Impact of the International Patent System on Productivity and Technology Diffusion

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Why should developing nations provide stronger patent protection? What is in it for them? The purpose of this paper is to gauge some of the economic benefits of increased patent protection. Does increased patent protection, for instance, stimulate international diffusion of technology and productivity growth? This paper provides *empirical evidence* that suggests that it does. Until now, most studies investigating the economic effects of patent protection have been largely theoretical in nature or have assumed channels by which patent protection affects economic performance (See, for example, Diwan and Rodrik 1991; Helpman 1993; Taylor 1994).

The empirical analysis of this chapter determines the extent to which patent protection matters to research and development (R&D) and to international patenting and, thus, to productivity growth. International patenting activity is an important source of the international diffusion of technology: it involves not only the diffusion of new products and processes but also "knowledge spillovers" from the information *disclosed* by inventors in exchange for the patent protection they receive.

There has been much international policy debate about the costs and benefits of strengthening patent régimes in developing economies

Notes will be found on page 64.

(the "South"). Strengthening, on the one hand, reduces the ability of the South to imitate foreign technologies important to their development. On the other hand, it should better enable the South to attract new technologies from the developed economies (the "North") and to foster a domestic (i.e. innovative rather than imitative) research sector.

There exist few studies on the impact of patent protection on international patenting. Two previous studies that investigate this issue are Bosworth 1984 and Eaton and Kortum 1996. Bosworth studies patent applications to and from the United Kingdom using a cross-sectional sample for 1974 and finds that patent law differences across countries do not in any significant fashion explain patenting to and from the United Kingdom. Eaton and Kortum study the determinants of patenting and productivity for a cross-section of OECD countries for 1990 and find that strong patent protection does significantly stimulate patenting. This study differs from these previous studies in the following respects. First, this paper has a larger sample of countries, including both developed and developing nations. This helps capture any bias derived from the sample in studying the economic effects of patent protection. Second, this paper uses a different measure of patent protection, which has both a time-series and a cross-sectional dimension. The time-series part helps to capture changes in patent law over time (particularly since standards have changed for a number of countries). Previous measures of patent protection have constrained research to cross-sectional analyses. For example, Eaton and Kortum (1996) use the Rapp and Rozek (1990) index, which describes the state of patent laws in 1984.

There also exist few studies on the effects of patent protection on economic growth. One study that investigates this issue is Gould and Gruben (1996), from which this study differs in two respects. First, Gould and Gruben also uses the Rapp and Rozek index. Second, Gould and Gruben attempt to estimate the "direct" effect of patent rights on long-run productivity. This study focuses on the "indirect" effects of patent rights on growth via their effects on factor accumulation. Gould and Gruben (1996) essentially find that, once other growth variables are controlled for, patent laws are not directly statistically significant determinants of growth but that they interact with the "openness" variable in contributing to growth. That is, countries that trade more and have strong patent laws tend (in general) to grow faster. From this result, it is not clear by what channel stronger patent laws promote economic growth. Do they, for instance, encourage economies to be more open?

This chapter is organized as follows: section 1 describes how the measure of the strength of patent protection is constructed; section 2 describes some sample statistics of patenting, research intensity, and patent protection in Latin America; section 3 presents the empirical findings on the effects of patent protection on the international diffusion of technology (using international patenting data); section 4 presents the empirical findings on the effects of patent protection on economic growth; and section 5 concludes.

1 Measurement of patent rights

This section describes how patent-rights protection is measured. Information was obtained directly from national patent laws. The index of patent rights (PR) takes on values between 0 and 5, higher numbers reflecting stronger levels of protection.

The index consists of five categories: (i) coverage, (ii) membership in international patent agreements, (iii) provisions for loss of protection, (iv) enforcement mechanisms, and (v) duration. Each category takes on a value between 0 and 1 and the sum of these five values gives the overall value of the PR for a particular country.

Except for category (v) duration (which is elaborated below), each category consists of *several conditions*, which, if they exist in a country, indicate a strong level of protection in that category. The "scoring technique" is as follows. If there are three conditions in a category and given that each condition is of a binary character (yes, it exists or no, it does not), the value assigned to this category is the fraction of conditions met. As an example, if the value of enforcement is two-thirds, this indicates that the country satisfies two of the three conditions needed for strong enforcement.

(i) Coverage

There are seven conditions referring to whether the following are patentable: (1) utility models (i.e. improved utilization of objects, typically minor inventions such as tools); (2) pharmaceutical products; (3) chemical products; (4) food; (5) plant and animal varieties; (6) surgical products; and (7) microorganisms. A country that provides patent protection for all seven kinds of inventions receives a value of one, those that provide for two receive a value of two-sevenths.

(ii) Membership in international agreements

The three major agreements are: (1) the Paris Convention of 1883 (and subsequent revisions), (2) Patent Cooperation Treaty of 1970 (PCT), and (3) the International Convention for the Protection of New Varieties of Plants of 1961 (UPOV). Countries that are signatories to all three receive a value of 1 in this category; those that are signatories to just one receive a value of one-third.

The Paris Convention provides for national treatment to foreign nationals in the provision of patent rights—that is, it provides for non-discriminatory treatment. The main objective of the Patent Cooperation Treaty is to facilitate administrative procedures in applications for patents. It allows the filing of a single patent application that can be made effective in patent offices in any of the member countries. The UPOV confers plant breeder's rights, a form of protection similar to a patent. This treaty obliges its signatories to adopt common standards and scope of protection as national law, helping to make application procedures and laws much more clear and non-discriminatory.

(iii) Loss of Protection

This category measures protection against losses arising from three sources: (1) "working" requirements, (2) compulsory licensing, and (3) revocation of patents. A country that protects against all three receive a value of 1 in this category.

Working requirements refer to the exploitation of inventions (or utilization of patents). The authorities may, for example, require that a good based on the patent be manufactured or, if the patent is granted to a foreigner, that a good be imported into the country. Some countries impose conditions that inventions must be working by a certain period of time. Compulsory licensing requires patentees to share exploitation of the invention with third-parties, and usually works to limit the capacity of patent holders to appropriate the returns from their inventions (particularly if compulsory licensing is imposed within a short time after a patent is granted). Finally there are countries that may revoke patents entirely, usually if they are not working.

