacturing to manufacturing value added as a percent of GDP provides estimates for sector specific value added within manufacturing as a percent of GDP.

In order to identify the "value added" category corresponding with each high technology good listed in Table 3.1, the ISIC group characterizing each value added group as described above was matched with the SITC Revision 1 group for which the high technology goods are identified. There are some instances in which the high technology good is expected to impact value added in a "non-corresponding" ISIC group. For instance, potassic fertilizers (561.3, SITC Revision 1) will likely be used in agriculture and therefore impact value added in agriculture rather than chemicals, as its corresponding ISIC group for may suggest. The two other high technology exports which will expectedly effect value added in a different sector are: Coloring Materials (533.1, which is a characterized in the "chemicals" group for SITC Revision 1, but applied to value added in the "textiles" group) and Pharmaceutical goods excluding medicaments (541.9, which is characterized in the "chemicals" group for SITC Rev. 1, but applied to value added in the "other manufacturing" group as 541.9 does not include medicaments but rather other pharmaceutical related products).

B.3 Analysis of Low & Lower-Middle Income Countries

The empirical analysis conducted up until this point has considered developed (high income, 2005 per capita GNI greater than $10,725) country exports to least developed (low income, 2005 per capita GNI below $875) countries. This appendix expands the definition of developing countries to include low income and lower-middle income countries (2005 per capita GNI between $876 and $3,465).[2] There are some possible problems with interpreting estimates of exports to this broader definition of developing countries. First, the more dissimilar countries are, the more difficult it will be to make predictions about dominant market

[2]Recall, income classifications are based on World Bank classifications.

power versus market expansion effects using the theoretical model. Lower-middle income countries, for example, may have "pertinent usage" for a wider variety of high technology goods relative to low-income countries, thereby increasing the likelihood of a dominant market power effect of increasing IPRs, according to the theoretical model. A second problem is that it becomes increasingly possible that IPRs will attract high technology goods via foreign direct investment rather than trade, making it less desirable to only consider the case that the Northern innovating firm will supply high technology goods to the South via exports.

Despite the possible problems with using a broader definition of developing countries, the empirical estimates for developed country, high technology exports to these countries exhibit links to estimates of exports to low-income countries only. Using the expanded definition of developing countries, IPRs have a statistically significant impact on developed country exports in fewer high technology groups. Each group that exhibits statistical significance in IPRs, however, is a subset of those reporting statistical significance in Table 3.3. More specifically, the results (including the "value added" regressor) suggest that an increase in IPRs has caused developing (low and lower-middle income) countries to experience a dominant market expansion effect for the following high technology goods: internal combustion engines (711.5), office machinery (714), telecommunications apparatus (724), transistors, photocells and the like (729.3), electrical machinery and apparatuses (729.9), tape recorders (891.1), and recorders of sound (891.2). Estimates for high technology exports to low and lower-middle income countries can be found in Table B.1.

When considering exports to low and lower-middle income countries, there are a greater number of high technology groups for which IPRs are insignificant, signaling a dominant market power effect. Such deviation in results may occur because the broader definition of "developing" countries causes countries in consideration to be more dissimilar, as previously discussed. Of those commodity groups that indicate a dominant market power effect for low and lower-middle income countries, the commodity groups for coloring materials (533.1), potassic fertilizers (561.3), synthetic fibers (651.6), and yarn and artificial fibers (651.7), are of particular interest as they best satisfy empirical predictions based on the theoretical model.

Of additional interest is the result that the coefficient on IPRs is both negative and statistically significant for the commodity groups for pharmaceutical goods excluding medicaments (541.9) and fuses and detonators (571.2). (Developed country exports of these high technology goods to low-income countries only were statistically insignificant in the value-added regressions. Refer to Table 3.3.) One explanation would be that the reduction in developed country exports is met with an increase in foreign direct investment in this particular commodity group. This negative coefficient is particularly interesting is worthy of additional attention in future research.

Table B.1: Developed Country Exports to Low & Lower-Middle Income Countries (By Commodity Code)

