INTELLECTUAL PROPERTY AND INNOVATION:

NEW EVIDENCE ON THE RELATIONSHIP BETWEEN PATENT PROTECTION, TECHNOLOGY TRANSFER AND INNOVATION IN DEVELOPING COUNTRIES

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EXECUTIVE SUMMARY

Two key potential benefits of strengthened patent protection for developing countries are greater technology transfer from developed countries and higher levels of local innovation. Although stronger patent rules contribute to the incentives for these activities, they are but one of several motivating factors and there are a range of possible tradeoffs and time lags in the response to strengthened patents. As a result, the connection is often difficult to establish rigorously in empirical studies. The bottom line from the existing empirical analyses is that the effects are strongest in patent-sensitive industries such as pharmaceuticals (where imitation costs are low relative to the innovator's costs for discovering and developing new compounds), and that even for pharmaceuticals there appear to be negligible benefits for countries with low levels of education and economic development (Qian 2007, Kyle and McGahan 2008).

This paper examines a unique set of complementary variables that help identify the empirical relationship between strengthened patent protection and both technology transfer and local innovation outcomes in developing countries.[1] The key result of the paper is that for developing countries, domestic scientific and technological capabilities significantly affect their response to strengthened patent protection. Indeed, there is a robust and statistically significant relationship between increased patent protection and both patenting activity (as an indicator of the impact on local innovation) and R&D alliances (as an indicator of the impact on technology transfer), but exclusively for the more technologically-advanced developing countries. This research points to the need for a longer-term agenda of complementary policies and support measures to strengthen the science and technology (S&T) capabilities that are most critical to allow the less developed countries to reap the benefits from strengthened patent protection. Such interventions should be based on a prior and careful quantification of the effects of strengthening specific S&T capabilities and policies on the patent protection-innovation nexus, as well as the identification of the effectiveness of such policies and support measures in varying country contexts.

A compelling aspect of the paper is its combination of a common rigorous approach applied to four key indicators of technology transfer and innovation across distinct datasets for up to 114 countries—88 developing and 26 developed countries—for the time period 1990-2005.[2] Specifically, we analyze the impact of strengthening patent protection on the following outcome indicators:

- foreign direct investment stocks (from the United States) to manufacturing industries in developing countries, as our core measure of the impact of patent protection on technology transfer from developed countries;

[1] The classification of countries as "developing" versus high-income developed, as reported in Table A2, is based on the World Bank's classification of countries by income according to 1990 GNP per capita, at the beginning of the period of the various analyses.

[2] In response to the World Trade Organization's 1994 Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) and a number of other global and local pressures, many developing countries have been strengthening their IP protection, including product patent protection, over this period.

- R&D strategic alliances between developing country firms and developed country firms in high-tech sectors, as a complementary measure of technology transfer;

- patent applications by, and patents granted to, developing country innovators, as our core measure of the impact of patent protection on local innovation, with an additional examination of international co-invention patents that embody knowledge sourced in both developing and developed countries as a proxy for "higher-quality" patents (that is, those that benefit from such richer cross-national research interactions); and

- R&D expenditures by developing country firms, as a complementary measure of local innovation.

We are able to take advantage of the "natural experiments" that have been created by the strengthening of patent protection in a number of developing countries over the past twenty years. The varying strength of patent protection across different countries and over time is quantified by one of the most popular indices of the *de jure* strength of the patent protection system, the Park (2008) IP index—which reflects membership in international treaties, product coverage, restrictions on patent rights, enforcement mechanisms, and duration of patent protection.

This paper goes beyond an examination of all developing countries as a group, and presents more detailed analyses of our outcome variables for two groups of more technologically-advanced developing countries:

- The four "Asian tigers": Hong Kong, Singapore, South Korea and Taiwan; and
- The "emerging 8" countries: Argentina, Brazil, China, Hungary, India, Mexico, Russia and South Africa.

We categorize developing countries into these two groups to explore our main hypothesis that the shorter-term benefits of a stronger patent regime accrue to more technologically-advanced developing countries that have the sufficient levels of human capital, infrastructure, supporting policies and institutions necessary to attract more global technology transfer and to engage in more substantial innovation. We also provide more specific analyses for the medical-related industries, and particularly for the pharmaceutical and biotechnology sectors, because these sectors have reported the greatest effectiveness of patents as a means of appropriating the returns from industrial R&D (Levin et al., 1987). The common approach applied to each dataset provides consistency and facilitates comparisons of the impact of the strengthening of patent protection on the different outcome variables across countries.

Our common analytical approach is to examine the impact of increased patent protection on our outcome variables across all countries for the following country and industry breakdowns: all developing countries (relative to developed countries); our three breakdown country groups (Asian tigers, emerging 8, and all other developing countries –

76 countries from Algeria and Angola to Zambia and Zimbabwe); and the medical industries (which include pharmaceutical and biotechnology sectors, in addition to a number of other related sectors).

In order to explore the robustness of our country-group findings, we then examine the same statistical relationships exclusively for developing countries. Although restricting the analysis to only developing countries decreases the sample size, it has the benefit of reducing the potential biases arising out of confounding cross-country differences. Additionally, we examine sector-specific relationships in the data by exploring whether increased patent protection has a separate effect on the pharmaceutical sector (relative to the biotechnology sector).

The summary table provides an overview of key findings, where the robust results (statistically significant across both the full sample of all countries as well as the restricted sample of only developing countries) are highlighted, and the most statistically significant results (estimated impact different from zero at the one percent level of significance) are represented by three stars.[3]

The most striking feature of the summary table is that developing countries are not a monolith: there are stark differences across developing countries in their response to strengthened patent protection. There is a robust and statistically significant relationship between increased patent protection and most outcome variables for the technologically-advanced Asian tigers and emerging 8 countries, but no such association across any of the outcome variables for the group of other developing countries.

Summary Table: Impact of Strengthened Patent Protection in Developing Countries

		Country Groups across all sectors				**Sector Groups**		
Outcome Variable		All developing	Asian tigers	Emerging 8	Other developing	Medical industries	Pharma sector	Other
Technology Transfer through								
FDI:	U.S. stocks	no	no	no	no	no	no	**yes*** **
Alliances:	R&D alliances	no	**yes***	**yes*****	no	**yes*****	no	no
Local Innovation through								
Patents:	EPO applications	**yes***	**yes***	**yes*****	no	no	no	**yes***
	USPTO grants	no	**yes*****	**yes****	no	no	no	no
	Coinvention filings	no	**yes*****	**yes*****	no	no	no	**yes*****
	Coinvention grants	no	**yes*****	**yes*****	no	no	no	no
R&D:	Expenditures	no	no	no	no	no	no	no

Note: ***=estimated impact of IP index is positive and different from zero at least at the 1% level of statistical significance in both "all countries" and "developing countries" samples, **=at least 5% in both, *=at least 10% in both. For Sector Groups, there is only one set of regressions across all developing countries for each outcome variable.

[3] The "other" column under sector groups refers to one or more aggregate sectors for our FDI outcome variable (chemicals, food, electronics/electrical and machinery, metals, and transport equipment), and to the non-medical industries and/or biotechnology sector for our other outcome variables.

The robust and significant country-group findings (at the 5 percent level of significance or greater) across all sectors are:

- *Strengthened patent protection spurs technology transfer in the emerging 8 countries as proxied by strategic R&D alliances.* A one-unit increase in the IP index predicts a roughly 25 percent increase in R&D strategic alliances (29 percent relative to developed countries in the all-country sample, and 19 percent in the sample of only developing countries).

- *Strengthened patent protection spurs local innovation in the emerging 8 countries as proxied by patenting activity.* A one-unit increase in the IP index predicts a roughly 50 percent increase in applications to the EPO (50 percent relative to developed countries in the all-country sample, and 53 percent in the sample of only developing countries), and a roughly 20 percent increase in patents granted to the USPTO (16 percent relative to developed countries in the all-country sample, and 24 percent in the sample of only developing countries). For co-invention patents, a proxy for higher-quality patents (embodying knowledge sourced in more than one country), a one-unit increase in the IP index predicts a roughly 30 percent increase in co-invention applications to the EPO, and a roughly 55 percent increase in co-invention patents granted to the USPTO.

- *Strengthened patent protection spurs local innovation in the Asian tiger countries as proxied by patenting activity.* A one-unit increase in the IP index predicts a roughly 75 percent increase in patents granted to the USPTO (74 percent relative to developed countries in the all-country sample, and 80 percent in the sample of only developing countries). For co-invention patents, a one-unit increase in the IP index predicts a 46 percent increase in co-invention applications to the EPO, and a 20 percent increase in co-invention patents granted to the USPTO.

The only significant findings (at the 5 percent level of significance or greater) at the sector level across all developing countries are:

- *Strengthened patent protection spurs technology transfer in the transport equipment sector as proxied by U.S. FDI stocks to developing countries.* A one-unit increase in the IP index predicts a 123 percent increase in FDI stocks to developing countries.

- *Strengthened patent protection spurs technology transfer in the medical industries as proxied by strategic R&D alliances.* A one-unit increase in the IP index predicts a 19 percent increase in strategic alliances in the medical industries, relative to all other high-tech industries.

- *Strengthened patent protection spurs local innovation in the non-medical industries as proxied by patent applications.* A one-unit increase in the IP index predicts an 11 percent increase in applications to the EPO in the non-medical sectors of developing countries.

A final set of robust and significant findings concerns the pharmaceutical and biotechnology sectors in the technologically-advanced country groups. The impact of strengthened patent protection on local innovation as proxied by applications to the EPO is roughly the same for the emerging 8 countries as across all sectors, but is now also robust and significant for the Asian tigers: a one-unit increase in the IP index predicts a roughly 50 percent increase in applications to the EPO. In the case of patents granted to the USPTO, the association is stronger in magnitude than across all sectors: a one-unit increase in the IP index predicts a roughly 35 percent increase in patents granted to the emerging 8 countries (relative to 20 percent across all sectors), and a roughly 85 percent increase to the Asian tigers (relative to 75 percent across all sectors).

Compared to earlier empirical studies on developing countries, this study uses more detailed data and employs a common analytical approach across outcome variables. The study therefore analyzes previously unexplored questions, including the differential effect across the Asian tigers and the emerging 8 countries of increased patent protection on firm-level R&D strategic alliances and firm-level R&D expenditures. It is noteworthy that the relationship between increased patent protection and the outcome variables is strongest in the patent datasets, where individual observations are the most accurately recorded and available at the most disaggregated level. No doubt more robust and statistically significant analyses will become possible as other datasets become publicly available that record enterprise-level responses as accurately and consistently as the existing patent datasets.

There are at least three areas for further empirical research on the impact of strengthened IP protection on developing countries as natural extensions of this work:

- *Additional analyses of the impact of increased patent protection on technology transfer and local innovation.* While the common analytical approach adopted in this study facilitates comparisons across outcome variables, it would be interesting to explore appropriate modifications to the common regression models, such as allowing for non-linearities in the relationship between patent protection and firm-level R&D expenditures. Another direction for extension is to include additional measures of quality of outcomes rather than just counts and values, such as substituting patents granted for patent applications in the EPO analysis, or examining citation-weighted patents in both EPO and USPTO analyses. A complementary direction is to explore similar variables in other datasets, such as FDI data with a finer breakdown of products by technology class, patent filings data in a range of developing countries, or patent family data (that eliminate double counts of patent applications filed with multiple offices for the same invention). Additional measures of technology transfer and innovation could include scientific publications, clinical drug trials, and other forms of knowledge-sharing partnerships between developing and developed country firms. Finally, it would be desirable to complement cross-country analyses with additional rigorous country case studies along the lines of Arora et al. (2008), where special local characteristics can be given appropriate emphasis.

- *Analyses of the impact of other rules protecting IP*. Trademarks are the IP category most frequently used by developing country firms. In some developing countries, industrial designs, utility models, geographical indications and copyrights are also frequently used. It would be interesting to explore the impact of the strengthening of the other important rules protecting IP on relevant outcome variables.

- *Analyses of the impact of IP rules and complementary capabilities on broader innovation-related indicators.* As highlighted by our analyses, merely introducing stronger IP laws on the books is unlikely to lead to significant improvements in innovation-related outcomes unless countries have some significant level of existing S&T capabilities, namely human capital, infrastructure, supporting policies and institutions. One relevant direction for further research involves quantifying the effect of strengthening specific S&T capabilities and policies on the IP protection-innovation nexus, such as: (1) improvements in the availability, quality and relevance of university/tertiary education; (2) expenditures by enterprises for in-service (enterprise-based) training and by workers for additional vocational training; (3) the extent and quality of public and privately-funded support services for improving awareness, access and use of the IP system by enterprises; (4) explicit policies to attract foreign-educated and foreign-experienced national diasporas to contribute to their home countries; and (5) increased investments and an improved policy environment for broadband internet and National Research and Education Networks (dedicated high-speed broadband infrastructure that facilitate data traffic for specific purposes) to allow high-caliber researchers to stay better connected to global knowledge networks. A complementary direction would be to analyze the impact not just of the *de jure* strength of IP protection systems, but the *de facto* effectiveness of enforcement practices – which would require a better understanding of the effectiveness of actual IP policy implementation across countries, ideally also including the effectiveness of support policies to improve enterprise IP asset management strategies. Finally, it would be instructive to analyze the extent to which a greater awareness and strengthening of IP rules impacts broader innovation-related indicators, such as the diffusion of new technologies to developing country firms and the absorption and adaptation of these technologies to local conditions – including the extent to which patent disclosures are being utilized productively within developing countries.