(iv) Enforcement

Laws are not effective without adequate mechanisms for their enforcement. In this category, the pertinent conditions are the availability of (1) preliminary injunctions, (2) contributory infringement pleadings, and (3) burden-of-proof reversals. A country that provides all three receives a value of 1 for this category.

Preliminary injunctions are pre-trial actions that require individuals to cease an alleged infringement. Preliminary injunctions are a means of protecting the patentee from infringement until a final decision is made in a trial. Contributory infringement refers to actions that do not in themselves infringe a patent right but cause or otherwise result in infringement by others. In short, contributory infringement makes third-party participants liable as infringers. Burden-of-proof reversals are procedures that shift the burden of proof in process patent infringement cases from the patentee to the alleged infringer. In light of the difficulty that patentees have in proving that others are infringing on their patented processes (because there are often several means of producing the same product), the shift in burden can be a powerful enforcement mechanism.

(v) Duration

The length of the patent term is important for ensuring adequate returns to innovative activity. Here, a country receives a 1 if it provides the minimum duration recommended by the United States Chamber of Commerce (USCC). The minimum duration is 17 years from the date of patent grant or 20 years from the date of patent application. Countries that give less than this minimum duration receive a value equal to the fraction of the minimum standard provided, and countries that give more than the minimum duration are assigned a value of 1.

2 Sample statistics with emphasis on Latin America

Table 1 (page 65–66) presents sample statistics for some Latin American economies. In particular, the table shows real GDP per capita in this region, the PR levels, patent filing costs, R&D intensities, and patenting activities within this region. In general, the level of patent rights here is low (relative to that of the industrialized world, which typically scores above 3.5).Since the signing of the TRIPS agreement, however, several countries have significantly strengthened their patent régimes (in particular, Brazil, Colombia, Mexico, Peru, and Venezuela). In general also, the R&D intensities are low in this region, where typically less than 1 percent of GDP is devoted to research and development. However, there has been a significant rise in the share of GDP going to R&D in countries like Chile, Mexico, and Peru. In addition, patenting costs are quite high in this region (the next section describes in detail how the patent filing costs were derived). This is likely due to the cost of translating patent documents into Spanish or Portuguese.

The major patenting nations in this region are Brazil and Mexico. In 1995, Brazil filed almost 3,000 domestic patents, which is comparable to the number filed domestically by countries like Austria and Denmark. Brazil and Mexico are also the favoured patent destinations in this region. Mexico, for instance, in 1995 attracted nearly 5,000 patent applications from abroad, and an additional 18,431 PCT applications from abroad (i.e. international applications filed through the World Intellectual Property Bureau). Mexico in turn filed 99 of its inventions in the United States for patent protection in that same period, and an additional seven via the PCT. Brazil filed 115 applications in the United States in 1995 and an additional 62 via the PCT. Brazil's use of the PCT to gain foreign patent protection has increased since the mid-1980s.

Chile has experienced an increase in the inflow of foreign patent applications from abroad; e.g. foreign filings in Chile in 1995 are more than double those in 1990.

These data show low but *rising* levels of patenting and research activities in Latin America, as well as a gradual strengthening of patent rights. The next two sections empirically investigate the effects of this strengthening on international patenting, research, and productivity growth.

3 Patent protection and international diffusion of technology

The purpose of this section is to estimate the effects of patent protection on the international diffusion of technology, using international patenting data to measure the diffusion of inventive knowledge internationally. The empirical results show that the index of patent rights (PR) is a significant determinant of international patenting, even after controlling for other important determinants of patenting (e.g. market size, patent filing costs).

A panel data set of 16 source countries and 40 destination countries was assembled for four time periods: 1975, 1980, 1985, and 1990. "Source" countries refer to the countries from which patent applications emanate and "destination" countries to the countries in which patent applications are filed. Before presenting the empirical results, a few words on the equation to be estimated and the data to be used.

The estimation equation relates the patenting propensity of the source country to various destination factors, like the strength of patent protection. Each source country has a certain number of patentable inventions, and has a choice of 40 foreign markets (or "destinations") in which to file patent applications. In any one destination, the source country may file applications for all of its inventions, for some of them, or none of them. In general, the higher the quality of inventions and the more attractive the destination is in terms of market size, levels of patent protection, and other factors, the greater the fraction of inventions that will be patented in that destination. Thus, the estimation equation in this section relates the fraction of source country inventions that are patented in a destination to the legal and economic characteristics of the destination country.

The reasoning is as follows: assume that a particular source country has $q = 1, \ldots, Q$ inventions, and assume that those inventions are sorted in increasing order of quality; that is, invention 2 is of higher quality than invention 1 and so on. An invention is patented if the value of patenting in a destination (in terms of an increase in the discounted present value of profits) exceeds the patent filing costs. Let q^* be the quality level of that source country invention that breaks even—i.e. the benefit of patenting that invention just equals the cost of patenting it. Then, all inventions whose quality level exceeds q^* will be patented, and those whose quality levels follow below q^* will not be. More precisely, $F = 1 - (q^*/Q)$ is the fraction of Q inventions that will be patented in a destination. Now, holding the quality of inventions constant, this fraction will be higher the more attractive a destination is in terms of market size, patent filing costs, patent protection levels, and so forth because the more attractive a destination is, the lower the threshold q^*—that is, inventions of even lower quality will become profitable to patent.

Thus the basic equation to estimate is:

$$\log(F_{jnt}) = \log(x_{nt})'b_j + e_{jnt}, \qquad \textit{(Equation 1)}$$

where F denotes the fraction of inventions from source country j (where $j = 1, \ldots, 16$) that are patented in destination n (where $n = 1, \ldots, 40$), $t = 1, \ldots, 4$ denotes the four time periods (i.e. 1975, 1980, 1985, and 1990), and x denotes the vector of destination factors (or explanatory variables). The error term e is motivated by the fact that some profitable inventions fail to be patented, while some unprofitable ones are patented. This is the case either if inventors file (or fail to file) unprofitable (profitable) patent applications or if substantive law differences across destinations result in differences in examination standards.