	513	513	514	514	515	515	533.1	533.1
log(IPR)	0.08	-0.35	-0.28	0.18	-2.09*	-1.11	0.12	0.08
	(0.19)	(-0.54)	(-0.67)	(0.31)	(-2.65)	(-1.03)	(0.22)	(0.10)
log(GDP_{rep})	2.33*	2.23*	2.72*	2.94*	2.72*	3.14*	2.83*	2.99*
	(15.25)	(8.80)	(18.80)	(12.15)	(9.45)	(6.48)	(14.07)	(9.24)
log(GDP_{part})	1.63*	1.53*	2.23*	2.09*	3.46*	4.07*	1.49*	1.32**
	(5.44)	(3.79)	(7.94)	(5.52)	(4.04)	(3.83)	(3.34)	(2.32)
log(Pop_{rep})	-0.97*	-0.93*	-1.45*	-1.80*	-0.91*	-1.28*	-1.35*	-1.54*
	(-6.06)	(-4.05)	(-9.61)	(-8.22)	(-3.22)	(-3.08)	(-6.45)	(-5.24)
log(Pop_{part})	-0.05	0.04	-0.79*	-0.72***	-2.22**	-2.90**	-0.30	-0.08
	(-0.15)	(0.09)	(-2.59)	(-1.75)	(-2.45)	(-2.57)	(-0.62)	(-0.13)
colony	6.11*	4.56*	5.17*	4.17*	4.95*	3.97*	5.99*	5.53*
	(11.52)	(6.05)	(10.23)	(5.79)	(6.27)	(3.64)	(9.84)	(6.62)
log(dist)	-2.82*	-3.09*	-2.57*	-2.58*	-2.42*	-2.49*	-3.57*	-3.59*
	(-13.56)	(-10.90)	(-12.99)	(-9.64)	(-6.57)	(-5.24)	(-13.45)	(-10.59)
language	0.25	0.98**	0.74**	0.88***	1.33**	1.61**	0.81***	0.69
	(0.71)	(2.09)	(2.22)	(1.96)	(2.29)	(2.13)	(1.81)	(1.17)
border	-4.42**	-5.62**	-5.79*	-7.16*	5.05	4.52	-10.16*	-11.57*
	(-2.16)	(-2.46)	(-2.86)	(-3.14)	(0.78)	(-0.69)	(-4.21)	(-4.20)
1975	0.82***	0.16	1.28*	0.70	4.24*	3.57*	-0.05	-1.05
	(1.66)	(0.23)	(2.76)	(1.05)	(4.33)	(2.69)	(-0.08)	(-1.18)
1980	2.12*	1.61**	2.07*	1.44**	3.88*	3.85*	0.85	0.22
	(4.26)	(2.28)	(4.44)	(2.17)	(3.90)	(2.89)	(1.31)	(0.25)
1985	0.94***	1.23***	1.15**	1.31***	2.16**	2.87**	-0.21	-0.47
	(1.88)	(1.73)	(2.45)	(1.95)	(2.16)	(2.14)	(-0.32)	(-0.53)
1990	1.50*	1.44**	0.48	0.39	3.63*	3.66*	0.37	0.33
	(2.96)	(1.99)	(1.01)	(0.57)	(3.54)	(2.65)	(0.56)	(0.36)
1995	0.45	0.71	-0.54	-0.60	4.32*	3.77*	-0.66	-1.38
	(0.88)	(0.98)	(-1.12)	(-0.88)	(4.19)	(2.71)	(-0.98)	(-1.49)
2000	-0.71	-0.29	-0.49	-1.02	3.59*	2.22	-0.52	-0.47
	(-1.29)	(-0.35)	(-0.94)	(-1.33)	(3.20)	(1.42)	(-0.71)	(-0.44)
chemical		0.00		0.00		0.00		
		(1.51)		(0.26)		(1.05)		
textile								0.00
								(0.24)
Constant	-54.02*	-48.07*	-59.74*	-56.17*	-87.36*	-96.33*	-46.39*	-45.61*
	(-13.80)	(-8.15)	(-15.80)	(-10.00)	(-9.46)	(-7.94)	(-8.44)	(-5.95)
N	6251	3409	6333	3416	2627	1576	4315	2537

Note: z-statistics are in parenthesis. $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance. Standard errors are corrected using White's correction. The comparison year for the year dummies is 1970.