I. INTRODUCTION

This paper examines the relationship between the strengthening of patent protection in developing countries from 1990 to 2005 and its effect on both technology transfer and local innovation. Strong legal protection of intellection property (IP) is typically credited for allowing innovators to appropriate the returns of their efforts, thereby increasing incentives for future investment in the production of such property. Because a wide variety of technologies relevant to developing countries are classified as IP, the impact of stronger patent and other forms of IP protection in developing countries has been an issue of immense interest to producers, household consumers, policymakers, and others. Furthermore, because IP protection in developing countries was notably weaker than that in developed countries until the 1990s, this issue has acquired even greater significance.

A major development on this front was the TRIPS Agreement of 1994, which obligated developing countries to bring their IP standards closer to those in the developed world.[4] Consequently, the TRIPS Agreement intensified the debate regarding the costs and benefits of stronger IP protection in developing countries. The potential benefits of stronger IP protection include the possibility of greater innovation by local firms in developing countries as well as the increased potential for firms in developed countries to transfer frontier technologies to the more secure IP environments now offered by a number of developing countries.

While many theoretical predictions have been made about the trade-offs of stronger IP protection, a growing literature has emerged to seek empirical evidence on these costs and benefits – with a focus largely on patents given that they are explicitly intended to stimulate innovative activity, as opposed to trademarks which are primarily about signaling quality and reducing search costs. Since many of the benefits of patent protection occur in the longer term, the evidence is far from conclusive.[5] However, initial studies suggest that stronger IP protection has increased innovative activities by firms in some of the more technologically-advanced developing countries and has also led to a greater transfer of technology in various forms into these locations. The evidence also suggests that the extent of economic benefit for a given country is limited by the initial level of development within that country – in other words, the ability to undertake indigenous innovation or to locally absorb cutting-edge technologies from abroad requires some minimum level of technological ability or economic development. Among the most recent published papers undertaking related cross-country analyses in this area, Chen and Puttitanun (2005) use per capita GDP as their indicator of technological ability to examine the impact of changes in the Park IP index on patents granted by the USPTO over the 1975-2000 period, while Qian (2007) uses GDP per capita and average years of schooling as indicators of levels of economic development in a study of pharmaceutical patent protection, again based on the Park IP index, over the 1978-2002 period. Kyle and

[4] In response to the World Trade Organization's 1994 Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) and a number of other global and local pressures, many developing countries have been strengthening their IP protection, including product patent protection, over the 1990-2005 period.

[5] See Dutz et al. (2009) for a more detailed discussion of the studies mentioned in this paper.

McGahan (2008) also focus on pharmaceutical investments, but use a more detailed dataset on drug development projects from 1990-2006 to examine whether research efforts, location and collaboration respond differentially in developed, developing and least-developed countries to measures of TRIPS compliance based on WTO rules as well as on the Park IP index.

In this study, we build on the existing literature by analyzing four distinct indicators of local innovation and channels of technology transfer across a large sample of countries: (i) U.S. foreign direct investment (FDI) stocks to developing countries, (ii) R&D strategic alliances by developing country firms, (iii) patent applications by, and patents granted to, developing country innovators, and (iv) developing country firm-level R&D expenditures. Our main hypothesis is that the shorter-term benefits of a stronger IP regime accrue to more technologically-advanced developing countries that have levels of human capital, infrastructure, supporting policies and institutions necessary to attract more global technology transfer and to engage in more substantial innovation. We therefore consistently examine the relationship between the level of patent protection and technology transfer/local innovation for two distinct groups of the more technologically-advanced developing countries – under the presumption that country groups better capture the mix of human capital, infrastructure, supporting policies and institutions needed to attract technology transfer and to engage in innovation than one or more individual variables such as GDP per capita or years of schooling. We focus on the four "Asian tigers", Hong Kong, Singapore, South Korea and Taiwan, and the "emerging 8" countries, eight of the most advanced emerging economies, namely Argentina, Brazil, China, Hungary, India, Mexico, Russia, and South Africa. Wherever feasible, we also present more detailed analyses for the medical industries, and in particular for the pharmaceutical and biotechnology sectors (where we analyze the behavior of the pharmaceutical relative to the biotechnology sector). This is because previous studies have found that pharmaceutical and biotechnology sectors are industries where patents are the preferred method for protecting IP.[6]

Section II presents our common and consistent approach for the subsequent economic analyses. The following sections present econometric results across all available countries and manufacturing sectors, thereby providing a robust empirical assessment of the economy-wide impact of increased patent protection. Section III focuses on the relationship between patent protection and technology transfer. Our main results focus on the evolution of FDI stocks over time. Complementary data on R&D strategic alliances allow a more robust assessment of impact on innovation diffusion, by permitting an assessment of the extent of collaboration between developing and developed country innovative firms. Section IV focuses on the relationship between patent protection and local innovation. Our main results focus on non-resident patents by developing countries filed in Europe and granted in the United States over time. Complementary data on firm-level R&D expenditures in developing countries, as a measure of local innovation input, allow a more robust assessment of impact on local innovation. A final section provides some concluding remarks, including suggestions for further research.

[6] See Levin et al. (1987).

II. MEASURING PATENT PROTECTION AND ITS IMPACT IN DEVELOPING COUNTRIES

Our approach in this study is to provide concrete evidence on the impact of strengthened patent protection by examining a range of complementary outcome indicators in developing countries that represent technology transfer and innovation, keeping developed countries in the background as a comparison.[7] We seek to better understand the extent of a causal relationship in the data between the strength of patent protection and the selected outcome variables across developing countries. Because of data limitations, the time frame for the study ranges from 1990 to 2005. This time span allows an analysis of responses by market participants to the strengthening of patent standards spurred by the run-up to the 1994 TRIPS Agreement and other contemporaneous local and regional efforts at increased patent protection. The strengthening of patent protection in a number of developing countries over the past twenty years provides a "natural experiment" that we are able to exploit.

Our main hypothesis is that the shorter-term benefits of a stronger IP regime accrue to more technologically-advanced developing countries that have significant levels of existing science and technology (S&T) capabilities, namely sufficient levels of human capital, infrastructure and supporting policies and institutions to attract more global technology transfer and to engage in more substantial innovation. To test this hypothesis, we divide developing countries into three groups based on their underlying S&T capabilities:

- the Asian tigers, Hong Kong, Singapore, South Korea, and Taiwan;
- the "emerging 8" countries, eight of the most advanced emerging economies, namely Argentina, Brazil, China, Hungary, India, Mexico, Russia, and South Africa;
- the other developing countries (see Appendix Table A2 for the list of 76 countries, from Algeria and Angola to Zambia and Zimbabwe).

Table 1 provides available statistics, both in absolute levels and scaled by population, on four indicators of S&T capabilities that motivate our choice of these country groups:

- R&D personnel as an indicator of scientific human capital;
- tertiary students reflecting the number of available graduate students, professors and the underlying extent of research facilities;
- personal computers as an indicator of S&T-related capital;
- internet users as an indicator of knowledge flow-related infrastructure.

The underlying data are described in Appendix 1. Across both developed and developing countries, China, India, Russia, Brazil, Mexico, and South Korea are in the top 20 countries in terms of overall number of R&D personnel, tertiary graduate study enrollment, number of computers, and number of internet users. These countries are ahead of all other developing countries in these categories. In terms of density of

[7] The advantages of using distinct but related outcome indicators in the field of innovation have recently been explored by Nelson (2009).

infrastructure knowledge networks, the four Asian tigers are in the top 20 countries in terms of internet users per capita and computers per capita.[8] The Asian tiger countries are ahead of most developed countries and are the only developing countries in this group. Therefore, relative to most other developing countries, the Asian tigers and the emerging 8 economies provide a more homogenous setting within which to compare outcomes, as well as a more relevant environment for studying the effects of strengthened patent protection. As a reflection of their S&T capabilities, the Asian tigers and the emerging 8 countries are the top-ranked developing countries in patent applications in Europe and in overall cumulative patents granted in the U.S.[9]

Table 1: Science and Technology Capabilities

2000 Counts and Ratios

		R&D Personnel		Tertiary Students		PCs		Internet Users	
Country Group	Max. # Countries Reporting	Count (000s)	Per 1,000 People	Count (000s)	% Gross Enrollm. Rate	Count (000s)	Per 100 People	Count (000s)	Per 100 People
Developing Countries	88	71.8	1.17	757	18.2%	1,418	4.7	1,191	3.9
Asian tigers	4	68.0	3.48	1,097	49.7%	7,096	37.8	7,114	32.3
Emerging 8	8	311.6	1.61	4,041	27.8%	6,879	5.1	5,834	4.0
Other	76	14.1	0.78	378	15.2%	483	2.8	390	2.4
Developed Countries	26	199.0	5.43	1,254	52.0%	13,087	34.8	10,921	30.1
Full Sample	114	118.4	2.73	873	26.2%	4,201	11.9	3,410	9.9

Note: Summary statistics are means based on one observation per country.

The varying strength of patent protection across different countries and over time has been quantified in many ways, the most common of which is by constructing composite indices of IP protection. In this study, we use one of the most popular indices of patent protection, the Park (2008) index. This patent index was designed to provide an indicator of the strength of patent protection, not the quality of patent systems. The index ranges in value from 0 to 5, with scoring between 0-1 in each of 5 components: membership in international treaties, product coverage, restrictions on patent rights, enforcement mechanisms, and duration of protection (see Appendix Table A1 for a more detailed outline of the components and scoring method of the Park index). A higher number indicates stronger patent protection. The index is available for 122 countries at 5-

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[8] Based on the publicly-available data from the International Telecommunications Union for internet users, and from the World Bank's World Development Indicators for personal computers

[9] See www.epo.org and www.uspto.gov/web/patents/stats.htm. In terms of total patent applications to the European Patent Office in 2008, the only other emerging EPO member states ahead of Hungary were Turkey, Poland, Slovenia and the Czech Republic. In terms of cumulative total patents granted in the U.S. to end-2008, the ranking is: Taiwan (70,643), South Korea (57,968), China (5,162), Singapore (4,097), India (4,080), South Africa (3,976), Hong Kong (3,805), Hungary (2,871), Mexico (2,509), Russia (2,409 – without inclusion of the pre-1991 stock of patents of the U.S.S.R.), Brazil (2,094), and Argentina (1,249). These countries also have the highest number of combined patents granted in the pharmaceutical and biotechnology sectors in the U.S. over the past five years (2003-2007): South Korea (478 patents), India (430), Taiwan (258), China (189), Hong Kong (94), Russia (74), Hungary (54), Brazil (52), Singapore (47), Argentina (33), Mexico (22), and South Africa (19). This ranking excludes Croatia, which has a total of 25 patents over the 2003-2007 period, since it has only pharmaceutical and no biotechnology patents over this period.

year intervals. Of these 122 countries, the availability of outcome variables and additional explanatory variables results in a common data set of 114 countries, including 88 developing countries and 26 developed countries (see Appendix Table A2 for a listing of these countries).

Table 2 presents the evolution of the IP index over the benchmark years 1990-2005, averaged across all 88 developing countries and 26 developed countries. While both groups of countries increased patent protection from 1990 to 2005, the largest changes in the strength of patent protection have been realized by developing countries. Developed countries begin the time period with a relatively high standard of patent protection, and increase by a much smaller percentage. There is less change and less variation in the developed country data. Therefore, our focus on developing countries is justified because most of the significant changes picked up by the data during this period are from developing, rather than developed, countries.

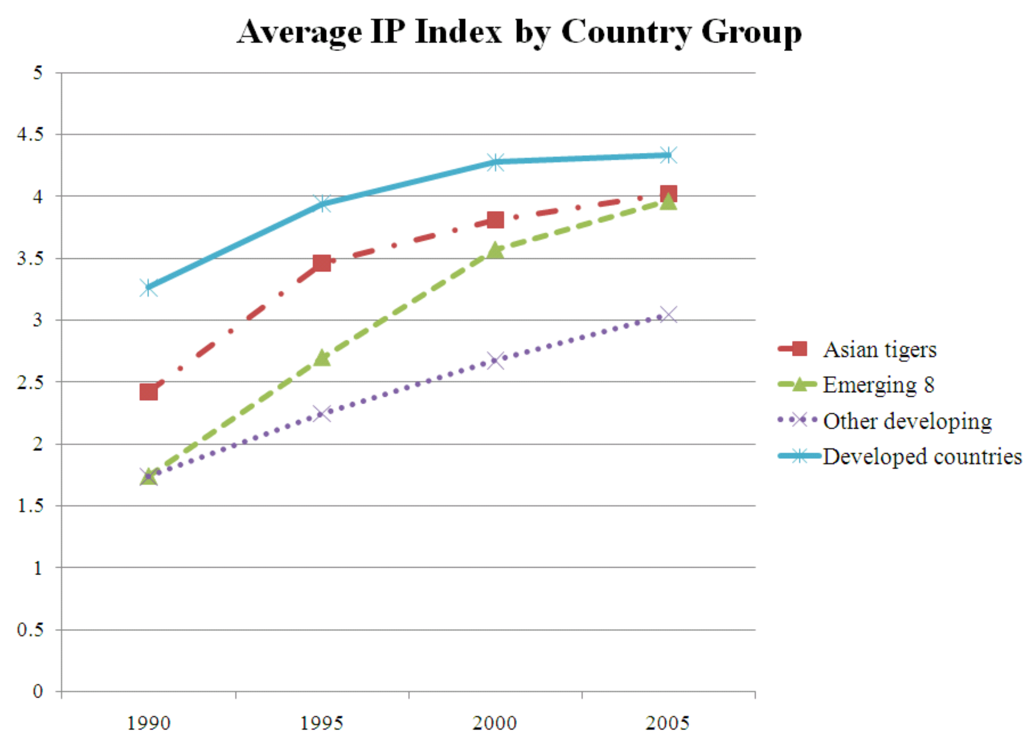

Table 2: IP Index

Possible range: 0-5

Country Group	# Countries	1990	1995	2000	2005	% Change, 1990-2005
Developing Countries	88	1.77	2.35	2.81	3.17	79.1%
Asian tigers	4	2.42	3.46	3.81	4.02	66.0%
Emerging 8	8	1.74	2.70	3.57	3.97	127.9%
Other	76	1.74	2.25	2.68	3.05	75.4%
Developed Countries	26	3.26	3.94	4.28	4.33	32.8%
Full Sample	114	2.13	2.70	3.13	3.43	60.9%

Note: Summary statistics are means based on one observation per country-year.