The error term could also be influenced by specific *destination* and *source* country effects; that is, $e_{jnt} = a_n + l_j + u_{jnt}$, where the u_{jnt}'s are orthogonal and spherical disturbances. The destination effects may be either fixed or stochastic. The source country effects may be reflected in the intercept, error term, or in the slopes. Hence, in what follows, two types of samples are considered. The first is a pooled sample (where all 16 sources countries are pooled) in which the source country heterogeneities are reflected in "intercept" dummies. The second type splits the sample by individual source countries in which source country heterogeneities can be reflected in the coefficient estimates ("slopes"). Moreover, as will be explained later, the individual source country sample allows for an interdependent (cross-source country) error structure.

The explanatory variables (i.e. the x's in equation (1)) are the destination's market size (as proxied by GDP per capita (GDPC) measured in real 1992 PPP adjusted US dollars),[1] the index of patent rights (PR), share of scientists and engineers in the workforce (S&E), and cost of filing patents (PCOST). The number of scientists and engineers per 10,000 workers is used as a crude measure of the capacity of a country to imitate.[2] A European Patent Office (EPO) dummy is also included, which will equal 1 if the destination country belongs to the EPO. An EPO destination is attractive to the extent that it is easier, by design, to add an extra designation to a European patent application than to make a separate application to another state. There may also be time effects (due to technological progress or globalization) that influence trends in foreign patenting. Hence, a time trend (TIME) is also included as a regressor.

International patenting data are from the World Intellectual Property Office's (WIPO) *Industrial Property Statistics*, 1975 to 1990.[3] The PR measure used is the one constructed earlier. The patent cost variable must also be constructed since international patent filing cost data are not widely available. Patenting costs include official filing fees, translation fees, and agent fees. Helfgott (1993) provides estimates of patent filing costs for 28 countries in 1992; the measured filing costs refer to a particular type of invention (e.g. one that allows ten claims, 20 pages of specification, two sheets of drawing, is drafted in English, and has a corporate assignee). Most importantly, the filing costs are from an American applicant's point of view. The estimated filing cost of $690 (in real 1992 US dollars) in Canada need not be the filing cost faced by German or Chilean applicants in Canada.

To generate patent costs for more than the sample covered in Helfgott (1993), and for applicants from countries other than the United States, an equation is first estimated that best fits the patent filing costs data in Helfgott 1993. The fitted equation is then used to predict patent filing costs for all of the required bilateral country pairs. As determinants of filing costs, geographic distance from the United States (and its square) and linguistic similarity with the United States were used. The reason is that the bulk of filing costs is due to translation. Thus, the more similar the languages between two countries, the less expensive it would be to apply for patents in each other's markets. Filing in a foreign market is also likely to be affected by geographic distance, reflecting transportation costs and perhaps differences in economic structure (regulations, customs, and practices), which may make patenting in foreign jurisdictions costly.

Based on Helfgott's original sample of 28 countries, the following regression results were obtained (equation 2):

(*Equation* 2)

$$\widehat{\log(\textit{Patent Costs})} = \underset{(7.5)}{-22.17} + \underset{(1.81)}{7.57} \log \textit{Dist} - \underset{(0.11)}{0.47^{*}} (\log \textit{Dist})^2 - \underset{(0.015)}{0.032} \log \textit{Ling},$$

(Adj. $R^2 = 0.51$, Standard Error of the Regression = 0.51)

where standard errors are in parentheses. The two variables (Distance and the Index of Linguistic Similarity) have the expected effects on patent costs, where *Dist* denotes "distance" and *Ling*, "Linguistic Similarity." Distance, however, affects filing costs up to a point. Beyond that (at longer distances), inventors are likely to find ways to reduce global filing costs, such as multiple patent filings (to spread the costs of filing among several destinations) or (if a transnational corporation) establish a corporate patenting branch in a foreign office.

With the above fitted equation, patent costs between any pair of source and destination countries can be generated, as distance and linguistic similarity data are widely available.[4] The data thereby generated are the measure of patent filing costs. The generated costs are in real 1992 US dollars. To obtain time-series estimates of patent filing costs for 1975, 1980, 1985, and 1990, the GDP deflator (where 1992 = 100) was used for each country to infer the filing costs for those years in real 1992 US dollars.[5] For example, if the 1975 deflator = 50, the 1975 filing cost figure was considered to be half the 1992 estimate. This approach, however, assumes no "real" changes in filing costs. To allow for them, the cost figures were adjusted upward by the real GDP per capita growth rates (that is, each cost figure was multiplied by one plus the destination's real GDP per capita growth rate in that period). The working assumption here is that the growth in demand for patenting resources (and consequent rise in real filing costs) parallels the growth in market size.

The empirical results are in tables 2 and 3. Table 2 presents estimates of equation (1) for the aggregate (pooled) sample and table 3 for the disaggregated sample, source-country by source-country.

Pooled sample

Table 2 (page 67) presents the panel-data estimates for the aggregate sample. In this case, the *bj*'s are assumed to be the same for all *j* source countries. The regressors (i.e. x_n's) all have the expected signs and are statistically significant at conventional levels, except for the ratio of scientists and engineers to the workforce (which has a significance level exceeding 5 percent). The results also show the advantage of applying in European Patent Office (EPO) destinations. Controlling for EPO destinations causes the coefficient estimates of the index of patent rights (PR) to be lower. The coefficient estimate of logPR in all cases is greater than 1, indicating a highly elastic response; that is, a 1 percent increase in the level of patent rights, holding everything else constant, raises the rate of foreign patenting by more than 1 percent. However, it would not be proper to interpret this as a type of increasing return since in order to determine the "return," information is needed on what it costs to strengthen patent rights by 1 percent and on the benefits from foreign patents.

An F-test rejects the null of no individual effects and a c^2-test finds the random effects estimates (RE) not to be consistent (the individual effects indeed are correlated with the RHS variables). There are likely to be a number of omitted destination factors that are important to the foreign patenting decision and that correlate with the market size and level of development of nations (factors such as political rights, property rights in general, and level of institutional development, particularly of their patent offices and administration). There is also a high degree of serial correlation in the residuals, which is consistent with the omission of important variables. Thus the rest of this paper focuses on the fixed effects (FE) estimates.

Country-by-country sample

Equation (1) is now estimated separately for individual source countries, so as to see how reactions of source countries to destination factors can vary. However, the individual source-country equations are estimated as a *system of equations* because the disturbances in the foreign patenting equations (e.g. between e_{int} and e_{jnt}, for source countries i and j) are correlated due to "shocks" that are common to source countries—shocks such as international political and economic events, government policies, and increases in knowledge capital.