	541	541	541.9	541.9	561.3	561.3	571.2	571.2
log(IPR)	-0.01	-0.04	-0.04	-1.11***	0.06	0.83	-2.15***	-3.82**
	(-0.03)	(-0.10)	-0.08	(-1.82)	(0.05)	(0.60)	(-1.90)	(-2.55)
log(GDP_{rep})	2.05*	2.11*	2.13*	1.98*	2.95*	2.49*	1.30*	1.01
	(19.39)	(12.25)	(13.93)	(8.23)	(5.94)	(2.78)	(2.94)	(1.40)
log(GDP_{part})	3.96*	3.53*	3.74*	3.89*	-1.51	-2.28***	2.89*	2.04
	(19.97)	(13.03)	(11.75)	(9.57)	(-1.25)	(1.81)	(2.74)	(1.62)
log(Pop_{rep})	-1.18*	-1.60*	-1.06*	-1.06*	-1.42*	-0.93	-0.34	0.06
	(-10.43)	(-9.89)	(-6.44)	(-4.66)	(-2.94)	(-1.06)	(-0.73)	(-0.09)
log(Pop_{part})	-3.46*	-3.00*	-2.75*	-2.91*	2.82**	3.53**	-1.53	-0.36
	(-15.41)	(-9.75)	(-8.05)	(-6.64)	(2.09)	(2.52)	(-1.26)	(-0.25)
colony	5.40*	4.11*	5.79*	4.59*	-1.06	-0.51	8.70*	7.58*
	(12.35)	(6.72)	(11.32)	(6.70)	(-0.76)	(-0.34)	(7.72)	(4.68)
log(dist)	-2.34*	-2.14*	-2.71*	-2.84*	-3.48*	-3.33*	-3.09*	-4.01*
	(-15.65)	(-10.57)	(-12.98)	(-10.56)	(-5.94)	(-5.46)	(-6.10)	(-6.25)
language	0.95*	1.09*	0.98*	0.88**	4.09*	4.07*	1.79**	2.87**
	(3.99)	(3.33)	(2.91)	(1.99)	(3.57)	(3.32)	(2.07)	(2.48)
border	-10.53*	-11.67*	-6.97*	-7.04*	-7.98***	-7.97***	6.57	9.01
	(-5.64)	(-5.73)	(-2.91)	(-2.66)	(-1.87)	(-1.85)	(1.23)	(1.44)
1975	0.39	0.11	1.68*	1.32***	0.64	0.49	0.48	1.40
	(1.12)	(0.21)	(3.19)	(1.84)	(0.42)	(0.31)	(0.38)	(0.78)
1980	1.30*	0.83	2.60*	2.24*	0.32	-0.73	1.62	2.96***
	(3.72)	(1.64)	(4.95)	(3.10)	(0.21)	(-0.45)	(1.25)	(1.65)
1985	1.12*	1.40*	2.55*	2.62*	1.16	1.43	-1.80	1.97
	(3.22)	(2.75)	(4.89)	(3.65)	(0.75)	(0.87)	(-1.37)	(1.10)
1990	0.98*	1.03**	3.25*	2.35*	0.47	0.22	0.10	2.77
	(2.76)	(1.98)	(6.15)	(3.23)	(0.29)	(0.13)	(0.08)	(1.49)
1995	1.28*	1.60*	2.80*	2.65*	1.19	0.90	-2.44***	-0.43
	(3.59)	(3.09)	(5.26)	(3.66)	(0.73)	(0.53)	(-1.75)	(0.22)
2000	1.12*	1.64*	4.06*	4.16*	1.14	0.57	-4.55*	-1.70
	(2.94)	(2.82)	(7.20)	(5.17)	(0.65)	(0.30)	(-2.96)	(-0.78)
chemical		0.00***						
		(1.81)						
agriculture						-0.07		
						(-1.09)		
other				0.00				0.00
				(0.12)				(0.67)
Constant	-48.34*	-41.17*	-62.34*	-57.94*	-30.33**	-19.3	-50.75*	-42.43*
	(-18.30)	(-10.33)	(-14.99)	(-10.22)	(-2.34)	(-1.29)	(-5.09)	(-3.22)
N	8784	4409	5772	3282	1962	1811	1529	1004

Note: z-statistics are in parenthesis. $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance. Standard errors are corrected using White's correction. The comparison year for the year dummies is 1970.

	571.4	571.4	581.1	581.1	581.2	581.2	651.6	651.6
log(IPR)	-0.89	-1.85	0.37	0.02	0.97**	0.51	1.30**	0.64
	-1.02	(-1.59)	(0.87)	(0.04)	(2.53)	(0.97)	(2.52)	(0.92)
log(GDP_{rep})	2.02*	1.77*	2.27*	2.35*	2.27*	2.21*	3.28*	2.75*
	(6.40)	(3.46)	(15.94)	(10.41)	(17.99)	(11.26)	(17.77)	(9.60)
log(GDP_{part})	1.57***	1.72***	3.04*	2.87*	1.91*	1.80*	0.68**	0.53
	(1.91)	(1.78)	(11.54)	(8.38)	(8.23)	(5.90)	(2.19)	(1.30)
log(Pop_{rep})	-1.29*	-1.26*	-1.10*	-1.24*	-1.26*	-1.41*	-2.05*	-1.85*
	(-3.92)	(-2.72)	(-7.23)	(-5.96)	(-9.32)	(-7.68)	(-10.62)	(-7.00)
log(Pop_{part})	-0.12	-0.07	-1.82*	-1.74*	-0.43***	-0.44	0.70***	0.99**
	(-0.13)	(-0.06)	(-6.33)	(-4.64)	(-1.67)	(-1.29)	(1.95)	(2.13)
colony	7.05*	7.08*	5.21*	4.12*	4.59*	3.13*	4.36*	3.53*
	(8.22)	(6.11)	(10.11)	(5.96)	(9.35)	(4.75)	(7.18)	(4.22)
log(dist)	-1.98*	-1.84*	-2.88*	-2.70*	-2.73*	-2.52*	-2.19*	-2.66*
	(-4.97)	(-3.70)	(-14.89)	(-10.85)	(-15.79)	(-11.32)	(-9.90)	(-9.26)
language	1.50**	1.49	-0.63***	0.02	0.39	0.80**	1.13*	0.98***
	(2.12)	(1.64)	(-1.89)	(0.04)	(1.34)	(2.14)	(2.72)	(1.78)
border	-63.99	-61.89	-7.24*	-8.51*	-6.20*	-6.96*	-6.54*	-8.85*
	(.)	(.)	(-3.48)	(-3.68)	(-3.13)	(-3.24)	(-2.75)	(-3.34)
1975	2.48*	1.98	0.96**	1.28***	0.58	-0.10	1.58*	1.13
	(2.58)	(1.53)	(2.03)	(1.96)	(1.36)	(-0.17)	(2.70)	(1.40)
1980	-0.67	-0.86	2.12*	2.32*	2.44*	1.82*	1.93*	1.79**
	(0.67)	-0.64	(4.49)	(3.55)	(5.78)	(3.16)	(3.29)	(2.22)
1985	-2.88*	-2.73**	1.66*	2.33*	2.05*	2.27*	0.18	0.75
	(-2.81)	(-2.01)	(3.52)	(3.55)	(4.84)	(3.92)	(0.30)	(0.92)
1990	-2.77*	-3.19**	1.06**	1.55**	2.99*	2.67*	0.02	0.79
	(-2.59)	(-2.22)	(2.22)	(2.33)	(7.00)	(4.52)	(0.03)	(0.96)
1995	-1.27	-2.00	2.52*	3.02*	2.90*	2.94*	0.49	1.44***
	(-1.19)	(1.40)	(5.30)	(4.63)	(6.75)	(5.06)	(0.82)	(1.75)
2000	-1.35	-1.37	2.26*	3.31*	2.23*	2.42*	-0.31	0.60
	(-1.17)	-0.86	(4.44)	(4.50)	(4.87)	(3.69)	(-0.48)	(0.64)
textile								0.00
								(0.37)
other		0.00		0.00		0.00		
		(0.65)		(0.20)		(1.25)		
Constant	-50.64*	-50.82*	-57.59*	-55.15*	-48.69*	-42.95*	-52.44*	-40.19*
	(-5.86)	(-4.41)	(-15.81)	(-10.75)	(-15.31)	(-9.56)	(-12.33)	(-6.63)
N	2604	1633	6577	3750	7594	4294	5399	3107