Both the Asian tigers and particularly the emerging 8 countries are characterized by significant increases in patent protection, reaching 4 out of 5 on the Park index (namely the level that the developed countries had reached by 1995). As highlighted in Table 2, the Asian tigers begin with a significantly higher average IP index than other developing countries, and increase over the 1990-2005 period at roughly double the rate of developed countries. The emerging 8 countries begin in 1990 with the same level of patent protection as the remainder of developing countries, but end up more than doubling their average level of protection, catching up with the Asian tigers by 2005. The "other developing countries" group increases their level of patent protection more slowly, on average. Among other potential determinants of this lesser change, the deadline of the TRIPS Agreement obligating most developing countries to improve their IP protection standards within a ten-year period was extended for the least developed countries to 2016.

In the ensuing analyses, we examine the impact of a one-unit increase in the IP variable on a range of outcome variables. India, a key member of our emerging 8 group of countries, provides a concrete illustration of what is meant by such a one-unit increase in terms of strengthening of patent protection. India started the period in 1990 with an IP index value of 1.03. Along with a number of other developing countries, India signed the TRIPS Agreement in 1994, obligating it to strengthen its domestic IP law within ten years. As highlighted in Appendix Table A1, this additional international treaty membership increased its index by 1/5 of a unit between 1990 and 1995, from 1.03 to 1.23. The Patents Amendments Act of 1999, that specifically allowed inventors to file patent applications in India, was a much more significant development and resulted in a further increase in the index by roughly one unit, namely from 1.23 to 2.27 by 2000. Finally, legal amendments in 2002 and 2005, which made India TRIPS-compliant, resulted in a further increase in the index from 2.27 to 3.76. The ability of this index to reflect specific steps taken by individual countries to strengthen IP protection and become TRIPS-compliant highlights an advantage of this index relative to other post-TRIPS measures (e.g., a simple indicator or dummy variable that equals zero or one), which would be constant across all countries after TRIPS implementation, or that would only reflect one change in the level of patent protection per country.

Our outcome variables are all theoretically sensitive to the strength of patent protection. For technology transfer, our core measure is U.S. FDI stocks to developing countries. By tracking FDI from one country to all developing countries, we avoid problems of comparability in the definition of FDI, and in differential accounting and statistical reporting across countries. As a complementary measure of technology transfer, we also examine the number of strategic alliances between firms located in developing countries and firms located in developed countries. We then examine, as our core measure for local innovation, patenting activity by residence of the inventors. Developing country non-resident patent applications to the EPO (European Patent Office) and patents granted by the USPTO (U.S. Patent and Trademark Office) are used as proxies for the extent of local innovation activity, an appropriate approach to the extent that a strong proportion of the more commercially successful local innovations in each country are also likely candidates for patenting in the major consumer markets of Europe and the United States. By restricting our analysis to an individual country's patent system, we again avoid problems of comparability of differing national patent systems over time. As a complementary measure of local innovation, we examine firm-level R&D expenditures. Data on these wide-ranging outcomes are brought together from different sources and are analyzed within a common framework.

In addition to international efforts to harmonize IP standards, the two decades covered by our study were also periods of intense globalization and industrialization in developing countries. These events introduce the possibility that globalization or other reforms that happened at the same time as changes in IP standards were responsible for some or most of the changes recorded in our outcome variable, rather than the changes in IP standards themselves. Additionally, using a large sample of countries with different institutional and infrastructural backgrounds always poses the risk that outcomes attributed to differences in IP standards are, in fact, the result of other factors. To reduce these concerns, we control for such factors by using country and industry fixed effects, differential time trends for developed and developing countries, as well as additional control variables including GDP per capita and an openness index which captures the degree of a country's economic integration with the rest of the world (see Table 4 below). Appendix 1 describes the underlying data sources.

Table 3 presents descriptive statistics about GDP per capita, in 2000 U.S. dollars, adjusted for inflation. As one might expect, the average GDP in the full sample has increased during the course of our sample, from $6,263 during the 1990-1995 period to $7,812 during the 2000-2005 period. When the average GDP per capita is broken down into different country groups, we can see that the average GDP per capita in the emerging 8 economies is more than two times higher than that of the other developing countries, while the average GDP per capita in the Asian tigers is more than ten times higher.

Table 3: GDP per Capita

2000 US dollars

Country Group	# Countries	1990-1995 Mean	1990-1995 Standard Deviation	2000-2005 Mean	2000-2005 Standard Deviation
Developing Countries	88	$2,151	$3,318	$2,728	$4,480
Asian tigers	4	$14,243	$6,381	$20,047	$7,157
Emerging 8	8	$3,111	$2,045	$3,764	$2,460
Other	76	$1,409	$1,413	$1,708	$1,797
Developed Countries	26	$20,100	$7,605	$25,018	$9,414
Full Sample	114	$6,263	$8,870	$7,812	$11,101

Note: The calculations across years are for two benchmark years, not each year; for example, the mean for 1990-1995 is the average of the 1990 and 1995 values.

Table 4 presents descriptive statistics on the Openness index, a control variable used in the analyses presented below. The Openness index measures a country's policy openness to the flow of goods and capital (from the Fraser Institute's Freedom of the

World report, see Appendix 1). Components of the index include trade tariff and tax levels, regulatory trade barriers, the size of the trade sector, and international capital market controls. The range of possible scores is 0-10, with 10 being the most open to goods trade and capital flows. In the full sample, the Openness index increases from an average of 6.35 during the 1990-1995 period to 6.76 during the 2000-2005 period, an increase of about 6 percent that reflects the increasing globalization that took place over these years. When broken down further into country groups, the average value of the index is consistently highest for the Asian tigers, followed by the developed countries, the emerging 8, and finally the other developing countries. The growth rate of the index is the highest in the emerging 8 sample (13.6 percent) followed by the other developing country sample (10.9 percent), with the index for the Asian tigers actually slightly falling between both periods.

Table 4: Openness Index

Possible range: 0-10

		1990-1995		2000-2005	
Country Group	# Countries	Mean	Standard Deviation	Mean	Standard Deviation
Developing Countries	88	5.88	1.48	6.45	1.15
Asian tigers	4	8.61	1.23	8.43	1.21
Emerging 8	8	5.96	1.29	6.76	0.71
Other	76	5.69	1.34	6.31	1.09
Developed Countries	26	7.63	0.78	7.74	0.74
Full Sample	114	6.35	1.54	6.76	1.20

Note: The calculations across years are for two benchmark years, not each year.

Our common analytical framework is to use linear regressions to study the statistical relationship between the strength of patent protection and the outcome variables. In addition to GDP per capita and the Openness index, each regression includes country-level fixed effects to control for any additional time-invariant country-level factors that may affect our outcome variables, as well as industry-level fixed effects, which control for differences between industries in their propensity to affect the outcome variables. Each regression also includes separate time trends for developing and developed countries, to control for different trajectories over time that may be causally unrelated to patent protection in the outcome variables.

To add greater detail to our descriptive results, we typically present our analyses in two complementary tables. First, we consider the impact of the strengthening of patent protection across all sectors of the economy. Second, we focus on the pharmaceutical and biotechnology sectors wherever the data allow this level of disaggregation (this is not possible for our FDI outcome variable since these data are not publicly available at the product line level to protect company confidentiality). In each set of regressions, we examine a similar set of models, namely a baseline model to quantify the impact of the IP index on our outcome variable across all countries, followed by two country group models: (i) examining the differential impact of our IP index on developing countries (versus developed countries); (ii) examining a breakdown of the effect of the IP index on our outcome variables for the Asian tigers, the emerging 8 economies, and other developing countries (versus developed countries). The final model across all countries examines whether the IP index has a separate statistically significant effect in the medical industries (which include pharmaceutical and biotechnology sectors in addition to a number of other related sectors).

In order to explore the robustness of our country-group findings, we then examine an analogous set of models exclusively for developing countries. We include a baseline model, followed by a breakdown of developing countries into the differential effect of the Asian tigers and the emerging 8 economies (relative to the other developing countries), and a final model examining whether the IP index has a separate developing-country effect in the medical industries. Although restricting the analysis to only developing countries reduces the sample size, it has the benefit of reducing the potential biases arising out of confounding cross-country differences. When we examine similar sector-specific relationships in the data by focusing on the pharmaceutical and biotechnology sectors, we explore whether the IP index has a unique effect on the pharmaceutical sector (relative to the biotechnology sector).

III. PATENT PROTECTION AND TECHNOLOGY TRANSFER

(1) Technology transfer through foreign direct investment

In this section, we analyze the relationship between the strengthening of patent protection and U.S.-based FDI to recipient countries. Direct investment in weak-IP environments exposes investing firms to a higher risk of technology theft.[10] Consequently, previous studies have found that FDI, particularly in high-tech manufacturing sectors such as pharmaceuticals and organic chemicals, can be quite sensitive to the IP standards of the host nation.[11] Conversely, because of the greater contact that this kind of investment implies with the local economy, high-tech FDI has the potential to lead to significant technological transfers and spillovers to the local economy.

[10] See Fink (2009) on how the welfare effects of stronger IP enforcement vary across producers, consumers and the economy at large.

[11] Javorcik (2004), for instance, finds that stronger patent rules increase FDI in technology-intensive sectors such as drugs, cosmetics and health care products, chemicals, machinery and equipment, and electrical equipment, based on a survey of 24 economies in Eastern Europe and the former Soviet Union. Branstetter et al. (2005), based on firm-level observations underlying the U.S. BEA dataset used in this section, from 16 countries of which 13 are developing, find that stronger patent rights increase technology transfer as captured by royalty payments for technology transferred to affiliates. Park and Lippoldt (2008), also using the BEA dataset, find as reported in their Table 11 that stronger patent protection in developing countries is associated with a greater expansion of U.S. operations in several manufacturing industries, but do not use controls for country or time effects.

Table 5: US Foreign Direct Investment Stocks

2000 US dollars, millions, five manufacturing sectors

Country Group	# Countries Reporting	1990-1995 Mean	1990-1995 Standard Deviation	2000-2005 Mean	2000-2005 Standard Deviation
Developing Countries	84	$577	$1,758	$839	$2,342
Asian tigers	4	$2,196	$1,104	$5,206	$4,315
Emerging 8	8	$3,005	$4,267	$4,207	$4,624
Other	72	$128	$347	$204	$616
Developed Countries	25	$5,499	$8,109	$7,662	$10,662
Full Sample	109	$1,922	$4,978	$2,433	$6,223

Note: The calculations across years are for two benchmark years, not each year. The five manufacturing sectors are chemicals, food, electronics/electrical and machinery, metals, and transportation equipment.

As highlighted in Table 5, our sample for the FDI analysis consists of 109 countries and five manufacturing sectors - chemicals, food, electronics/electrical and machinery, metals, and transportation equipment manufacturing.[12] Across the 1990-95 period, the emerging 8 economies received roughly 25 times more FDI than the remainder of developing countries, while the Asian tigers received about 17 times more. FDI for the Asian tigers more than doubled over this period, and increased by 40 percent for the emerging 8 economies, at about the same rate as for the developed countries.

Regression results are reported in Appendix Table A3, and the underlying data are described in Appendix 1. We use the log of annual U.S. FDI stocks within five manufacturing sectors of a given country as our dependent variable. Our explanatory variable of interest is the Park (2008) IP index. To control for other annual country-level features that may affect U.S. FDI, we use the log of per capita GDP and the Openness index.[13] In addition, each regression also includes country-fixed effects to control for time-invariant country-level factors that may affect U.S. FDI, and industry-fixed effects, which control for differences between industries in their propensity to attract U.S. FDI. Each regression also includes separate time trends for developing and developed countries.

In our first regression, we examine a baseline model of U.S. FDI across all countries. The result suggests that a one-unit increase in the IP index does not have a statistically significant effect on U.S. FDI levels across all countries, a result that is not surprising given the relatively small changes in the IP index for most developed countries

[12] In comparison with the 114 countries included in the patent-based analyses, the U.S. is necessarily not included in this sample and three developing countries have insufficient data to be used in the regressions, namely Burkina Faso, Burundi, Mozambique, and Rwanda.