To incorporate these correlated disturbances, the following system is estimated, with each equation corresponding to a source country; that is, disaggregating equation (1):

(*Equation1'*)

$$\log F_{AUS,\,nt} = a_{AUS,\,n} + \log (x_{nt})'\, b_{AUS} + e_{AUS,\,nt}\,,\ n = 1, \ldots, 40,\ t = 1, \ldots, 4$$
$$\log F_{CAN,\,nt} = a_{CAN,\,n} + \log (x_{nt})'\, b_{CAN} + e_{CAN,\,nt}\,,\ n = 1, \ldots, 40,\ t = 1, \ldots, 4$$
$$\vdots$$
$$\text{v}\log F_{USA,\,nt} = a_{USA,\,n} + \log (x_{nt})'\, b_{USA} + e_{USA,\,nt}\,,\ n = 1, \ldots, 40,\ t = 1, \ldots, 4$$

where, as before, the x's are the vector of destination factors, b's their corresponding parameter vector, a's the fixed effects, and e's the error term. Stacking the above equations gives a 16 by 16 system of equations. Each equation has 160 observations (where $N = 40$ and $T = 4$). While quite large, the system can be readily estimated by a conventional seemingly unrelated regression (SUR).

As there does exist significant individual (or destination) effects, as shown earlier, the SUR is combined with a fixed effects estimation (FE). In practical terms, this means that all the variables (F's and x's) were demeaned by destination unit; that is, a variable, say z_{jnt}, is replaced by $(z_{jnt} - \bar{z}_{jnt})$, where j denotes source country, n destination country, and t time. The bar above $\bar{z}$ refers to the mean of z taken over only the $T = 4$

observations for each destination unit *n*. The transformed dependent variable and regressors were substituted into the system of equations above, and the system then estimated by SUR (without constant terms).

The results in table 3 (pages 68–69) show how source countries vary in their sensitivity to destination factors. Foreign patenting by the United States, Germany, Japan, and Canada is highly elastic with respect to the destination's level of patent rights (the coefficients of logPR exceed 3), while that of Spain and Sweden is less elastic. Patent rights matter greatly to all but one source country, namely India.

One explanation for India's being an exception is that, since it applies for so few patents abroad, there is not much variation being captured in the data. A second explanation has to do with the fact that different sectors exhibit different sensitivities to patent protection: the pharmaceutical sector is quite sensitive (as discussed in Mansfield 1994) and Indian patents abroad were non-pharmaceutical, the domestic Indian pharmaceutical sector being largely imitative. A third explanation may be that the quality of Indian inventions was not high enough to warrant patent protection. If so, rivals are not likely to target Indian inventions for imitation. This is consistent with the finding that the only statistically significant factor here is the proxy for the capacity to imitate (log S&E). India appears to target regions (for patenting) for their ability to imitate Indian inventions, and not for the strength of their patent regimes.

As for the other regressors, GDP per capita has a significantly positive influence, except to India and New Zealand, and only moderately to Switzerland. The proxy for imitative capacity is not an important determinant of foreign patenting by France, Germany, Japan, Netherlands, New Zealand, Spain, Sweden, Switzerland, the United Kingdom, and the United States.[6] The coefficients for patent-filing costs are significantly negative for *all* the source countries. The EPO dummy is not especially significant at this country level; the variable exhibits little variability within source country samples. The EPO factor matters primarily in explaining patenting behaviour among source countries in the pooled sample.

To summarize, patent rights, patent filing costs, and market size have in general the *expected* effect on international patenting, except that of India. The serial correlation has been eliminated for all source countries but a significant degree of unexplained variance exists. Just 20 percent to 40 percent of the variation in the data is explained by the model; the remainder is due to unobserved destination fixed effects. The model is not capturing all of the other (relevant) motives for international patenting, say for corporate strategic reasons (e.g. obtaining early "priority" or blocking rival patents).

4 Patent protection and productivity growth

The key finding here is that the strength of patent rights affects economic growth by stimulating the accumulation of factor inputs like research and development capital and physical capital. The PR rating does not *directly* explain international variations in growth. What this means is that strong patent laws affect productivity growth indirectly by stimulating the accumulation of those factors (like physical capital and R&D capital) that do directly affect production. The intuition behind this result is that laws *per se* do not directly affect the technical efficiency of production but rather the environment in which research, innovation, and investment can take place.

An implication of the result that the strength of the patent system affects productivity growth through its effect on research and development is that countries that do not have an innovation sector, or have one that is limited, would be less likely to enjoy the "growth" benefits of patent laws (since the main conduit by which the index of patent rights variable (PR) affects economic growth is absent). Countries without an innovative R&D sector are likely, therefore, to attach a low priority to developing the infrastructure for providing patent rights. On the other hand, the development of an intellectual property system has the potential to attract foreign research resources and knowledge capital (via patent filings, for instance, as shown in the previous section), which should help to stimulate the creation of a *domestic* research sector. Policy authorities would then be more inclined to provide and enforce patent laws as there would be something of interest to protect. For policy-making purposes, it is useful to take into account this interdependence (i.e. endogeneity) between the intensity of domestic R&D and the level of the domestic PR rating.

The effect of property rights in general on economic growth have been studied elsewhere (see for example, Torstensson 1994 and Svennson 1994). In these studies, however, property rights are broadly defined while here the focus specifically is on the protection of intellectual property. To ensure that the PR variable is not picking up the effects of property rights in general, the empirical analysis controls for a market freedom variable that captures characteristics of a nation's overall level of property rights.