Note: z-statistics are in parenthesis. $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance. Standard errors are corrected using White's correction. The comparison year for the year dummies is 1970.

	651.7	651.7	711.3	711.3	711.4	711.4	711.5	711.5
log(IPR)	0.42	-0.11	0.66	-0.03	0.23	0.64	0.46	0.95***
	(0.58)	(-0.12)	(0.92)	(-0.03)	(0.31)	(0.61)	(1.34)	(1.85)
log(GDP_{rep})	2.38*	2.37*	3.00*	2.71*	2.05*	2.28*	1.84*	1.66*
	(8.60)	(5.49)	(11.12)	(5.68)	(8.32)	(4.99)	(16.06)	(7.86)
log(GDP_{part})	1.46*	1.10***	3.72*	3.69*	1.52*	0.64	4.73*	4.58*
	(3.08)	(1.87)	(5.10)	(4.08)	(2.79)	(0.88)	(21.13)	(14.72)
log(Pop_{rep})	-0.87*	-0.91**	-1.29*	-1.35*	-0.72*	-1.57*	-0.99*	-1.10*
	(-3.16)	(-2.38)	(-4.79)	(-3.41)	(-2.74)	(-4.02)	(-7.99)	(-5.83)
log(Pop_{part})	0.34	0.65	-2.00**	-1.79***	0.19	1.04	-3.44*	-3.38*
	(0.62)	(0.94)	(-2.57)	(-1.85)	(0.31)	(1.27)	(-14.04)	(-9.86)
colony	3.63*	3.11*	7.10*	6.51*	5.84*	4.59*	5.82*	4.74*
	(4.56)	(2.87)	(8.96)	(5.79)	(7.93)	(4.38)	(12.85)	(7.11)
log(dist)	-4.44*	-4.45*	-2.41*	-3.01*	-3.29*	-3.48*	-2.30*	-2.19*
	(-14.00)	(-11.09)	(-6.64)	(-6.32)	(-9.74)	(-7.67)	(-14.21)	(-9.69)
language	1.64*	1.74**	-0.14	-0.37	2.05*	2.72*	-1.10*	-0.97**
	(2.61)	(2.13)	(-0.22)	(-0.44)	(3.94)	(3.85)	(-4.01)	(-2.52)
border	-5.64***	-5.20	8.34	5.35	4.72	1.99	-8.48*	-8.78*
	(-1.93)	(-1.60)	(1.18)	(0.74)	(0.88)	(0.31)	(-4.36)	(-4.08)
1975	-1.25	-0.21	2.55*	1.86	1.97**	2.26***	0.99*	0.93
	(-1.57)	(-0.20)	(2.94)	(1.56)	(2.41)	(1.95)	(2.58)	(1.61)
1980	-2.11*	-0.90	2.41*	1.62	0.81	0.67	1.39*	1.31**
	(-2.58)	(-0.83)	(2.75)	(1.36)	(0.97)	(0.56)	(3.62)	(2.28)
1985	-3.95*	-2.10***	-0.72	-0.86	1.13	2.25***	0.14	0.05
	(-4.78)	(-1.91)	(-0.81)	(-0.71)	(1.37)	(1.92)	(0.35)	(0.08)
1990	-4.91*	-3.37*	0.19	-0.24	2.29*	3.51*	0.33	0.00
	(-5.75)	(-2.97)	(0.21)	(-0.19)	(2.72)	(2.94)	(0.85)	0.00
1995	-5.27*	-3.98*	0.17	0.30	2.78*	3.63*	0.43	0.58
	(-6.17)	(-3.51)	(0.19)	(0.24)	(3.26)	(2.99)	(1.10)	(0.99)
2000	-4.79*	-2.86**	-0.50	-0.35	2.28**	3.66*	-0.19	-0.27
	(-5.27)	(-2.21)	(-0.51)	(-0.25)	(2.47)	(2.65)	(-0.47)	(-0.40)
textile		0.00						
		(0.89)						
mach&trans				0.00**		0.01*		0.00***
				(2.13)		(3.27)		(1.71)
Constant	-46.82*	-42.90*	-96.47*	-85.91*	-54.64*	-36.98*	-69.12*	-61.47*
	(-7.40)	(-4.91)	(-11.88)	(-7.22)	(-8.61)	(-3.59)	(-22.97)	(-12.20)
N	3365	2061	3182	1858	3994	2234	7690	3817

Note: z-statistics are in parenthesis. $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance. Standard errors are corrected using White's correction. The comparison year for the year dummies is 1970.