[13] There is a potential endogeneity problem here, namely that FDI is part of GDP. However, since in these regressions our dependent variable is sector FDI from only one country, its impact on any given country's GDP is small (average U.S. sector FDI as a percentage of average GDP across countries and years is only 0.13 percent), so the endogeneity concerns are minimal. The general empirical approach in this area, as reviewed and adopted by Nunnenkamp and Spatz (2004), is to include host country per capita income as control in a gravity-type model of the determinants of FDI, with current FDI stocks as the dependent variable.

over this period. In the next two regressions, we break down the relationship between FDI and patent protection by allowing the effect of IP on FDI to vary by different country groups by introducing two basic models of country-level decomposition. The first regression includes an interaction term between the IP index and a developing-country "dummy." There is a stark difference in the extent to which developing countries, relative to developed countries, affect the significance of IP in determining levels of FDI: a one-unit increase in the IP index predicts a 152 percent increase in FDI across developing countries (though the effect is only significantly different from zero at the 10 percent level). The effect of the IP index on developed countries (captured by the non-interacted IP index term) is not statistically significantly different from zero. The second regression breaks down the relationship between patent protection and FDI across our different developing country groups, by introducing separate interactions between the IP index and the Asian tigers, the emerging 8 countries, and the other developing countries. Interestingly, the effect of strengthening of IP on FDI for developing countries captured in the previous model appears to be predominantly driven by the emerging 8 countries and other developing countries, rather than by the Asian tigers. A one-unit increase in the IP index predicts a 165 percent increase in FDI across the emerging 8 countries and a 148 percent increase in FDI across the other developing countries (though the effect again is only significant at the 10 percent level). The effect of the IP index on FDI across the Asian tigers is not statistically significantly different from zero.

In order to further test the reliability of these findings, we systematically explore whether our results based on the larger "all countries" sample (relative to developed countries) are replicated in the smaller sample restricted exclusively to available developing countries. In our baseline model of U.S. FDI across developing countries (column 5 in Table A3), the coefficient on the IP index term is analogous to the interaction term between the IP index and all developing countries in the full sample, but is now not statistically significantly different from zero. Similarly, in our subsequent country-level model across developing countries (column 6), the IP index interactive terms with the Asian tigers, the emerging 8 countries, and the other developing countries groups are not significantly different from zero. Based on these results, it appears that the positive relationship in the "all countries" data between strength of patent protection and FDI flows for the emerging 8 countries and other developing countries may reflect some relative effects between these countries and the developed country group. It appears that the IP-FDI relationship is not sufficiently robust across all manufacturing sectors to remain significant when focusing exclusively on the developing countries sample.

The additional regressions in Table A3 suggest that more disaggregated data would be helpful to highlight which sectors experience the greatest change in FDI in response to increased patent protection. In column 4 for all countries, and in column 7 for developing countries, we break down the relationship between FDI and patent protection across the available five manufacturing industries – given the anticipated important differential effect of patents across industries. Of the five industries, the coefficients on two industries are statistically significant across all countries: a one-unit increase in the IP index has the strongest effect in transportation equipment manufacturing (64 percent), followed by electronics/electrical and machinery (61 percent). Across developing countries, transportation equipment manufacturing increases its statistical significance as well as its magnitude: a one-unit increase in the IP index now predicts a 123 percent increase in FDI levels. While the electronics/electrical and machinery industries lose their statistical significance, the chemical industries increase in magnitude and are almost statistically significant at the 10 percent level. Although these industrial categories are much too broad to permit a testing of the impact of strengthening of patent protection on technology transfer flows to specific industrial sub-sectors such as pharmaceuticals or biotechnology, these results are quite closely in line with industries that have traditionally been perceived to be most sensitive to patent protection.[14] There are clearly strikingly different effects across industries, but the level of aggregation in the publicly-available FDI data prevent patterns at the level of pharmaceuticals or biotechnology sectors to be uncovered.

(2) Technology transfer through strategic alliances

Strategic alliances are cooperative business activities that include joint ventures, where two or more firms form an independent business entity, as well as non-joint venture strategic alliances. Both types of alliances can include materials supply agreements, licensing agreements, royalty agreements, other technology transfer agreements, and explicit R&D agreements. To examine the effect of a strengthening of patent protection on technology transfer from developed to developing countries, we consider only those explicit R&D strategic alliances that include firms from both developing and developed countries.[15]

Table 6 presents summary statistics for developing-developed country R&D strategic alliances in our sample. The most striking feature of these data is the significant increase in strategic alliances between the 1990-95 period and the 2000-05 period. Given the construction of the data, there is a natural symmetry between the average increase in strategic alliances across the 14 reporting developing countries from 0.5 to 4.0, and the converse increase in alliances across the 13 reporting developed countries from 0.7 to almost 4.7.[16] The other notable feature of these data is that the sharpest increase in

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[14] Based on the responses of firms to a separate Yale survey questionnaire administered in the early 1980s about the effectiveness of patents as a mechanism for protecting the returns from innovation, the top 4 of 55 industrial sub-sectors expressing a need for patent protection were pharmaceuticals, followed by industrial organic chemicals (both part of the broad chemicals industries, which also includes sectors such as soap, detergents and cleaners that conversely did not express a need for patent protection), automobile electronics/electrical and storage batteries (part of transportation equipment), and oilfield machinery and equipment (part of electronics/electrical and machinery). See Appendix C in Cockburn and Griliches (1987), based on Levin et al. (1987).

[15] Oxley (1999) uses the Park index to examine how differences in patent protection affect the choice between equity-based alliances or contract-based strategic alliances as vehicles for technology transfer between U.S. and non-U.S. firms across 110 countries. She finds that weaker patent protection leads U.S. firms to favor more hierarchical equity-based alliances rather than the type of strategic alliances examined here.

[16] See Appendix Table A2. The developing countries are: China, Hong Kong, Hungary, India, Malaysia, Mexico, Russia, Singapore, South Africa, South Korea, Taiwan, Thailand, Turkey and Uruguay. The developed countries are: Australia, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, Switzerland, United Kingdom, and United States.

strategic alliances is for the emerging 8 countries, increasing more than 14-fold, from an average of 0.4 per country in the 1990-95 period to an average of 5.7 per country in the 2000-05 period. Appendix Figure A1 presents a comparison between strategic alliance and patent counts for pharmaceutical and biotechnology sectors in the emerging 8 countries. India and China have the largest increases in the number of strategic alliances over the 1990-2005 period.

Table 6: R&D Strategic Alliances

Count of alliances

		1990-1995		2000-2005	
Country Group	# Countries	Mean	Standard Deviation	Mean	Standard Deviation
Developing Countries	14	0.5	0.9	4.0	5.5
Asian tigers	4	1.0	1.4	4.9	3.4
Emerging 8	6	0.4	0.5	5.7	7.4
Other	4	0.1	0.4	0.6	1.1
Developed Countries	13	0.7	2.2	4.7	8.9
Full Sample	27	0.6	1.6	4.3	7.3

Note: Summary statistics are based on one observation per country-year, namely the total number of strategic alliances between at least one own-country firm and at least one firm from the other country bloc (developed if the own-country is developing, or developing if the own-country is developed). The calculations across years are for two benchmark years, not each intervening year.

The outcome variable in these regressions is the logarithm of the total number of strategic alliances, while the explanatory variable of interest is the Park index of patent protection. As discussed in Section II, we include country-, industry- and year-level controls to account for other factors that may affect the outcome variable. To add greater descriptive detail to our statistical results, the analysis is divided into two components. First, we examine R&D strategic alliances across all sectors. Second, we focus on those R&D strategic alliances that are exclusively in the pharmaceutical and biotechnology sectors.

Regression results are reported in Appendix Tables A4 and A5, and the underlying data are described in Appendix 1. Across all countries and sectors, a one-unit increase in our IP index does not have a statistically significant effect on strategic alliances between developed and developing countries. However, this figure needs to be disaggregated into separate effects in order to clarify the extent to which this overall effect may be masking a possible significant effect for all developing countries, for the Asian tigers and emerging 8 countries relative to developed countries, and for the medical industries relative to other high-tech industries. This is done in the second, third and fourth reported regressions in Table A4. According to our estimates across all countries, a one-unit increase in the IP index in developed countries is not associated with a statistically significant effect on strategic alliances while a one-unit increase in the IP index in developing countries is associated with a 21 percent increase in strategic alliances. The next regression examines the country group decomposition for developing countries. The estimated effect associated with a unit increase in the IP index is 29 percent for the emerging 8 countries, and 22 percent for the Asian tigers, while the estimated effect for all other developing countries is statistically equivalent to zero. The final regression across all countries examines the effect of IP strengthening for the medical industries relative to all other high-tech industries. Here, a one-unit increase in the IP index for the medical industries is associated with a 13 percent increase in strategic alliances.

To analyze this issue further and examine the robustness of these country-group findings, we restrict the sample in two different ways and study the effect of the Park index on strategic alliances separately in these restricted samples. In the first case, the sample is restricted to only developing countries and the significance of the IP index is analyzed separately for the country group decompositions and the medical industries break-out (columns 6 and 7 in Table A4). A unit increase in the IP index is estimated to result in a 19 percent increase in strategic alliances for the emerging 8 countries, and in a 17 percent increase for the Asian tigers – with an overall increase in statistical significance for these results. Similarly, the effect of strengthened IP for the medical industries relative to all other high-tech industries becomes even more pronounced in the developing countries sample: a one-unit increase in the IP index for the medical industries is now associated with a 19 percent increase in strategic alliances.

The results of the analysis of the second more restricted sample —strategic alliances exclusively in the pharmaceutical and biotechnology sectors— are presented in Table A5. In line with our expectation that the strengthening of patent protection should have a particularly pronounced effect in these sectors, a one-unit increase in the IP index results in a 107 percent increase in strategic alliances across all countries in the baseline model. According to the second reported regression, the strengthening of patent protection does not have a statistically significant impact on strategic alliances in the pharmaceutical and biotechnology sectors across all developing countries as a group, relative to developed countries. This weak or non-existent IP effect is supported in the third regression, where no statistically significant effect was found for either the Asian tigers or for the emerging 8 countries. The effect for other developing countries appears to be slightly negative: a one-unit increase in the IP index predicts an 8.5 percent reduction in strategic alliances in the pharmaceutical and biotechnology sectors, suggesting that a strengthening of patent protection from initially relatively low levels could lead to a reduction in strategic alliances between other developing countries and developed countries.[17] The sector-interaction regression for all countries examines the effect of IP strengthening for the pharmaceutical sector relative to the biotechnology sector: a one-unit increase in the IP index predicts a 33 percent increase in strategic alliances in the pharmaceutical sector.

The final three columns of Table A5, examining the effect of increasing patent protection on the pharmaceutical and biotechnology sectors exclusively for developing countries, are based on a small sample size of only 51 observations. The baseline regression suggests that there is no statistically significant effect across all developing countries as a group. The weak negative effect for the “other developing countries” group

[17] In cases where the stand-alone IP index term is statistically significant, the net effect is calculated by combining both effects, namely 47.9 percent minus 56.4 percent, or minus 8.5 percent.

based on the sample of all countries does not persist in the developing countries sample, and is not statistically different from zero (based on the stand-alone IP index term in the sixth column of Table A5). And a strengthening of patent protection now matters for the emerging 8 countries: a one-unit increase in the IP index predicts a 36 percent increase in strategic alliances, but only at the 10 percent level of significance. Finally, the sector-interaction regression suggests that there is no statistically significant effect across developing countries, neither for the pharmaceutical sector nor for the biotechnology sector, implying that the statistically significant effect in the full sample is largely driven by developed countries. The fact that the pharmaceutical sector, rather than biotechnology, is more responsive to the IP index in strategic alliances driven by developed countries is consistent with the view that to make significant research advances in biotechnology, greater human capital and technological infrastructure is required than most of the more advanced developing countries currently have.[18]

IV. PATENT PROTECTION AND LOCAL INNOVATION

(1) Local innovation through patent applications and grants

In this section, we analyze the relation between strengthening of patent protection and patenting activity. Our data on patenting comes from two main sources: non-resident patent applications submitted to the European Patent Office (EPO) and successful patent awards by the U.S. Patent and Trademark Office (USPTO). Patents are a commonly used measure of innovation in the literature and the use of data from the EPO and USPTO presents many advantages. Since patents are the output of investment in R&D and human capital, they represent the fruitful utilization of resources. Furthermore, non-resident patent applications by developing country innovators in Europe and the U.S. are likely to represent more substantial innovation than minor upgrades to existing technology or technologies developed for localization or adaptation. One important finding in the existing empirical literature is that stronger patent protection has not stimulated domestic innovation in the less developed countries, that is, those characterized by lower levels of national income and education, and more restrictive government policies regarding investment and trade.[19]

Since an important question is whether stronger IP in developing countries leads to greater technology and knowledge sharing between developing and developed countries in the process of innovation, we also analyze the relationship between strengthening of patent protection and a special sub-set of the patent data, namely cross-country collaboration between developing and developed country inventors – the subset of the patent datasets where collaboration between more than one inventor involved at

[18] See, for instance, Cockburn (2004).

[19] Chen and Puttitanun (2005), based on a panel of 64 developing countries, find that increasing patent protection has a greater impact on non-resident patenting in the U.S. in countries with higher levels of economic development as captured by per capita GDP. Qian (2007), based on a panel of 26 countries including 17 developing, finds that national patent protection on pharmaceutical innovations does not stimulate non-resident patenting in the U.S. except at higher development levels, as captured by per capita GDP, education, and our openness index.

least one developing country and one developed country. Stronger protection of IP rights may not only increase the total number of innovators, but it may also encourage greater collaboration between individuals – with international collaboration-driven patenting a possible proxy for higher-quality patents, embodying knowledge sourced in more than one country. We use data on co-invention patents from both EPO as well as USPTO for these additional analyses.