The empirical results are based on the following structural model of growth:[7]

(*Equation 3*)

(*3a*) GROWTH = G (INITIAL, INVEST, SCHOOL, R&D, NGD, PATRIGHT, MARKET)

(*3b*) INVEST = I (INITIAL, PATRIGHT, MARKET, REVOL, GOVT, EDUC)

(*3c*) SCHOOL = S (INITIAL, PATRIGHT, MARKET, REVOL, GOVT, EDUC)

(*3d*) R&D = R (INITIAL, PATRIGHT, MARKET, REVOL, GOVT, EDUC) where INITIAL denotes the log of GDP per adult worker in 1960, INVEST the fraction of GDP invested in physical capital, SCHOOL the fraction of GDP invested in human capital, R&D the fraction of GDP invested in research capital, and NGD the sum of the depreciation rate, population growth rate, and exogenous technical efficiency growth rate. Moreover, PATRIGHT denotes the log of the patent rights index, MARKET the log of the market freedom index, REVOL the log of 1 plus the number of revolutions, GOVT the log of the ratio of government consumption to GDP, and EDUC the log of initial secondary school attainment (in years). Data on INITIAL, GROWTH, NGD, INVEST, and GOVT are from Summers *et al.* 1995. Data on R&D are from UNESCO, MARKET from Gwartney *et al.* (1995), and REVOL and EDUC are from Barro and Lee 1994. GROWTH is the growth rate of GDP per adult worker between 1960 and 1990.

The model shows that productivity GROWTH is a function of standard explanatory factors, plus the PR variable. The explanatory factors in turn are functions of environmental factors like the PR ratings, general market freedom, political events, and the stock of human capital attainment. A few remarks on expected signs. INITIAL should have a negative effect on the rate of growth if conditional convergence occurs, and INVEST, SCHOOL, and R&D should have a positive effect to the extent that they are important factors of production. A higher rate of population growth, depreciation rate, or rate of growth in labour efficiency has a negative effect because the available stocks of capital must be spread more thinly over the population. Since few studies exist on the role of institutions in economic growth, it is difficult to sign the market freedom and patent rights variables. On the one hand, more liberalized markets and protection of legal rights should provide a positive environment for economic activity and thus be conducive to growth. On the other hand, command economies (with less free markets and rights) have also achieved (at times) high growth rates.

Regarding the accumulation equations (3b to 3d), there are two opposing effects of initial development on investment rates. On the one hand, less developed countries have smaller amounts of reproducible assets, and hence higher marginal productivities of those assets. This should make less developed countries have a higher rate of investment than the more developed. On the other hand, the market size is smaller, and hence the less developed should have a lower rate of investment than the developed. The net effect is therefore ambiguous. Higher PR ratings are expected to contribute positively to investment to the extent that they raise the incentive to invest, but may discourage investment in new plants and equipment (and new products and processes) to the extent that they grant excessive market power. Again, market freedom is difficult to sign given the present lack of empirical evidence about the role institutions play. The empirical analysis should shed light on how important "liberal" markets are to investment behaviour. Political revolutions should have a negative effect on investment to the extent that they render investments riskier. The GOVT variable captures the size of government. Larger government sizes might capture the effects of distortionary taxation or financial and resource crowding out. Finally, EDUC proxies for the initial level of education. By raising the marginal productivities of factors, a higher level of EDUC should exert a positive influence on investments.

The system 3a to 3d is also estimated by Seemingly Unrelated Regressions (SUR) in order to exploit the interrelationships among the equations. The combined results are in tables 4 and 5: table 4 (page 70) reports the growth rate equation results and table 5 (page 71) the investment equation results. In each table, there are four columns, each of which corresponds to one set of SUR estimation results. Set (1) considers a full sample of 60 countries (for which data were available) but considers only the patent rights variable as the measure of institutions. Set (2) includes other institutional and related factors (such as market freedom, political instability, government size, and initial education). It is possible that PR ratings are proxies for the effects of property rights in general and thus it is important to control for the broader measure (like MARKET). Finally, in sets (3) and (4) the full sample is split into half, and separate SUR estimates are obtained for countries whose sample average GDP per worker is, respectively, above or below the median level. This allows for an examination of whether PR ratings matter differently for developed and developing regions.

While the estimation of the growth and investment equations was done jointly, the discussion will proceed first with the growth regression results and then the accumulation regression results. Column (1) of table 4 presents the first set of results. Patent rights have no statistically significant influence on growth. Thus the model essentially reduces to a standard growth regression model, driven by reproducible factors of production. Yet this does not preclude PR ratings having an indirect effect on GROWTH through their effect on some of these reproducible factors that do contribute to growth, like R&D.

The purpose of column (2) is to introduce another measure of institutions, namely market freedom. The MARKET index includes the strength of property rights more generally (over land, wealth, and earnings). As the results show, the broader measure does contribute positively to economic growth but the narrower measure (patent protection) does not. The interpretation is that PR ratings do not augment the technical efficiency of factors of production in the act of production.

Column (3) contains estimates for the top 30 countries (in terms of the average level of GDP per worker) and column (4) contains estimates for the bottom 30. The variable PR remains insignificant while MARKET continues to be an important determinant of growth. A key difference is that R&D has a larger measured impact on growth among the richer half. Another difference is that the market freedom measure has a larger impact for the poorer half. These economies, in other words, could benefit more from a given "liberalization" of markets. This could also suggest a type of diminishing returns to improving market freedom. Once quite liberalized, further liberalization does not yield as large a return (in terms of the impact on growth).

Table 5 presents the estimates of the investment equations. The underlying theme is that patent protection is a significant determinant of physical and R&D capital accumulation, even after controlling for market freedom. Indeed, market freedom here does not help to explain investment behaviour. This suggests that the broader measure of property-rights protection does not capture the importance of the ability of investors to appropriate the returns to their investments, as does the patent rights variable. However, neither the narrower nor broader measure of property-rights protection helps explain investments in education. The reason might be that investments in basic, general education are hard to appropriate in the first place, and thus the ability to establish proprietary rights to knowledge is not a factor determining human capital accumulation.

In column (1), table 5, the other control variables are not considered. The results show that patent rights do indirectly affect growth by stimulating the accumulation of physical and research capital. The positive influence of initial GDP per worker indicates that richer countries invest more in reproducible assets, and this certainly is a factor behind cross-country divergence. Since all the variables are in logs, the coefficients can be interpreted in percentage units. For example, a 1 percent increase in the PR (making laws stronger) raises the tangible capital investment rate by 0.26 percent and the research investment rate by 0.77 percent.