	711.6	711.6	711.8	711.8	714	714	724	724
log(IPR)	0.98	0.79	0.13	0.34	0.74**	1.35*	1.28*	0.92***
	(1.25)	(0.71)	(0.26)	(0.48)	(2.35)	(2.86)	(3.89)	(1.92)
log(GDP_{rep})	2.32*	2.33*	2.28*	1.76*	1.73*	1.68*	1.87*	1.82*
	(8.41)	(4.59)	(12.72)	(5.72)	(16.76)	(8.73)	(17.24)	(9.19)
log(GDP_{part})	4.41*	3.60*	3.93*	3.62*	4.79*	4.68*	3.63*	3.55*
	(5.64)	(3.68)	(9.24)	(6.83)	(23.33)	(16.12)	(17.71)	(12.45)
log(Pop_{rep})	-0.37	-0.91**	-0.60*	-0.64**	-0.78*	-1.06*	-0.85*	-1.45*
	(-1.31)	(-2.17)	(-3.21)	(-2.40)	(-7.01)	(-6.19)	(-7.27)	(-8.19)
log(Pop_{part})	-2.64*	-1.61	-2.79*	-2.52*	-3.93*	-3.83*	-2.76*	-2.84*
	(-3.16)	(-1.52)	(-6.15)	(-4.46)	(-17.41)	(-11.92)	(-12.06)	(-8.88)
colony	5.90*	5.34*	6.29*	5.78*	4.32*	3.57*	4.04*	2.93*
	(7.09)	(4.59)	(11.10)	(7.28)	(10.29)	(5.72)	(8.92)	(4.44)
log(dist)	-3.10*	-3.29*	-2.72*	-2.79*	-1.82*	-1.74*	-1.07*	-1.24*
	(-8.16)	(-6.55)	(-11.54)	(-9.00)	(-12.52)	(-8.44)	(-7.07)	(-5.92)
language	1.31**	1.52***	0.92**	0.48	1.06*	1.19*	1.08*	1.17*
	(2.19)	(1.89)	(2.32)	(0.91)	(4.50)	(3.48)	(4.43)	(3.37)
border	3.33	5.42	-6.07**	-8.18*	-7.22*	-8.45*	-4.60**	-6.35*
	(0.60)	(0.87)	(-2.26)	(-2.85)	(-4.03)	(-4.16)	(-2.51)	(-3.19)
1975	5.25*	4.56*	1.62*	2.55*	0.44	0.50	1.78*	0.78
	(4.88)	(3.16)	(2.65)	(3.03)	(1.25)	(0.95)	(4.93)	(1.46)
1980	9.52*	8.46*	0.92	2.30*	0.46	0.68	2.14*	1.84*
	(9.08)	(6.00)	(1.48)	(2.73)	(1.31)	(1.28)	(5.90)	(3.45)
1985	9.15*	9.49*	0.83	2.00**	0.63***	0.86	1.51*	1.16**
	(8.74)	(6.75)	(1.35)	(2.36)	(1.80)	(1.62)	(4.14)	(2.16)
1990	10.46*	10.46*	2.59*	3.73*	1.70*	1.66*	2.23*	1.62*
	(9.78)	(7.28)	(4.15)	(4.36)	(4.82)	(3.10)	(6.04)	(2.99)
1995	6.69*	6.38*	3.81*	5.26*	1.95*	2.53*	2.72*	2.75*
	(6.15)	(4.36)	(6.09)	(6.19)	(5.48)	(4.74)	(7.33)	(5.08)
2000	6.25*	6.14*	3.93*	5.29*	2.13*	2.51*	3.07*	2.73*
	(5.43)	(3.80)	(5.86)	(5.54)	(5.62)	(4.13)	(7.74)	(4.41)
mach&trans		0.00***		0.01*		0.00**		0.00*
		(1.68)		(3.15)		(2.40)		(2.65)
Constant	-104.46*	-89.97*	-79.25*	-63.72*	-67.92*	-62.66*	-65.94*	-49.27*
	(-12.47)	(-7.32)	(-15.05)	(-8.23)	(-24.80)	(-13.66)	(-23.49)	(-10.67)
N	3496	1942	5108	2830	8479	4181	8910	4344

Note: z-statistics are in parenthesis. $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance. Standard errors are corrected using White's correction. The comparison year for the year dummies is 1970.