Table 7: Patent Applications Filed with EPO

Count of applications

		1990-1995		2000-2005	
Country Group	# Countries	Mean	Standard Deviation	Mean	Standard Deviation
Developing Countries	88	9.9	31	57.7	308
Asian tigers	4	92.9	96	874.4	1,301
Emerging 8	8	33.3	25	155.9	162
Other	76	1.4	3	4.4	13
Developed Countries	26	2,443.3	4,745	4,295.3	8,060
Full Sample	114	649.0	2,627	1,024.2	4,199

Note: Summary statistics are based on one observation per country-year, namely the total number of patent applications where the first-listed inventor is from a given country of residence. The calculations across years are for two benchmark years, not each intervening year.

We first consider patent applications to the EPO. Patent applications are our preferred measure relative to patents granted, given that they are the more immediate and direct measure reflecting a potentially patentable inventive activity that has just occurred.[20] Table 7 presents summary statistics for patent applications filed with the EPO reflecting innovations from the 88 developing countries and 26 developed countries in our sample. The emerging 8 countries, on average, exhibit an almost five-fold increase in patent applications from the 1990-95 period to the 2000-05 period, from 33 to 156. The Asian tigers increase patent applications on average by almost ten-fold over the same time period, from 93 to 874. The number of applications in the other 76 developing countries, on the other hand, only changes from an average of 1 application per country to an average of 4 applications per country over this period. So compared to this group, it is clear that the emerging 8 economies as well as the Asian tigers are very significant users of the patenting systems. And there is even more dynamism apparent in the emerging 8 economies when focusing specifically on the pharmaceutical and biotechnology sectors. Appendix Figure A1 presents the evolution over time of patent counts (both EPO patent applications and USPTO patents granted) for pharmaceutical and biotechnology sectors for the emerging 8 economies. The corresponding average number of patent applications in Europe by the emerging 8 economies increases almost

[20] An inventor seeking patent protection typically files a first application in the country of residence (this first filing worldwide is referred to as the "priority date"). The inventor then has 12 months legal delay for making an application in other countries. Any such applications are typically published at least 18 months after the priority date. Finally, it can take three to ten years for a patent to be granted.

eight-fold, from 2.7 to 20.5 over this period, and with India, in particular, increasing its filings almost 45-fold, from 2 in 1990 to 87 in 2005.

The outcome variable employed in the regressions is the logarithm of the total annual patent counts from a given country-industry pair. Again, the primary explanatory variable that we focus on is the Park (2008) index of patent protection. Country-, industry- and year-level controls add greater rigor and accuracy to our analysis.

Regression results for patent filings to the EPO, for all patents and for the pharmaceutical and biotechnology sectors, are reported in Appendix Tables A6 and A7, and the underlying data are described in Appendix 1. In the base regression in Table A6 across all sectors, a one-unit increase in the IP index in a country is estimated to have a statistically very significant 13 percent increase in the total number of patent applications filed. We further expand on this result by considering interactions between the IP index and our country groups, as well an interaction between IP and the medical industries.

When interacted with an indicator for whether the country is classified as developing, both the IP index and its interaction with developing country status have a statistically significant effect on the outcome. In particular, the net effect of a one-unit increase in the IP index predicts an 11 percent increase in patent applications (namely 23.4 percent minus 12.6 percent, as reported in column 2 of Table A6). The next regression breaks down the relationship between patent protection and patent applications across our different developing country groups, by introducing separate interactions between the IP index and the Asian tigers, the emerging 8 countries, and the other developing countries. The strongest impact of strengthening of patent protection is for the emerging 8 countries: a one-unit increase in the IP index predicts a statistically very significant 50 percent increase in applications (namely 24.6 percent plus 25.3 percent). The impact of strengthening of patent protection is less significant but still positive at the 10 percent level for the Asian tigers: a one-unit increase in the IP index predicts a 45 percent increase in applications (24.6 percent plus 20.2 percent). On the other hand, the impact is much closer to zero for the other developing countries: a one-unit increase in the IP index predicts a 2.8 percent decrease in applications (24.6 percent minus 27.4 percent). Finally, when interacted with an indicator representing the medical industries, the net effect of a one-unit increase in the IP index predicts a 7.4 percent increase in patent applications across all countries (14.2 percent minus 6.8 percent), less than the average effect across all other sectors but still significant and positive.

A complementary approach to study the same issue is to restrict the sample of countries to only developing countries. The analysis from the restricted sample confirms and strengthens our findings across all developing countries, as well as for the emerging 8 countries and for the Asian tigers. The baseline model for developing countries (column 5 in Table A6) confirms the finding from the larger "all countries" sample: a one-unit increase in the IP index predicts an 11 percent increase in patent applications across all developing countries. The decomposition according to country groups confirms the similar finding from the larger sample (column 6): a one-unit increase in the IP index predicts a very significant 53 percent increase in applications for the emerging 8 countries, and a very significant 46 percent increase for the Asian tigers. And the statistically insignificant effect for other developing countries based on the coefficient on the stand-alone IP index suggests that the slight negative effect for other developing countries across all countries is not statistically significantly different from zero. Finally, there is no statistically significant effect for the medical industries for the sample of developing countries.

We also performed a separate analysis of the pharmaceutical and biotechnology sectors, reported in Table A7. In our most basic regression across all countries, the IP index has a weak statistically significant effect (at the 10 percent level) on the number of patent applications: a one-increase in the IP index is associated with a 7 percent increase in applications in the pharmaceutical and biotechnology sectors. Further analysis reveals that a one-unit increase in the IP index is associated with a 46 percent increase in patentable pharmaceutical and biotechnology inventions for the Asian tigers, and a 43 percent increase for the emerging 8 countries, though there is no statistically significant effect for other developing countries, nor for developed countries. Finally, across the two sectors, a one-unit increase in the IP index is associated with an 11 percent increase in biotechnology applications, and a lower but still positive net increase of 4 percent in pharmaceutical applications (11.0 percent minus 7.3 percent). These findings are confirmed and amplified in the developing countries-only sample. Here, a one-unit increase in the IP index is associated with a net 51 percent increase for the Asian tigers (58.1 percent minus 7.0 percent), and a net 50 percent increase for the emerging 8 countries (56.5 minus 7.0 percent). Across the two sectors for developing countries, a one-unit increase in the IP index is associated with a 9 percent increase in biotechnology applications, versus no statistically significant effect for pharmaceutical applications.

Our second data source on patenting comes from the USPTO. A key difference between the two sources of data is that while the EPO data are patent applications according to the year of application, the USPTO data are the subset of applications that were granted according to the year in which the patent was granted.[21]

[21] Before enactment of the American Inventor's Protection Act (AIPA) of 1999, U.S. patent applications were not published until and only if they were issued as patents.

Table 8: Patents Granted by USPTO					
Count of patents					
		1990-1995		2000-2005	
Country Group	# Countries	Mean	Standard Deviation	Mean	Standard Deviation
Developing Countries	88	35.9	158	118.4	652
Asian tigers	4	490.6	546	2,287.3	2,387
Emerging 8	8	62.4	35	126.8	87
Other	76	2.6	6	3.4	9
Developed Countries	26	3,572.7	10,591	5,285.6	16,012
Full Sample	114	964.8	5,575	1,296.9	7,861

Note: Summary statistics are based on one observation per country-year, namely the total number of patents granted where the first-listed inventor is from a given country of residence. The calculations across years are for two benchmark years, not each intervening year.

Table 8 presents summary statistics for patent applications to the USPTO for the same group of 88 developing countries and 26 developed countries as in our EPO sample. In terms of patents granted, the emerging 8 countries more than double the number of patents granted over the period, from 62 to 127. On average, the Asian tigers exhibit more than a four-fold increase in number of patents granted, from 491 to 2,287. Compared to the other developing countries with an average of 3 patents granted per country across both periods, the emerging 8 economies and the Asian tigers are not only very significant users of the global patenting system, but also significant beneficiaries in terms of actual patents granted. There is again more dynamism apparent in the emerging 8 economies when focusing specifically on the pharmaceutical and biotechnology sectors. The corresponding average number of patents granted in the U.S. by the emerging 8 economies, as pictured in Appendix Figure A1, increases almost three-fold, from 5.8 to 16.3, with in particular India increasing its granted patents almost forty-fold, from 2 in 1990 to 77 in 2005.

Regression results are reported in Appendix Tables A8 and A9, and the underlying data are described in Appendix 1. In our baseline regression in Table A8 across the full sample of countries and all sectors, as well as in the following regression where IP is interacted with all developing countries, there is no statistically significant effect on the outcome. The absence of these more general effects in this sample may be due to the weaker link between the timing of IP strengthening and the timing of granting of patents, given the variable lag between the time a local innovative activity yields a patentable output, a patent application is filed in the U.S. market, and the review and ultimate granting of the patent by the U.S. authorities. On the other hand, there are statistically very significant and large effects for the developing country decomposition model, analogous to the effects for patent filings to the EPO: here, a one-unit increase in the IP index predicts a 74 percent increase in patents granted for the Asian tigers, and a 16 percent increase in patents granted for the emerging 8 countries. Again, the impact for the other developing countries is negative. One surprising result from this analysis is that the interaction between IP and the medical industries is estimated to be negative and statistically significant: although it is not large in magnitude, a one-unit increase in the IP index predicts an 8 percent decrease in patents granted for the medical industries across all countries.

When the USPTO data is restricted to the smaller sample of only developing countries, the key results derived across all countries are confirmed. A one-unit increase in the IP index predicts a statistically very significant and large 80 percent increase in patents granted for the Asian tigers, and a 24 percent increase in patents granted for the emerging 8 countries.[22] Surprisingly, the impact for the other developing countries is once again negative: a one-unit increase in the IP index predicts an actual decrease of 11 percent in patents granted. A clearer understanding of this result will require further research, but it at the very least suggests that there may be a threshold level below which increases in patent protection not only have no effect but actually discourage the type of local activities that lead to patenting by diverting innovative proclivities into other pursuits, such as copying and imitation rather than patentable creative activities.[23]

The other surprising result in the developing country sample is that the estimate of the interactive "medical" term is again negative: here, a one-unit increase in the IP index predicts a 7 percent decrease in patents granted in the medical industries. Although this estimated relationship may not be causal, this has the counter-intuitive implication that an increase in the IP index actually is associated with a decrease in patents granted in the medical industries. As the "medical" category is quite broad, including not only pharmaceutical and biotechnology sectors, but also laboratory equipment, medical imaging and monitoring systems, and surgical equipment as well as prosthetics/artificial limbs, it is conceivable that the negative term is capturing a displacement effect with some sub-sectors falling more at the expense of others.

Once again, as an additional step, we restrict our attention only to the pharmaceutical and biotechnology sectors and adopt an otherwise identical methodology to analyze the relationship between patent protection and patenting activity with the USPTO. As reported in Table A9, this analysis confirms our previous results about the significance of the Asian tigers and the emerging 8 countries. For the pharmaceutical and biotechnology sectors, the response of the Asian tigers and the emerging 8 countries to the strength of IP laws is predicted to be statistically significant and large in magnitude: a one-unit increase in the IP index is associated with an 87 percent increase in patenting activity for the Asian tigers, and a 37 percent increase for the emerging 8 countries. The corresponding response of the other developing countries to a strengthening of the IP index is not statistically significantly different from zero. At the sector level, a one-unit increase in the IP index is associated with a 22 percent increase in patenting activity in

[22] For the Asian tigers, 80 percent is based on 91.5 percent minus 11.4 percent, while for the emerging 8 countries 24 percent is based on 35.2 minus 11.4 percent – as reported in column 6, Table A8.

[23] A related result, derived by Chen and Puttitanun (2005) from a theoretical model and confirmed in the data, concerns the relationship between patent protection and per capita GNP. Starting from low levels of economic development, an initial increase in a developing country's technological ability can have a greater impact on the efficiency of imitating cutting-edge global technologies than on the efficiency of domestic innovations, which makes it desirable for the country to lower patent protection. Once the country's technological ability is above a certain threshold, the imitation effect can then become dominated by the innovation effect, leading the optimal protection to increase with economic development.

the pharmaceutical sector across all countries. The country-group results are again largely confirmed in the restricted sample of only-developing countries. A one-unit increase in the IP index is associated with a net 79 percent increase in patenting activity for the Asian tigers (87.6 minus 8.9 percent), and a net 32 percent increase for the emerging 8 countries (40.5 minus 8.9 percent). Moreover, at the sector level, the impact of a strengthening of the IP index on the pharmaceutical sector and the biotechnology sectors is not statistically different from zero for developing countries.

Finally, we consider international collaboration-driven patenting as a proxy for higher-quality patents, embodying knowledge sourced in more than one country. We use data on developing-developed country co-invention patents from both EPO as well as USPTO for these additional analyses. Table 9 presents summary statistics for all such patents filed with the EPO, and Table 10 presents similar statistics for all such patents granted by the USPTO, in the 88 developing countries and 26 developed countries in our sample. Given the construction of the data, with coverage restricted to patents with multiple inventors where at least one inventor is from a developing country and one inventor is from a developed country, there is a natural symmetry between the average number of co-invention patents in developed countries and in the most technology advanced developing countries, namely the Asian Tigers. The Asian tigers co-invention patent applications increase almost six-fold, from 11 in the 1990-05 period to an average of 65 in the 2000-05 period, and co-invention patents granted by the USPTO also increase almost six-fold, from an average of 6.5 to 36. The largest increase in percentage terms in co-invention applications is for the emerging 8 countries, a more than seven-fold increase, from an average of less than 3 to more than 20 over this period, while co-invention patents granted by the USPTO more than double, from 7.3 to 16.2. In contrast, developed country co-invention patent applications to the EPO increase roughly four-fold, from an average of 15 to an average of 63 over this period, while patents granted by the USPTO increase almost four-fold, from an average of 8.5 to 32.