In column (2), table 5, the other control factors affecting the rates of return to investment are introduced, including market freedom. The measured impact of PR changes only slightly. A 1 percent increase in the index raises the R&D investment rate by 0.8 percent and the physical capital investment rate by 0.21 percent. Here, MARKET does not contribute to factor accumulation. This suggests that the effects of market freedom work through the "organization" of markets, exchange, and production, to affect directly the technical efficiency of production, but market freedom as a whole is likely to be too broad a measure to influence the relevant rates of return to investments.

The REVOL and GOVT variables have the right sign but are not statistically significant. A higher initial stock of education capital is important to the accumulation of physical and human capital but not of R&D capital. One reason might be that R&D requires much more specialized knowledge (as embodied in, say, the stock of science and engineering education) and thus is insensitive to the initial level of basic education.

Columns (3) and (4) report estimates of the split sample. Even within groups, market freedom does not affect investment (at conventional levels of significance). Patent rights, however, explain only the physical and research capital investment behaviour of the top 30 economies. The PR variable is significant at only the 24 percent significance level for the less-developed countries' R&D investment rates. There are two possible reasons for this: (1) the PR values tend to be low in this (less developed) region and thus R&D, when it does occur, responds to different incentives; (2) much of the R&D here may be adaptive or imitative R&D (for example, in Singapore and South Korea). Patent protection is likely to matter more for R&D activities targeted towards producing new innovations. Note that the result indicates that the less-developed countries' R&D is only weakly positively influenced by patent rights. It does not indicate that it is strongly negatively influenced by PR ratings, which would be the case if all or most of their R&D were imitative for, in this case, stronger patent protection would discourage their kind of R&D.

As for the other variables, INITIAL is not important to determining physical or human capital accumulation. This is attributable to there being less variability within groups in INITIAL than between groups. The initial stock of education also exhibits low variability among the top 30 but high variability within the bottom 30 group, and is thus an important factor determining the latter's rates of return to investment in physical and human capital. Government size has a negative effect on the less-developed countries' research but a positive effect on the developed countries' research. This suggests that, in the former, a larger government size reduces R&D investment through the distortionary effects of taxation but that, in the latter, a larger government size tends to be associated with more subsidies for company and institutional research (including research in higher education). Finally, revolutions have a significantly negative effect on human capital investment only for the top 30. This is due mostly to the presence of Latin American economies in this sample, which experienced coups and assassinations. The results indicate that political instability manifested itself more in disrupting education investments than in discouraging tangible investments.

In conclusion, the split samples show that it is important to distinguish between developed and developing economies when examining the role of patent protection on growth and investment.

5 Conclusion

According to the evidence presented, stronger patent protection has the potential to improve economic growth. Stronger patent rights will not on their own contribute to growth merely by being codified into laws. Rather, they will do so by making it possible for more investment activities to occur, particularly research and development activities. The investments in tangible and intangible capital in turn stimulate long-term growth. Productivity growth is also likely to be enhanced by attracting foreign investment and technologies. The evidence on international patenting shows that stronger patent rights attract foreign patent filings. Foreign patents in turn would be a source of much technological information (through the disclosure function of patents). Moreover, possessing patent rights makes foreign firms more secure in entering into joint ventures or cooperative R&D undertakings with local firms. Access to foreign knowledge, resources, and technology is an important means for technological catch-up and source of economic growth.

Thus, the results suggest that it would very much be in the interest of developing countries to provide stronger patent rights. Stronger patent rights are instrumental in attracting foreign technology and encouraging domestic innovation. Of course, the key barriers are: (1) that some depend (or thrive) on imitation for their livelihood, and are threatened by stronger patent laws; (2) that it is costly to develop an "infrastructure" for protecting and enforcing patent laws (and providing supporting institutions for patent searching and examination, trials, and training of examiners and judges). There is also an *incentive* problem: developing countries with a weak domestic research sector (or lack of one) do not have strong incentives to incur the costs of creating a stronger patent regime and of phasing out their "imitation" sectors. Some innovative activity needs to be present—to give authorities something of interest to protect. However, a sufficiently developed domestic research (or innovation) sector, may take a long time to evolve and may not develop at all. What is perhaps more efficient is for developing nations to take advantage of the stock of technology and knowledge that already exists in the more developed, industrialized world. By linking into foreign research sectors, domestic research sectors (in developing economies) have a greater chance of evolving. But a key *incentive* in turn for the developed world to share its knowledge and resources is the protection and enforcement of patent rights. Thus, once a credible commitment to providing and enforcing patent laws is established, domestic research activities and patent protection levels could co-evolve (endogenously). It need not be the case that the process be *sequential*; that is, a country need not develop a domestic research sector first, and a strong patent regime next.

Future research should ask not whether developing countries should have strong patent protection but how patent protection can be provided in developing countries. A patent system requires resources and training (for searching and examination, administration and enforcement); it also requires a *choice* of patent laws and procedures: should a developing nation join the Patent Cooperation Treaty? Should a developing nation determine invention "priority" based on first-to-file or first-to-invent, allow pre-grant disclosure, or permit pre-trial discovery?

Another issue that all patent systems alike have to face is that of patent filing *costs*, which have increased significantly during the past decade. One component of patent filing costs is translation, and this component will continue to be important as more nations join the international patenting community. Many national offices regard their translation requirement as a matter of sovereignty. From a practical point of view, it is also the case that unless patent documents are translated, no new knowledge is "disclosed" to the local economy (in exchange for patent protection). However, from the point of view of inventors and applicants, translation is a major financial burden, and may even discourage them from seeking protection. This is, therefore, an issue for less developed countries to deal with; it may be necessary to trade off a certain amount of sovereignty (and accept imperfect knowledge disclosure) in order to encourage more patent filings from abroad.

Notes

1 GDP, population, and exchange rate data are taken from Summers, Heston, Aten, and Nuxoll 1995.
2 Data on scientists and engineers are from the UNESCO *Statistical Yearbook*, various years.
3 For 1980, patents filed through the European Patent Office (EPO) were added to the WIPO figures. Subsequent WIPO figures (after 1980) included EPO patents.
4 Data on distance and linguistic similarity are from Boisso and Ferrantino 1996.
5 Deflator data are from Summers, Heston, Aten, and Nuxoll 1995.
6 This could mean either that the capacity to imitate is not a significant determinant of foreign patenting or that log S&E is a poor proxy for the capacity to imitate for these countries.
7 Detailed derivations are in Park and Ginarte 1997.