	729.3	729.3	729.7	729.7	729.9	729.9	734	734
log(IPR)	0.52	1.15***	0.09	-1.28	0.76**	1.29*	0.07	0.39
	(1.13)	(1.82)	(0.03)	(-0.37)	(2.19)	(2.58)	(0.11)	(0.42)
log(GDP_{rep})	2.60*	2.75*	3.64*	4.53**	2.29*	2.00*	2.10*	1.96*
	(16.95)	(11.21)	(3.32)	(2.22)	(19.54)	(9.47)	(9.55)	(4.96)
log(GDP_{part})	3.45*	3.07*	0.67	2.51	3.86*	4.02*	3.22*	2.86*
	(10.72)	(7.34)	(0.21)	(0.67)	(16.54)	(12.87)	(6.23)	(4.37)
log(Pop_{rep})	-0.79*	-0.85*	-2.02**	-2.71***	-1.01*	-1.26*	-0.77*	-1.45*
	(-4.87)	(-3.73)	(-2.02)	(-1.69)	(-8.12)	(-6.78)	(-3.37)	(-4.34)
log(Pop_{part})	-1.95*	-1.56*	0.89	-1.35	-2.81*	-3.16*	-2.02*	-1.91*
	(-5.51)	(-3.37)	(0.24)	(-0.32)	(-10.95)	(-9.16)	(-3.57)	(-2.64)
colony	5.33*	4.15*	0.75	1.29	5.26*	4.33*	2.91*	0.60
	(10.19)	(5.75)	(0.31)	(0.45)	(11.81)	(6.68)	(4.07)	(0.59)
log(dist)	-1.95*	-2.00*	-0.46	-0.61	-1.65*	-1.71*	-2.99*	-3.00*
	(-9.74)	(-7.62)	(-0.44)	(-0.47)	(-10.42)	(-7.95)	(-10.01)	(-7.55)
language	1.58*	2.09*	1.29	2.60	0.28	0.48	3.61*	4.34*
	(4.65)	(4.68)	(0.61)	(1.02)	(1.09)	(1.32)	(7.97)	(7.07)
border	-7.42*	-9.87*	-0.67	-3.87	-4.99*	-6.70*	5.13	1.02
	(-2.79)	(-3.07)	(-0.07)	(-0.37)	(-2.71)	(-3.28)	(0.66)	(0.13)
1975	2.23*	2.81*	0.75	-2.69	1.59*	1.31**	2.62*	2.56**
	(4.10)	(3.68)	(0.24)	(-0.71)	(4.10)	(2.36)	(3.61)	(2.53)
1980	3.11*	3.39*	2.85	0.74	1.98*	1.40**	2.62*	2.17**
	(5.74)	(4.45)	(0.91)	(0.20)	(5.10)	(2.50)	(3.56)	(2.13)
1985	2.54*	3.03*	-2.78	-4.31	0.75***	0.34	1.79**	2.76*
	(4.68)	(3.96)	(-0.84)	(-1.10)	(1.92)	(0.60)	(2.43)	(2.70)
1990	4.08*	4.87*	-3.02	-7.29***	1.19*	0.83	0.55	1.15
	(7.49)	(6.34)	(-0.89)	(-1.74)	(2.99)	(1.46)	(0.73)	(1.10)
1995	4.19*	4.49*	-1.10	-5.47	1.58*	1.69*	1.86**	2.05***
	(7.62)	(5.87)	(-0.33)	(-1.28)	(3.97)	(2.99)	(2.45)	(1.96)
2000	5.18*	5.98*	9.71*	7.10	1.38*	1.19***	1.82**	2.56**
	(8.87)	(7.06)	(2.69)	(1.51)	(3.25)	(1.85)	(2.22)	(2.13)
mach&trans						0.00*		0.01*
						(3.49)		(3.70)
other		0.00		0.00				
		(1.42)		(0.98)				
Constant	-91.41*	-91.53*	-92.89*	-112.12*	-74.05*	-61.35*	-63.79*	-42.46*
	(-21.93)	(-15.72)	(-3.42)	(-2.92)	(-23.76)	(-12.25)	(-10.26)	(-4.57)
N	6210	3631	543	418	7566	3880	5188	2793

Note: z-statistics are in parenthesis. $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance. Standard errors are corrected using White's correction. The comparison year for the year dummies is 1970.