Table 9: Co-Invention Patents Filed with EPO					
Count of applications					
		1990-1995		2000-2005	
Country Group	# Countries	Mean	Standard Deviation	Mean	Standard Deviation
Developing Countries	88	1.1	3	5.3	19
Asian tigers	4	11.0	6	65.0	51
Emerging 8	8	2.8	2	20.3	29
Other	76	0.3	1	0.6	2
Developed Countries	26	14.8	34	62.5	131
Full Sample	114	4.7	19	18.3	68

Table 10: Co-Invention Patents Granted by USPTO					
Count of patents					
		1990-1995		2000-2005	
Country Group	# Countries	Mean	Standard Deviation	Mean	Standard Deviation
Developing Countries	88	1.6	4	3.6	10
Asian tigers	4	6.5	5	36.0	13
Emerging 8	8	7.3	8	16.2	13
Other	76	0.6	2	0.6	2
Developed Countries	26	8.6	32	31.6	114
Full Sample	114	3.4	17	10.0	55

Note: Summary statistics are based on one observation per country-year, namely the total number of patents granted where the first-listed inventor is from a given country of residence. The calculations across years are for two benchmark years, not each intervening year.

Regression results are reported in Appendix Tables A10 and A11, and the underlying data are described in Appendix 1. It is striking how consistent the results are between the EPO patents filed data and the USPTO patents granted data. The baseline model across all countries suggests that an increase in the IP index actually reduces co-inventions, though the results are not large (4.8 percent reduction in patent filings for the EPO data, 4.1 percent reduction in patents granted for the USPTO data) and not very significant (at the 10 percent level for the EPO data, at the 5 percent level for the USPTO data). However, when we break down this relationship to examine the effect across all developing countries, we find that a one-unit increase in the IP index predicts a 5.8 percent increase in patent filings (60.1 minus 54.3 percent), and predicts a 1.4 percent increase in granted patents (31.2 minus 29.8 percent). When we further break down this relationship into our developing country groups (column 3 in both tables), we find that a one-unit increase in the IP index predicts larger and highly significant increases for Asian tigers and emerging 8 countries: a 45.6 percent increase for Asian tigers and a 27.9 percent for emerging 8 countries for patent filings, and a 19.9 percent increase for Asian tigers and a 56.9 percent increase for emerging 8 countries for granted patents. Based on the sector interaction regressions, we find that the medical industries do not have a significant effect in either dataset.

These findings are largely confirmed when we restrict the analysis to only developing countries. Across all developing countries, a one-unit increase in the IP index predicts a 5.4 percent increase in patent filings, though the effect on granted patents is not statistically different from zero. The results are strongest for the country group breakdowns: a one-unit increase in the IP index predicts a 45.9 percent increase for Asian tigers and a 30.6 percent increase for emerging 8 countries for patent filings, and a 19.9 percent increase for Asian tigers and a 54.1 percent increase for emerging 8 countries granted patents (column 6 in both tables). Again, based on the sector interaction regressions, the medical industries do not have a significant effect in either dataset.

(2) Local innovation through firm-level R&D expenditures

In this section, we consider the effect of patent protection on firm-level R&D. R&D spending is an input into the innovation process and is commonly used to measure investment in technological development. R&D may be undertaken by firms for a variety of different reasons, including for minor technological upgrading, localization and adaptation of imported technologies, and investment in indigenous innovation. Most data sources on R&D expenditure do not distinguish between the different kinds of R&D expenditure, which makes it difficult to fully detail the relationship between stronger IP and R&D spending. However, our focus on firm-level R&D expenditures is motivated by at least three factors. First, our results on patenting activity suggest that IP reforms led firms in developing countries to allocate some R&D spending to indigenous innovation. By studying the corresponding effect of the IP reforms on R&D spending in developing countries, we may be able to place bounds on the monetary value of these innovations. Second, the patenting of an invention may occur well after monetary investments have been made towards developing the invention. Especially given the recent nature of IP reforms in developing countries, R&D data may reveal important additional information on the effect of these reforms. Third, to the extent that stronger IP led to increased availability of foreign technology for firms in developing countries, evidence of R&D spending related to localization, upgrading or adaptation is also an indirect indicator of the benefits of stronger IP in developing countries.[24]

[24] Allred and Park (2007a), based on Thomson Reuters' Datastream/Worldscope data from 706 firms across 29 countries, report a positive influence of patent rights and changes in patent rights on R&D expenditures as a share of sales. However, the results are based on countries with higher development levels, with only some 10 percent of the sample from developing countries (and the most technologically-advanced developing countries, including Brazil, Chile, India, and South Africa). Innovation investment by firms in only two out of ten manufacturing industries is significantly associated with the level of patent rights — namely industrial chemicals, including pharmaceuticals, and scientific instruments. A parallel study by Allred and Park (2007b), based on Datastream/Worldscope data from 2,446 firms (with only 303 observations from developing country firms), but using firm sales rather than lagged sales as an independent variable and no country fixed effects, finds no significant linear or nonlinear effect of the IP index on firm-level R&D expenditures.

Table 11: Firm-level R&D Expenditures						
2000 US dollars, millions						
			1995		2000-2005	
Country Group	# Countries	# Firms	Mean	Standard Deviation	Mean	Standard Deviation
Developing Countries	15	575	$6.2	$26	$12.5	$37
Asian tigers	4	445	$3.7	$9	$12.1	$35
Emerging 8	6	117	$13.4	$50	$14.7	$45
Other	5	13	$8.0	$10	$9.2	$18
Developed Countries	21	3,363	$25.9	$47	$29.0	$50
Full Sample	36	3,938	$24.4	$46	$26.6	$49

Note: Summary statistics are based on firm-level observations. The calculations for 2000-05 are for these two benchmark years, not each intervening year. Firms must appear in more than one year to remain in the dataset. Extreme outliers have been dropped.

Our data for firm-level R&D expenditures come from Standard & Poor's Compustat Global database, with data availability dictating the more restricted 1995-2005 period of analysis.[25] Table 11 presents summary statistics for the approximately 4,000 firms in the sample. At over $24 million, developed country firms have roughly four times the level of R&D expenditures of the average developing country firm at the beginning of the period, with the difference falling over time as developing country firms increase their average R&D expenditures. The Asian tiger firms exhibit the largest increase in average R&D expenditures over the period, a more than three-fold increase from $3.7 million to $12.1 million. The emerging 8 firms begin with the highest average R&D expenditures across developing countries, and increase average expenditures about 10 percent over the period, from $13.4 to $14.7 million.[26]

Regression results are reported in Appendix Tables A12 and A13, and the underlying data are described in Appendix 1. The outcome variable in the regressions is the logarithm of firm-level R&D expenditures. We use our usual list of control variables (per capita GDP, the openness index, country and industry fixed effects plus separate time trends for developed and developing countries) and add a firm's previous year's lagged sales as an additional control for firm size. As one would expect, a firm's previous

[25] In the analysis of these data, it is important to keep in mind a key difference that may introduce significant noise in the information on firm-level R&D expenditures. While the data on U.S. FDI, and the European and U.S. patenting data contain information about multiple countries, they are each generated by a common source entity such as the U.S. Department of Commerce Bureau of Economic Analysis, the EPO or the USPTO, which all have consistent definitions and standards for all variables on which information is collected. In contrast, the Compustat Global data are based on company balance sheet information from many different countries. While attempts have been made to include the same broad categories of information from each country, the recorded values reflect the many varieties of actual reporting practices used across the globe. This concern is less prevalent in the strategic alliances dataset given that we are using counts and not underlying values.

[26] The high average R&D expenditures in the emerging 8 economies are driven by a few large firms in the petroleum refining industries (SIC 2911), such as Petrobras (Brazil), Gazprom (Russia), Reliance Industries (India), Petrochina, and China Petroleum (China), as well as a number of other firms in the automotive and steel industries. The relatively lower average in the Asian tigers is driven by the presence of a larger number of smaller firms in less R&D intensive industries.

year's sales are associated positively with current firm-level R&D spending consistently across all models, indicating that bigger firms make larger R&D expenditures.

As reported in Table A12, the only developing country group where there is a statistically significant relationship between increased patent protection and firm-level R&D expenditures is the Asian tigers (relative to developed countries). A one-unit increase in the IP index predicts a 136 percent increase in R&D expenditures. However, this relationship is not replicated in the smaller sample restricted exclusively to developing countries, where the coefficient is not significantly different from zero. The main result across all sectors, in line with the existing literature, is that firms in the drugs industries increase their R&D expenditures in response to increased patent protection. A one-unit increase in the IP index predicts a very significant 62 percent increase in R&D expenditures across all countries. However, this effect is also not replicated in the smaller developing country sample.

The results of the analysis of R&D expenditures exclusively in the pharmaceuticals and biotechnology sectors are presented in Table A13. The strengthening of patent protection does have a significant impact on R&D expenditures across all developing country firms as a group, relative to developed countries: a one-unit increase in the IP index predicts a 162 percent increase in R&D expenditures, but only at the 10 percent level of significance. However, this result does not appear to be sufficiently strong across enough countries within any given country group to remain significant in the breakdown groups. The result also is not replicated in the smaller developing country sample. The other significant finding from the analysis in these sectors is that across all countries, it is firms in the “in vitro and in vivo diagnostic substances” and “biological products except diagnostic substances” sectors (labeled as “biotech”) that are responsive to changes in the IP index, rather than the firms in the “pharmaceutical preparations” and “medicinal chemicals and botanical products” (labeled “pharma”). A one-unit increase in the IP index here predicts a 104 percent increase in R&D expenditures, though only at the 10 percent level of significance. This result is again not replicated in the much smaller developing country sample.

V. CONCLUSIONS

In this paper, we focused on four key variables that represent technology transfer and innovation, and analyzed the relationship between increased patent protection and these outcomes.

The key finding of the paper is the stark difference across developing countries in response to strengthened patent protection. There is a robust and statistically significant relationship between increased patent protection and both patenting activity (as an indicator of impact on local innovation) and R&D alliances (as an indicator of impact on technology transfer), but exclusively for the more technologically-advanced developing countries, namely the emerging 8 and Asian tiger countries.

We believe this to be the case for several reasons. First, the average developed country already has a sufficiently high degree of patent protection in our sample, so that marginal differences in their IP systems are unlikely to predict large statistical differences in the selected outcomes. This is consistent with the view in the existing literature that there may be constant or diminishing returns to strengthening patent protection beyond a point. Second, over and above the absolute levels of patent protection, there is significantly more variation in the IP index for developing countries during the selected time frame, which allows us to better statistically estimate the relationship between patent protection and our outcome variables.

Compared to earlier empirical studies on developing countries, this study used a unique set of complementary variables that characterize the empirical relationship between strengthened patent protection and technology transfer/innovation, and a common analytical approach. The study has therefore been able to analyze questions that have been previously unexplored, including the differential effect across emerging 8 countries and the Asian tigers of increased patent protection on firm-level R&D strategic alliances and firm-level R&D expenditures. It is noteworthy that the relationship between increased patent protection and outcome variables is strongest in the patent datasets, where individual observations are the most accurately recorded and available at the most disaggregated level. No doubt more robust and statistically significant analyses will become possible as other datasets become publicly available that record enterprise-level responses as accurately and consistently as the existing patent datasets.

Our findings point to the need for a longer-term agenda of complementary policies and support measures to strengthen those S&T capabilities that are most critical to allow the less developed countries to reap the benefits from strengthened patent protection. Such interventions should be based on a prior and careful quantification of the effects of strengthening specific S&T capabilities and policies on the IP protection-innovation nexus, as well as the identification of the effectiveness of such policies and support measures in varying country contexts.

There are at least three areas for further empirical research on the impact of strengthened IP protection on developing countries as natural extensions of this work:

- *Additional analyses of the impact of increased patent protection on technology transfer and local innovation.* While the common analytical approach adopted in this study facilitates comparison across outcome variables, it would be interesting to explore appropriate modifications to the common models, such as allowing for non-linearities in the relationship between patent protection and firm-level R&D expenditures. Another direction for extension is to include additional measures of quality of outcomes rather than just counts and values, such as substituting patents granted for patent applications in the EPO analysis, or examining citation-weighted patents in both EPO and USPTO analyses. A complementary direction is to explore similar variables in other datasets, such as FDI data with a finer breakdown of products by technology class, resident patent filings data in a range of developing countries, or patent family data (that eliminate double counts of patent applications filed with multiple offices for the same invention). Additional measures of technology transfer and innovation could include scientific publications, clinical drug trials, and other forms of knowledge-sharing partnerships between developing and developed country firms. Finally, it would be desirable to complement cross-country analyses with additional rigorous country case studies along the lines of Arora et al. (2008), where special local characteristics can be given appropriate emphasis.

- *Analyses of the impact of other rules protecting IP*. Trademarks are the IP category most frequently used by developing country firms. In some developing countries, industrial designs, utility models, geographical indications, and copyrights are also frequently used by resident developing country firms.[27] It would be interesting to explore the impact of the strengthening of the other important rules protecting IP on relevant outcome variables.