Tables

Table 1: Patent destination characteristics, Latin America

	Patent Filing Costs	Real GDP per capita	PR Level	R&D as % of GDP	Domestic Patenting	Foreign Patenting Inflows via		Foreign Patenting Outflows to US via	
						National Route	PCT	National Route	PCT
Argentina									
1985	1,088	5,324	2.26	0.482				39	
1990	2,079	4,706	2.26	0.499				56	
1995			3.20	0.400				65	
Bolivia									
1985	2,393	1,754	1.98	0.033	5	41			
1990		1,658	1.98	0.033					
1995	4,271	2,514	1.98		17	106			
Brazil									
1985	1,397	4,017	1.85	0.600	1,954	4,565	1,858	78	10
1990	2,946	4,042	1.85	0.663	2,427	4,148	5,856	88	24
1995	7,796	4,748	3.05	0.600	2,737	3,237	19,803	115	62
Chile									
1985	1,148	3,467	2.41	0.437	122	550			
1990	2,125	4,338	2.41	0.450	169	642			
1995	4,116	9,382	2.74	0.700	171	1,535			
Colombia									
1985	2,908	2,968	1.12	0.150	72	441			
1990		3,300	1.12	0.150					
1995	6,252	5,990	3.24		141	1,093			

Table 1 continued: Patent destination characteristics, Latin America

	Patent Filing Costs	Real GDP per capita	PR Level	R&D as % of GDP	Domestic Patenting	Foreign Patenting Inflows via		Foreign Patenting Outflows to US via	
						National Route	PCT	National Route	PCT
Mexico									
1985	2,101	5,621	1.40	0.180	590	3,091	311	81	
1990	2,776	5,827	1.63	0.180	661	4,400	139	76	
1995	4,204	6,302	2.52	0.400	432	4,802	18431	99	7
Peru									
1985	852	2,565	1.02	0.282	41	211			
1990	1,707	2,188	1.02	0.283	49	219			
1995		3,549	2.37	0.600	52	565			
Uruguay									
1985	987	3,969	2.26	0.100	63	105			
1990		4,602	2.26	0.100					
1995	4,099	6,281	2.26		35	221			
Venezuela									
1985	3,572	6,225	1.35	0.393	227	1,303			
1990	3,184	6,055	1.35	0.420	262	1,090			
1995		7,608	2.75	0.500	182	1,822			

Notes: Domestic Patents are Applications by Residents; Foreign Patent Inflows (Outflows) are Patent Applications into the region (to the U.S. from this region). GDP per capita and Patent Filing Costs are in real 1992 U.S. PPP dollars; PR is the index of patent rights (Source: Ginarte and Park 1997); PCT = Patent Cooperation Treaty

Table 2: Pooled estimates of the international patenting model

Sample Size = 2560 (T=4, N=640 bilateral pairs [16 source countries x 40 destination countries])

	No EPO Effect			With EPO Effect		
	OLS	**FE**	**RE**	**OLS**	**FE**	**RE**
Constant	-10.3	—	-11.7	-8.77	—	-10.9
	(0.67)		(0.73)	(0.66)		(0.73)
log GDPC	0.718	1.262	0.909	0.543	1.277	0.862
	(0.068)	(0.145)	(0.075)	(0.066)	(0.144)	(0.074)
log S&E	0.252	0.149	0.150	0.312	0.144	0.169
	(0.049)	(0.077)	(0.052)	(0.046)	(0.076)	(0.051)
log PR	2.161	2.478	2.289	1.679	2.058	1.928
	(0.099)	(0.209)	(0.132)	(0.105)	(0.229)	(0.139)
log PCOST	-0.427	-0.477	-0.442	-0.398	-0.494	-0.469
	(0.049)	(0.078)	(0.056)	(0.047)	(0.077)	(0.055)
Time	0.049	0.026	0.048	-0.024	0.014	0.029
	(0.028)	(0.025)	(0.017)	(0.029)	(0.026)	(0.017)
EPO	—	—	—	1.151	0.304	0.465
				(0.072)	(0.073)	(0.069)
Adj R2	0.64	0.92	0.63	0.66	0.92	0.65
F-test	14.16			13.11		
c2-test			15.6			23.9
DW	0.223	1.298	0.222	0.270	1.305	0.235

Notes: Dependent variable is log(F). Heteroskedastic-consistent standard errors are in parentheses. DW is the Durbin-Watson statistic, F-test the statistic for testing the null of common intercepts (or of no individual effects), and c2-test the statistic for testing the null of no correlation between the individual effects and other regressors. The EPO Effect refers to advantages of filing in European Patent Office destinations. EPO = 1 (for 1980, 85, 90) if the destination is an EPO member (i.e. Austria, Den, Fra, Ger, Ita, Neth, Spain, Swe, Swit, and UK).

Table 3: System of individual countries—seemingly unrelated regression (SUR) and fixed effects (FE) estimation

	log GDPC	log S&E	log PR	log PCost	Time	EPO	DW	Adj R-sq
Australia	0.854	0.425	2.785	-1.122	0.789	0.098	1.82	0.33
	(0.447)	(0.238)	(0.888)	(0.224)	(0.169)	(0.105)		
Canada	1.517	0.545	3.668	-1.057	0.023	0.055	2.004	0.28
	(0.358)	(0.181)	(0.485)	(0.213)	(0.169)	(0.098)		
Denmark	0.806	0.573	2.439	-1.234	0.275	0.007	1.89	0.21
	(0.379)	(0.222)	(0.703)	(0.179)	(0.157)	(0.073)		
France	1.038	0.202	2.358	-1.014	0.204	0.068	2.37	0.25
	(0.355)	(0.184)	(0.501)	(0.191)	(0.149)	(0.07)		
Germany	1.433	-0.128	3.466	-1.073	-0.201	0.044	2.03	0.34
	(0.459)	(0.271)	(0.639)	(0.196)	(0.161)	(0.079)		
India	-0.262	0.482	-0.196	-0.465	0.177	0.023	2.15	0.04
	(0.227)	(0.147)	(0.341)	(0.203)	(0.102)	(0.129)		
Israel	0.868	0.629	2.739	-1.123	0.074	0.134	1.8	0.27
	(0.382)	(0.212)	(0.633)	(0.172)	(0.132)	(0.07)		
Japan	1.579	-0.106	3.774	-0.982	-0.209	0.142	2.13	0.25
	(0.488)	(0.272)	(0.695)	(0.196)	(0.165)	(0.107)		
Netherlands	1.020	-0.243	2.106	-1.217	0.019	0.078	2.16	0.22
	(0.452)	(0.298)	(0.598)	(0.174)	(0.145)	(0.085)		