	861	861	862	862	891.1	891.1
log(IPR)	0.63**	0.47	0.84***	0.61	1.41*	1.26**
	(2.26)	(1.20)	(1.86)	(0.97)	(3.27)	(2.09)
log(GDP_{rep})	1.97*	2.00*	1.87*	1.87*	1.63*	1.47*
	(21.56)	(13.83)	(12.58)	(7.87)	(11.51)	(6.51)
log(GDP_{part})	4.80*	4.63*	3.13*	3.37*	3.01*	2.91*
	(27.27)	(19.60)	(10.32)	(8.44)	(10.95)	(7.94)
log(Pop_{rep})	-1.04*	-1.29*	-0.83*	-0.95*	-0.71*	-0.62*
	(-10.53)	(-9.36)	(-5.11)	(-4.23)	(-4.54)	(-2.90)
log(Pop_{part})	-4.11*	-4.01*	-1.72*	-1.84*	-2.12*	-2.01*
	(-21.03)	(-15.22)	(-5.17)	(-4.20)	(-7.06)	(-5.03)
colony	4.45*	3.46*	5.54*	4.37*	5.06*	3.73*
	(11.54)	(6.57)	(10.81)	(6.34)	(9.52)	(5.05)
log(dist)	-1.47*	-1.49*	-2.47*	-2.33*	-0.91*	-1.69*
	(-11.48)	(-8.77)	(-11.97)	(-8.71)	(-4.70)	(-6.51)
language	0.40***	0.57**	0.69**	1.33*	1.73*	2.01*
	(1.94)	(2.05)	(2.00)	(2.99)	(5.58)	(4.81)
border	-7.02*	-8.18*	9.88**	10.57**	-3.79	-5.66**
	(-4.40)	(-4.63)	-2.38	(2.19)	(-1.62)	(-2.16)
1975	1.22*	0.82***	1.40*	1.02	1.86*	1.34**
	(4.03)	(1.88)	(2.77)	(1.45)	(3.85)	(1.98)
1980	1.63*	1.25*	2.44*	2.03*	2.68*	2.55*
	(5.36)	(2.88)	(4.83)	(2.89)	(5.56)	(3.77)
1985	1.08*	0.76***	0.92***	0.75	2.14*	2.41*
	(3.54)	(1.74)	(1.81)	(1.06)	(4.46)	(3.57)
1990	1.32*	1.05**	1.13**	0.63	1.44*	1.55**
	(4.24)	(2.33)	(2.20)	(0.88)	(2.93)	(2.22)
1995	1.55*	1.36*	0.99***	0.63	1.75*	1.82*
	(4.96)	(3.08)	(1.92)	(0.89)	(3.54)	(2.65)
2000	1.26*	1.26**	0.52	-0.06	1.18**	1.28***
	(3.78)	(2.54)	(0.94)	(-0.08)	(2.22)	(1.66)
other		0.00		0.00		0.00
		(1.03)		(1.04)		(1.56)
Constant	-68.03*	-60.91*	-61.69*	-64.74*	-62.98*	-53.21*
	(-28.15)	(-17.73)	(-15.58)	(-11.77)	(-16.65)	(-9.87)
N	9009	4939	5801	3315	6410	3608

Note: z-statistics are in parenthesis. $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance. Standard errors are corrected using White's correction. The comparison year for the year dummies is 1970.

	891.2	891.2	894.3	894.3	899.6	899.6
log(IPR)	1.42*	0.81	0.60	-0.23	-1.40*	-1.97*
	(3.34)	(1.41)	(0.88)	(-0.25)	(-2.78)	(-2.96)
log(GDP_{rep})	1.88*	1.84*	1.54*	1.45*	2.92*	2.62*
	(13.58)	(8.42)	(6.50)	(3.72)	(16.27)	(9.42)
log(GDP_{part})	1.27*	1.45*	0.18	-0.45	4.82*	4.72*
	(4.58)	(4.01)	(0.33)	(-0.68)	(11.37)	(9.18)
log(Pop_{rep})	-0.62*	-0.69*	-0.75*	-0.91**	-1.37*	-1.34*
	(-4.18)	(-3.32)	(-2.99)	(-2.56)	(-7.51)	(-5.39)
log(Pop_{part})	0.08	-0.03	1.30**	2.00*	-4.37*	-4.46*
	(-0.28	(-0.08)	(-2.2	(2.70)	(-9.79)	(-8.23)
colony	5.23*	4.38*	5.45*	4.97*	5.79*	5.40*
	(10.53)	(6.55)	(7.79)	(5.29)	(10.34)	(7.52)
log(dist)	-1.52*	-1.94*	-2.66*	-2.30*	-3.26*	-3.03*
	(-8.26)	(-8.07)0	(-8.78)	(-5.90)	(-13.68)	(-10.24)
language	1.98*	1.99*	0.68	0.74	1.14*	1.38*
	(6.49)	(4.99)	(1.19)	(0.99)	(2.77)	(2.70)
border	-4.91**	-6.56*	8.51	8.99	2.04	1.31
	(-2.37)	(-2.89)	(1.35)	(1.38)	(0.50)	(0.28)
1975	3.06*	3.01*	0.75	0.64	2.25*	2.65*
	(6.08)	(4.31)	(1.00)	(0.62)	(3.62)	(3.19)
1980	3.33*	3.37*	0.80	0.61	3.92*	4.90*
	(6.59)	(4.82)	(1.06)	(0.58)	(6.38)	(5.94)
1985	3.63*	3.87*	-1.64**	-1.31	3.27*	4.39*
	(7.23)	(5.52)	(-2.12)	(-1.23)	(5.33)	(5.32)
1990	6.09*	5.88*	-2.63*	-2.19***	3.40*	4.90*
	(12.02)	(8.30)	(-3.26)	(-1.96)	(5.44)	(5.84)
1995	7.25*	7.47*	-0.75	-0.54	3.15*	3.95*
	(14.24)	(10.62)	(-0.93)	(-0.50)	(5.00)	(4.72)
2000	7.99*	8.77*	-2.36*	-1.48	3.85*	5.61*
	(14.78)	(11.30)	(-2.71)	(-1.21)	(5.73)	(6.06)
other		0.00		0.00		0.00
		(0.36)		(1.60)		(1.00)
Constant	-59.64*	-56.39*	-29.21*	-22.76*	-72.91*	-64.52*
	(-16.49)	(-11.17)	(-4.86)	(-2.73)	(-13.8)	(-9.50)
N	6961	3967	3178	1922	4437	2666

Note: z-statistics are in parenthesis. $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance. Standard errors are corrected using White's correction. The comparison year for the year dummies is 1970.