- *Analyses of the impact of IP rules and complementary capabilities on broader innovation-related indicators.* As highlighted by our analyses, merely introducing stronger IP laws on the books is unlikely to lead to significant improvements in innovation-related outcomes unless countries have some significant level of existing S&T capabilities, namely human capital, infrastructure, supporting policies and institutions. One relevant direction for further research involves quantifying the effect of strengthening specific S&T capabilities and policies on the IP protection-innovation nexus. A complementary direction would be to analyze the impact not just of the *de jure* strength of IP protection systems, but the *de facto* effectiveness of enforcement practices – which would require a better understanding of the effectiveness of actual IP policy implementation across countries, ideally also including the effectiveness of support policies to improve enterprise IP asset management strategies. Finally, it would be instructive to analyze the extent to which a greater awareness and strengthening of IP rules has impact on broader innovation-related indicators, such as the diffusion of new technologies to developing country firms and the adaptation of these technologies by enterprises to local conditions.

[27] In China in 2007, for instance, there were 681,358 trademark applications (of which the resident share was 88.8 percent), 267,432 industrial design applications (resident share of 94.8 percent), and 181,324 utility model filings (resident share of 99.3 percent), in contrast to 245,161 patent filings (resident share of 62.4 percent) (WIPO 2009).

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APPENDIX 1: Note on Data Sources

IP index

The patent rights index, which is available at 5-year intervals, comes from Walter Park, "International Patent Protection: 1960-2005," *Research Policy,* May 2008. Data were used from 1990 through 2005. Of the available 122 countries, 114 were used for these analyses given non-availability of other control data for the remaining 8 countries. See Table A1 for a description of the index components and scoring method.

FDI data

The foreign direct investment (FDI) data come from the U.S. Bureau of Economic Analysis (BEA) Survey of U.S. Direct Investment Abroad, from their Country Detail by Industry tables on U.S. direct investment position abroad on a historical-cost basis. These are comprehensive data on outward direct investment including all countries in which there is direct investment. We focused on manufacturing FDI in five sectors: chemicals (including pharmaceuticals and medicines, but also basic chemicals, resins and synthetic fibers, soap and cleaning compounds, pesticides and fertilizers, paints, coatings and adhesives, and other chemical products and preparations), food, electronics/electrical and machinery, metals, and transportation equipment. We examine data for 1990, 1995, 2000, and 2005, to coincide with the years available in the IP index. The FDI data are in nominal US dollars, so we transform to real values with the IMF's GDP deflator. Each observation is the logarithm of the FDI level in a given industry in a given country-year.

The set of data for which all variables are available includes 110 countries, 86 developing and 24 developed. In comparison with the 114 countries included in the patent-based analyses (see Table A2), the U.S. is necessarily not included in the sample and three developing countries have insufficient data to be used in the regressions: Burkina Faso, Mozambique, and Rwanda.

Strategic Alliances data

The strategic alliances data come from Thomson Reuters' SDC Platinum Joint Ventures/Strategic Alliances Database. In this dataset, strategic alliance deals are defined as cooperative business activities that include both: (i) joint ventures, where two or more separate organizations create an independent business entity with shared responsibilities and risks; and (ii) non-joint venture strategic alliances, where two or more separate organizations, for strategic purposes, contractually allocate ownership, responsibilities, and financial risks and rewards to each member, while preserving each member's separate identity/autonomy. We restricted our dataset to explicit R&D agreements, and dropped other types of alliances such as materials supply agreements or licensing agreements for the purpose of sales to local markets.

We collected data on the 27 countries in the dataset for which we have IP index observations, 14 developing and 13 developed, for the period 1990-2008, focusing on five distinct high-tech categories or groups of sectors: medical (including not only pharmaceutical and biotechnology sectors, but also lab equipment, medical imaging and monitoring systems, and surgical equipment as well as prosthetics/artificial limbs; healthcare services, mainly hospital management, which was included under this category in the original dataset, was moved to “other”), communications, computer equipment, electronics, and other. The list of countries is provided in Appendix 1 (with asterisks). For each country with at least one firm participating in a strategic alliance, we allocated one observation per alliance to that country. For example, if two U.S. firms and three Indian firms form a strategic alliance, we label this as one U.S.-India alliance and thus only count one observation for the U.S. and one for India. We further restricted our data coverage to alliances that involved at least one developing country firm and one developed country firm; alliances involving only own-country firms, only developed country firms or only developing country firms were deleted. We then summed the number of alliances per country, year and high-tech category combination – separately for all R&D alliances, and for R&D alliances in the pharmaceutical and biotechnology sectors.

Patent data

The patent data come from two distinct sources. For data on patents granted by the U.S. Patent and Trademark Office, data came from the USPTO Cassis CD-ROM (April 2008 version). For data on patent applications to the European Patent Office, data came from the PATSTAT CD-ROM (the EPO’s Worldwide Patent Statistical Database, April 2009 version). For both datasets, we have used the country of residence of the first inventor listed (by custom in the U.S. the most important inventor or most senior member of a team of more than one inventor) as the country to which the patent is allocated, to avoid double counting.

For allocation to industrial sector, we have used the first-appearing technology classification code (USPTO and IPC), and mapped these codes to a similar 6 categories technological classification (for USPTO data, the concordance is based on the NBER patents “Class, technological category, and technological subcategory crosswalk” available at http://www.nber.org/patents/; for EPO data, based on the “IPC and technology concordance table” available at http://www.wipo.int/export/sites/www/ ipstats/en/statistics/patents/xls/ipc_technology.xls, with the listed 4 fields of technology rearranged to match the 6 U.S. categories). The common 6 technological categories are: chemicals, computers and communications, medical (including not only pharmaceutical and biotechnology sectors, but also surgery and medical instruments, dentistry, optics and prosthetics/ artificial limbs), mechanical, and other.

For the collaboration-driven patenting analyses, we restricted our data coverage to patents with multiple inventors, where at least one inventor’s country of residence is different from the first-listed inventor. The international collaboration sample drops all patents with single inventors or multiple inventors exclusively from the same country. The developed-developing countries collaboration sample further restricts data coverage by dropping all international collaborations where multiple inventors are exclusively from either developed countries or developing countries.

Firm-level R&D expenditures data

The data for the firm-level R&D expenditures analysis comes from Standard & Poor's Compustat Global database. This dataset provides R&D expenditures and total sales revenue (in addition to other variables) at the firm level, based on company balance sheet information and public filings across many countries. We restricted our data coverage to the manufacturing sectors (SIC 2-digit codes ranging from 20 to 39), and created industry controls based on the appropriate industry disaggregation level (SIC 3 digit or SIC 4 digit industries) based on the specific IP-industry interaction terms included in the regression model.

We used data from all available countries that had firm-level observations with at least one firm reporting positive R&D expenditures; all firms with exclusively non-positive R&D observations were dropped. Although our dataset begins in 1989, the data only include a very small number of observations across all emerging 8 countries and Asian tigers in 1990 so that we only begin our analysis for 1995 data. Over time, Standard & Poor's has endeavored to increase the coverage of this database by making use of additional data sources; this has led to an increase in data availability for some developing countries in more recent years. We control for possible biases in subsequent additions to the dataset that may not be random or representative of the underlying population by limiting the dataset to firms that appeared for more than one year (among 1990, 1995, 2000 and 2005). The list of countries included is provided in Appendix 1 (underlined).

We adjust for inflation within countries over time by deflating all expenditures and sales figures to year 2000-equivalent U.S. dollars using an annual GDP deflator downloaded from the World Bank's World Development Indicators. We note that between 1995 and 2005, Turkey experienced hyperinflation and a subsequent revaluing of its currency. We find 1995 figures when R&D investment data for firms in Turkey is deflated to year-2000 values implausibly large, and thus drop Turkey altogether from the analysis due to the skewed (and likely unreliable) nature of the reported figures.

The "Drugs" industries correspond to the sectors falling under SIC 283. To examine the separate effect of IP strengthening on the pharmaceutical sector, we labeled SIC sectors 2833 (Medicinal Chemicals and Botanical Products) and 2834 (Pharmaceutical Preparations) as "pharma" and SIC sectors 2835 (In Vitro and In Vivo Diagnostic Substances) and 2836 (Biological Products, Except Diagnostic Substances) as "biotech".

Other variables

GDP per capita. This standard variable, in constant 2000 U.S. dollars, was downloaded from the World Bank's World Development Indicators.

Population. This standard variable was downloaded from the World Bank's World Development Indicators.

Openness index. The "Openness" index or Freedom to Trade index comes from the Fraser Institute's Economic Freedom of the World report. Components of the index include trade tariff and tax levels; regulatory trade barriers; size of the trade sector relative to expectations; black-market exchange rates; and international capital market controls. The range of possible scores is 0-10, with 10 being the most open or free.

Science and Technology capabilities. These standard variables were downloaded from UNESCO (www.uis.unesco.org) for R&D personnel and tertiary students, from the International Telecommunications Union (www.itu.int) for Internet users, and from the World Bank's World Development Indicators for personal computers.

Countries – selection and allocation. All countries for which the IP index was available for one or more of the years 1990 through 2005 were included in each dataset as candidate countries for regression analyses. The classification of countries as "developing" versus high-income developed, as reported in Table A2, is based on the World Bank's classification of countries by income according to 1990 GNP per capita, at the beginning of the period of the various analyses. It is worthwhile to note that in the World Bank's *World Development Report 1995*, based on 1993 GNP per capita data, South Korea is still considered as a middle-income developing country, and Hong Kong and Singapore are listed as "economies classified by the United Nations or otherwise regarded by their authorities as developing". Although the main criterion for classifying economies at the World Bank has been GNP per capita, classification by income does not necessarily reflect development status and upper middle income countries have continued to face substantial development challenges such as: achieving sustained growth that provides productive employment; reducing poverty and inequality; and strengthening the institutional and governance structures that underpin viable market-based economies.

APPENDIX 2: Tables and Figures

Table A1: Components and scoring method of IP (patent rights) index

Components of the Patent Rights Index*

1) Membership in International Treaties	Signatory	Not Signatory
-- Paris Convention and Revisions	1/5	0
-- Patent Cooperation Treaty	1/5	0
-- Protection of New Varieties (UPOV)	1/5	0
-- Budapest Treaty (Microorganism Deposits)	1/5	0
-- Trade-Related Intellectual Property Rights (TRIPS)	1/5	0
2) Product Coverage	Available	Not Available
-- Patentability of pharmaceuticals	1/8	0
-- Patentability of chemicals	1/8	0
-- Patentability of food	1/8	0
-- Patentability of surgical products	1/8	0
-- Patentability of microorganisms	1/8	0
-- Patentability of utility models	1/8	0
-- Patentability of software	1/8	0
-- Patentability of plant & animal varieties	1/8	0
3) Restrictions on Patent Rights	Does Not Exist	Exists
-- "Working" Requirements	1/3	0
-- Compulsory Licensing	1/3	0
-- Revocation of Patents	1/3	0
4) Enforcement Mechanisms	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
	1	$0 < f < 1$

-- where f is the duration of protection as a fraction of 20 years from the date of application or 17 years from the date of grant (for grant-based patent systems).

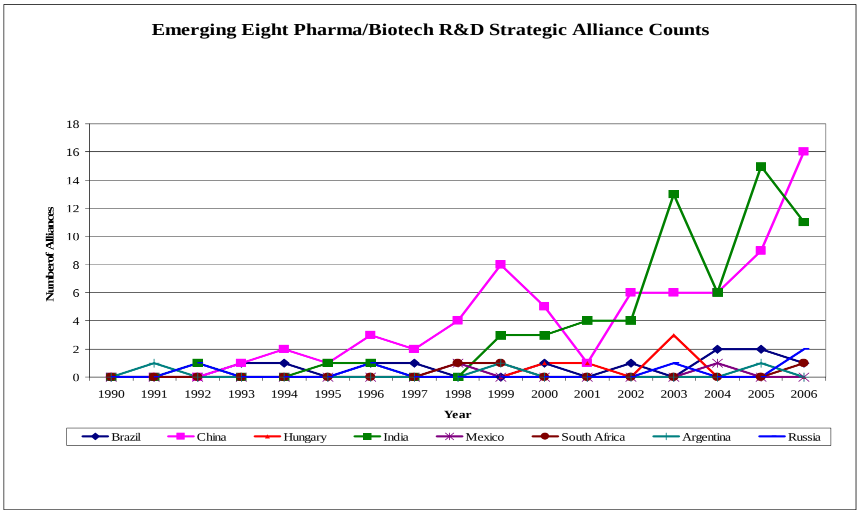
* As described at the beginning of Section II in the main text, the index ranges in value from 0 to 5, with scoring between 0-1 in each of the outlined five components. See Park (2008).