Table 3continued: System of individual countries—SUR and FE estimation

	log GDPC	log S&E	log PR	log PCost	Time	EPO	DW	Adj R-sq
New Zealand	0.094	-0.307	2.774	-0.977	0.977	0.225	2.27	0.4
	(0.317)	(0.220)	(0.674)	(0.196)	(0.137)	(0.088)		
Norway	0.848	0.470	2.587	-0.749	0.285	0.061	2.06	0.24
	(0.344)	(0.211)	(0.573)	(0.204)	(0.149)	(0.091)		
Spain	0.991	0.073	1.816	-0.790	0.167	0.041	2.07	0.18
	(0.400)	(0.258)	(0.534)	(0.179)	(0.136)	(0.081)		
Sweden	0.919	0.062	1.582	-0.999	0.801	0.009	2.005	0.32
	(0.349)	(0.244)	(0.641)	(0.202)	(0.163)	(0.071)		
Switzerland	0.700	-0.237	2.799	-1.012	0.516	0.021	2.38	0.22
	(0.443)	(0.284)	(0.553)	(0.189)	(0.129)	(0.063)		
United Kingdom	1.343	0.046	2.722	-0.665	0.205	0.111	2.07	0.26
	(0.330)	(0.243)	(0.572)	(0.176)	(0.119)	(0.080)		
United States	1.531	-0.189	3.126	-1.205	0.416	0.106	1.77	0.29
	(0.441)	(0.269)	(0.623)	(0.217)	(0.132)	(0.084)		

Notes: Heteroskedastic-consistent standard errors in parentheses. Number of Equations = 16 (each corresponding to a Source Country). Number of Observations per Equation = 160 (where T = 4 and N = 40 destinations) Fixed Effects Controlled for by demeaning each variable (by destination unit) prior to SUR

Table 4: Effect of patent rights on growth

	Dependent Variable: GROWTH RATE, Average 1960–1990			
	(1)	**(2)**	**(3)**	**(4)**
CONSTANT	3.528	3.714	8.60	6.16
	(1.20)	(1.15)	(1.28)	(2.82)
INITIAL	-0.483	-0.485	-0.841	-0.592
	(0.073)	(0.069)	(0.093)	(0.14)
INVEST	0.537	0.657	0.26	0.71
	(0.137)	(0.134)	(0.149)	(0.197)
SCHOOL	0.196	0.125	0.422	0.097
	(0.086)	(0.087)	(0.129)	(0.119)
R&D	0.121	0.117	0.180	0.133
	(0.042)	(0.041)	(0.066)	(0.053)
NGD	-1.144	-0.861	-0.402	-0.167
	(0.352)	(0.356)	(0.275)	(0.918)
PATRIGHT	-0.045	-0.049	-0.042	-0.06
	(0.098)	(0.094)	(0.132)	(0.114)
MARKET		0.343	0.334	0.47
		(0.141)	(0.131)	(0.208)
Adj R2	0.592	0.628	0.866	0.543
No. Obs.	60	60	30	30

Notes: Standard errors are in parentheses. Estimation is by Seemingly Unrelated Regression (equation in Column x is jointly estimated with equations corresponding to column x's of Table 2, where x = 1, 2, 3, 4). Column (3) represents the above-median income sample, and column (4) the below-median income sample.

Table 5: Effect of patent rights on the dependent variables: INVESTMENT, SCHOOL and R&D (accumulation regressions) 1960–1990

	INVEST				SCHOOL				R&D			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
CONSTANT	-3.32	-2.6	-0.64	-2.53	-6.65	-6.02	-2.46	-8.01	-11.6	-12.1	-12.5	-8.5
	(0.42)	(0.5)	(0.87)	(1.2)	(0.68)	(0.79)	(0.72)	(2.15)	(1.22)	(1.5)	(1.92)	(3.6)
INITIAL	0.19	0.064	-0.19	0.11	0.49	0.29	0.011	0.47	0.7	0.68	0.75	0.12
	(0.06)	(0.07)	(0.098)	(0.17)	(0.09)	(0.11)	(0.08)	(0.29)	(0.16)	(0.21)	(0.22)	(0.49)
PATRIGHT	0.26	0.21	0.43	0.043	-0.04	-0.12	0.036	-0.15	0.77	0.8	1.5	0.47
	(0.09)	(0.096)	(0.14)	(0.13)	(0.15)	(0.15)	(0.11)	(0.23)	(0.26)	(0.29)	(0.3)	(0.39)
MARKET		-0.2	-0.04	-0.33		0.245	-0.03	0.45		0.51	0.62	-0.16
		(0.16)	(0.21)	(0.22)		(0.25)	(0.17)	(0.4)		(0.48)	(0.47)	(0.67)
REVOL		-0.29	0.04	-0.31		-0.25	-0.91	-0.16		-0.75	0.51	-0.03
		(0.98)	(0.36)	(0.44)		(0.46)	(0.29)	(0.79)		(0.88)	(0.78)	(1.32)
GOVT		-0.17	-0.13	-0.02		-0.099	0.11	-0.17		-0.09	0.65	-1.06
		(0.13)	(0.15)	(0.19)		(0.202)	(0.13)	(0.34)		(0.38)	(0.34)	(0.56)
EDUC		0.15	0.092	0.22		0.203	0.083	0.303		-0.15	0.022	-0.27
		(0.06)	(0.066)	(0.095)		(0.093)	(0.054)	(0.17)		(0.18)	(0.14)	(0.29)
Adj R2	0.36	0.43	0.39	0.34	0.37	0.47	0.46	0.43	0.45	0.47	0.75	0.14
No. Obs	60	60	30	30	60	60	30	30	60	60	30	30

Notes: Standard errors in parenthesis. Estimation is by SUR, jointly with Growth Equation. Column (3) represents the above-median income countries, and column (4) the below-median income countries.

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