Appendix C

Appendix for Essay Three

C.1 USPTO Patent Count Data

This appendix takes a deeper look into using patent counts as a proxy for innovation. Specifically, this paper uses patent counts as reported by the United States Patent and Trademark Office (USPTO) to approximate innovation appropriate for sale on the foreign market. Patent counts are increasingly being used to approximate innovation. However, this approximation for total domestic innovation is less than ideal as countries, especially developing countries, may not apply for patents in the United States if they do not expect to sell their product on that market. One such example is the wind-up Clockwork Radio, which was developed in 1993, to be used in rural communities in developing countries that have no access to electricity or batteries (WIPO 2006). Such an invention would have little demand in the United States and so the inventor may never seek a patent from the USPTO. Therefore, USPTO patent counts is a better approximation for innovation appropriate for sale on the foreign market than for total innovation.

One benefit to using USPTO patent counts to approximate innovation, in general, is that USPTO patent counts provide a standardized source of data. Collecting data on patent counts from individual country data sources my not be comparable as individual legal standards such as patent breadth my vary across countries. The World Intellectual Property Organization (WIPO) provides some data on patent application in the country of origin, but the data is scarce, especially for developing countries. On a similar note, the Patent Cooperation Treaty (PCT) established by WIPO allows members to seek patent protection for an invention in many countries at one time by filing an "international" patent application through WIPO. Although the PCT was first established in 1970, many current members (both developed and developing) did not sign the treaty until the early to mid 1990s. Today there are 137 member countries that have signed the PCT. Since the objective of the PCT is take all domestic patent applications and file them internationally, it is likely that patent counts from a single source, such as USPTO, will increasingly include all non-resident innovations, thereby increasingly becoming a better approximation for total innovation rather than innovation intended for the foreign market.

An additional flaw in using USPTO patent counts to approximate innovation is that such patent counts are only noted for the country listed as the first inventor. Although this specification is favorable in that it uses the residence of the inventor (rather than the applicant) to classify the country filing the patent application, it is unfavorable in that it does not provide data on patent grants for secondary or tertiary inventors, or the like. This also means that innovation that occurs by way of joint ventures appear only as a patent granted to the inventor listed as the "first" inventor.

Alternate measures of innovation for the most part have not tried to adjust for possible mis-valued patent counts resulting from country's failure to apply for patents abroad or from the lack joint "ownership" of the patent. Instead, alternate measures of innovation exist that try to weight patent counts by their "importance" (Jaffe and Trajtenberg, 2002). Citations are often used to weight patent counts in order to derive an approximation for the importance of innovations. This weighting allows for variability, while the use of patent counts alone assigns a value of one to each patent.

Despite these many flaws, USPTO patent counts continue to be widely used as an approximation for innovation, and is particularly good at capturing innovation applicable to foreign markets. The USPTO, European Patent Office (EPO), and Japanese Patent Office (JPO) are the three patent offices receiving the greatest number of filings both domestically an internationally (OECD, 2004). Countries have the greatest likelihood of applying for a patent in one of these three countries, particularly if the innovation is "valuable" internationally.

C.2 First Stage Results for Essay 3

Below are the first stage results for Table 4.2 (with Inward FDI in Current Period).

Table C.1: First Stage Results: Low & Lower-Middle Income Countries

	log(Innovation)	log(Inward FDI)
log(R&D Expenditures)	0.16*	-0.61*
	(9.69)	(-18.49)
log(Business Environment)	-1.32*	4.98*
	(-17.63)	(33.09)
log(K in previous period)	-1.13*	0.36*
	(-29.03)	(4.54)
log(Population$_{reporting}$)	-2.20*	14.69*
	(-8.93)	(29.70)
log(Tertiary School Enrollment)	0.48*	-1.50*
	(12.80)	(-19.94)
log(IPRs)	0.31*	-0.17**
	(7.52)	(-2.07)
log(GDP$_{partner}$)	-0.00**	0.00
	(-2.45)	(0.31)
log(GDP$_{reporter}$)	1.46*	0.79*
	(30.13)	(8.15)
log(Distance)	-0.00	-0.00
	(-0.46)	(-0.02)
1980	0.04	-2.32*
	(0.90)	(-27.20)
1985	0.01	-4.09*
	(0.14)	(-27.71)
1990	1.15*	-3.47*
	(12.06)	(-18.16)
1995	1.80*	-3.97*
	(15.58)	(-17.14)
2000	2.48*	-4.21*
	(18.01)	(-15.23)
constant	27.86*	-235.94*
	(6.64)	(-28.01)
N	3836	3836
Adjusted R^2	0.9801	0.9648

Note: t-statistics are in parenthesis. $*$ = 99% significance, $**$ = 95% significance, $***$ = 90% significance. The comparison year is 1975. Country fixed effects are also found in empirical estimation, but not reported.

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