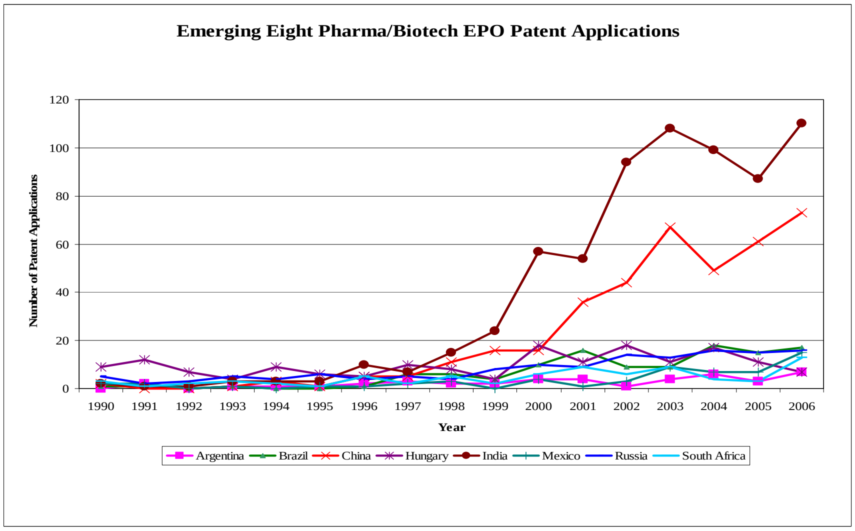
Table A2: Sample countries for regression analyses

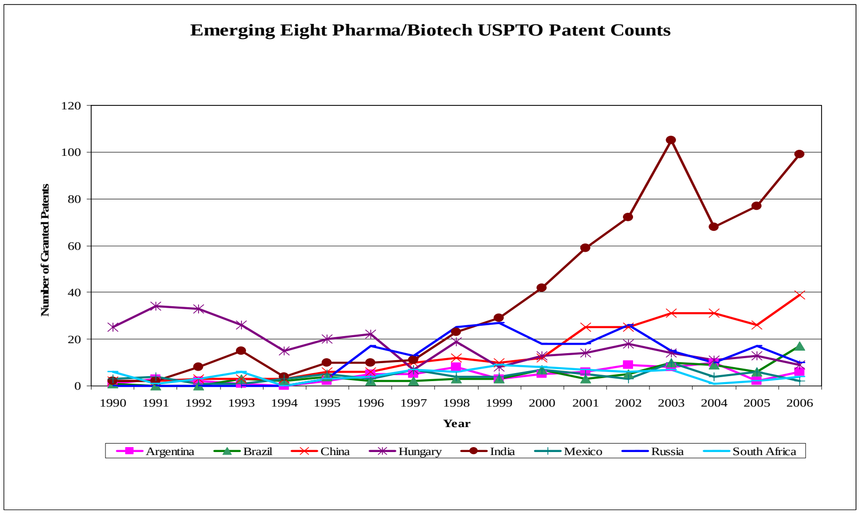
Developing Countries (88)		**Asian Tigers (of Developing)**	**Developed Countries (26)**
Algeria	Malawi	Hong Kong*	Australia*
Angola	Malaysia*	Singapore*	Austria
Argentina	Mali	South Korea*	Belgium
Bangladesh	Mauritania	Taiwan*	Canada*
Benin	Mauritius		Cyprus
Bolivia	Mexico*		Denmark*
Botswana	Morocco		Finland*
Brazil	Mozambique	**Emerging 8 Countries (of Developing)**	France*
Bulgaria	Nepal		Germany*
Burkina Faso	Nicaragua	Argentina	Greece
Burundi	Niger	Brazil	Iceland
Cameroon	Nigeria	China*	Ireland*
Central African Republic	Pakistan	Hungary*	Israel
Chad	Panama	India*	Italy*
Chile	Papua New Guinea	Mexico*	Japan*
China*	Paraguay	Russia*	Luxembourg
Colombia	Peru	South Africa*	Malta
Congo (Brazzaville)	Philippines		Netherlands*
Congo (Kinshasa)	Poland		New Zealand
Costa Rica	Romania		Norway
Czech Republic	Russia*		Portugal
Dominican Republic	Rwanda		Spain
Ecuador	Senegal		Sweden
Egypt	Sierra Leone		Switzerland*
El Salvador	Singapore*		United Kingdom*
Ethiopia	Slovakia		United States*
Fiji	South Africa*		
Gabon	South Korea*		
Ghana	Sri Lanka		
Guatemala	Syria		
Guyana	Taiwan*		
Haiti	Tanzania		
Honduras	Thailand*		
Hong Kong*	Togo		
Hungary*	Trinidad And Tobago		
India*	Tunisia		
Indonesia	Turkey*		
Iran	Uganda		
Ivory Coast	Ukraine		
Jamaica	Uruguay*		
Jordan	Venezuela		
Kenya	Vietnam		
Lithuania	Zambia		
Madagascar	Zimbabwe		

Note: Countries with asterisks are included in the R&D strategic alliance regressions. Underlined countries are included in the firm-level R&D expenditures regressions.

Figure A1: Strategic Alliance and Patent Counts for Pharmaceutical and Biotechnology Sectors*







* See Appendix 1 for a description of how these sectors were defined in the three underlying datasets.

Table A3: Patent Protection and US Foreign Direct Investment

Variable	All Countries: Base Model	All Countries: Developing Interaction	All Countries: Country Breakdown	All Countries: Sector Interaction	Developing Countries: Base Model	Developing Countries: Country Breakdown	Developing Countries: Sector Interaction
Constant	-8.781	-8.297	-8.422	-10.168	-5.176	-5.251	-4.846
	(7.886)	(7.883)	(8.090)	(7.890)	(7.809)	(8.035)	(7.834)
IP index	0.155	-1.092	-1.081		0.439		
	(0.311)	(0.716)	(0.716)		(0.358)		
IP*developing countries		1.518*					
		(0.785)					
IP*Asian tigers			1.088			0.078	
			(1.191)			(0.999)	
IP*emerging 8			1.652*			0.571	
			(0.860)			(0.528)	
IP*other developing			1.475*			0.410	
			(0.799)			(0.384)	
IP*chemicals				0.094			0.680
				(0.364)			(0.458)
IP*electronics				0.605*			0.361
				(0.366)			(0.454)
IP*food				-0.375			0.229
				(0.373)			(0.471)
IP*metals				-0.160			-0.271
				(0.381)			(0.483)
IP*transport equipment				0.643*			1.225***
				(0.382)			(0.479)
Ln per cap GDP	1.709	1.703	1.741	1.712*	1.436	1.471	1.481
	(0.936)	(1.041)	(1.070)	(1.038)	(1.136)	(1.172)	(1.133)
Openness index	0.371*	0.423**	0.402**	0.366*	0.478**	0.457**	0.458**
	(0.199)	(0.201)	(0.204)	(0.199)	(0.225)	(0.230)	(0.225)
Observations	1,716	1,716	1,716	1,716	1,276	1,276	1,276
Adjusted R^2	0.763	0.763	0.763	0.765	0.710	0.710	0.711

Notes: The dependent variable is the logarithm of US foreign investment stocks in a given industrial sector, country, and year. The five manufacturing sectors that are interacted with the IP index are described in Appendix 1. All models include country and industry fixed effects, and a linear time trend (allowing for different trends in developing and developed countries). Standard errors in parentheses. ***, **, * indicate statistical significance at the 1%, 5% and 10% levels, respectively.

Table A4: Patent Protection and R&D Alliances for High-Tech Sectors

	All Countries				Developing Countries		
Variable	Base Model	Developing Interaction	Country Breakdown	Sector Interaction	Base Model	Country Breakdown	Sector Interaction
Constant	-0.439	-0.569*	0.058	-0.338	-1.156***	-0.487	-1.033**
	(0.305)	(0.309)	(0.365)	(0.304)	(0.439)	(0.525)	(0.431)
IP index	0.022	-0.0137	-0.108	-0.004	0.041	-0.054	0.003
	(0.048)	(0.086)	(0.087)	(0.048)	(0.056)	(0.064)	(0.056)
IP*developing countries		0.210**					
		(0.095)					
IP*Asian tigers			0.222*			0.165**	
			(0.114)			(0.079)	
IP*emerging 8			0.287***			0.193***	
			(0.097)			(0.068)	
IP*other developing			0.07				
			(0.102)				
IP*Medical				0.134***			0.192***
				(0.042)			(0.056)
Ln per cap GDP	-0.061***	-0.055***	-0.055***	-0.061***	-0.022	-0.026	-0.022
	(0.019)	(0.019)	(0.019)	(0.019)	(0.032)	(0.032)	(0.031)
Openness index	0.114***	0.118***	0.076*	.114***	0.170***	0.122**	0.170***
	(0.040)	(0.040)	(0.044)	(0.040)	(0.050)	(0.058)	(0.049)
Observations	535	535	535	535	275	275	275
Adjusted R^2	0.363	0.368	0.380	0.374	0.301	0.321	0.330

Table A5: Patent Protection and R&D Alliances for Pharma & Biotech Sectors

	All Countries				Developing Countries		
Variable	Base Model	Developing Interaction	Country Breakdown	Sector Interaction	Base Model	Country Breakdown	Sector Interaction
Constant	-0.905	-0.840	0.483	0.029	-0.393	0.954	-0.133
	-(1.01)	(1.009)	(1.221)	(1.112)	(1.352)	(1.637)	(1.358)
IP index	1.066*	0.439**	0.479**	-0.044	0.079	-0.108	-0.148
	(0.282)	(0.209)	(0.208)	(0.216)	(0.168)	(0.191)	(0.249)
IP*developing countries		-0.289					
		(0.252)					
IP*Asian tigers			-0.223			0.323	
			(0.328)			(0.244)	
IP*emerging 8			-0.151			0.355*	
			(0.26)			(0.195)	
IP*other developing			-0.564**				
			(0.281)				
IP*Pharma				0.334*			0.258
				(0.179)			(0.211)
Ln per cap GDP	-0.104	-0.112*	-0.111*	-0.101	-0.211*	-0.217*	-0.190
	(0.066)	(0.067)	(0.066)	(0.065)	(0.112)	(0.112)	(0.112)
Openness index	-0.009	0.007	-0.080	0.029	0.141	0.042	0.179
	(0.126)	(0.126)	(0.139)	(0.125)	(0.137)	(0.159)	0.140
Observations	99	99	99	99	51	51	51
Adjusted R^2	0.214	0.218	0.242	0.241	0.290	0.325	0.300

Notes: The dependent variable is the logarithm of the number of strategic alliances between at least one developing country firm and one developed country firm for a given industrial sector, country and year. All models include country and industry fixed effects, and a linear time trend (allowing for different trends in developing and developed countries). Standard errors in parentheses. ***, **, * indicate statistical significance at 1%, 5% and 10% levels.

Table A6: Patent Protection and Patent Applications to EPO - All Sectors

Variable	All Countries: Base Model	All Countries: Developing Interaction	All Countries: Country Breakdown	All Countries: Sector Interaction	Developing Countries: Base Model	Developing Countries: Country Breakdown	Developing Countries: Sector Interaction
Constant	-8.920***	-8.899***	-6.786***	-8.953***	-9.035***	-6.814***	-9.039***
	(0.717)	(0.717)	(0.721)	(0.716)	(0.71)	(0.706)	(0.711)
IP index	0.130***	0.234***	0.246***	0.142***	0.110***	-0.025	0.112***
	(0.029)	(0.067)	(0.065)	(0.029)	(0.031)	(0.031)	(0.031)
IP*developing countries		-0.126*					
		(0.073)					
IP*Asian tigers			0.202*			0.463***	
			(0.103)			(0.075)	
IP*emerging 8			0.253***			0.531***	
			(0.079)			(0.044)	
IP*other developing			-0.274***				
			(0.072)				
IP*Medical				-0.068**			-0.011
				(0.027)			(0.035)
Ln per cap GDP	1.179***	1.183***	0.944***	1.179***	1.209***	0.954***	1.209***
	(0.098)	(0.098)	(0.098)	(0.098)	(0.098)	(0.096)	(0.098)
Openness index	-0.044**	-0.048***	-0.047***	-0.044**	-0.068***	-0.068***	-0.068***
	(0.018)	(0.019)	(0.018)	(0.018)	(0.019)	(0.018)	(0.019)
Observations	2,472	2,472	2,472	2,472	1,848	1,848	1,848
Adjusted R^2	0.945	0.944	0.948	0.945	0.784	0.791	0.772

Table A7: Patent Protection and Applications to EPO - Pharma & Biotech

Variable	All Countries: Base Model	All Countries: Developing Interaction	All Countries: Country Breakdown	All Countries: Sector Interaction	Developing Countries: Base Model	Developing Countries: Country Breakdown	Developing Countries: Sector Interaction
Constant	-7.31***	-7.314***	-4.904***	-7.417***	-7.618***	-5.090***	-7.635***
	(1.029)	(1.030)	(1.004)	(1.026)	(0.983)	(0.924)	(0.985)
IP index	0.073*	0.053	0.065	0.110**	0.079*	-0.070*	0.085*
	(0.042)	(0.096)	(0.090)	(0.044)	(0.042)	(0.041)	(0.046)
IP*developing countries		0.025					
		(0.105)					
IP*Asian tigers			0.462***			0.581***	
			(0.144)			(0.098)	
IP*emerging 8			0.426***			0.565***	
			(0.110)			(0.058)	
IP*other developing			-0.137				
			(0.100)				
IP*Pharma				-0.073**			-0.013
				(0.029)			(0.036)
Ln per cap GDP	0.957***	0.956***	0.679***	0.957***	1.004***	0.710***	1.004***
	(0.141)	(0.141)	(0.137)	(0.141)	(0.135)	(0.126)	(0.135)
Openness index	-0.029	-0.028	-0.025	-0.029	-0.049*	-0.045*	-0.049*
	(0.026)	(0.027)	(0.025)	(0.026)	(0.026)	(0.024)	(0.026)
Observations	824	824	824	824	616	616	616
Adjusted R^2	0.933	0.933	0.941	0.933	0.662	0.766	0.662

Note: The dependent variable is the logarithm of patent counts in a given industrial sector, country, and year. All models include country and industry fixed effects, and a linear time trend (allowing for different trends in developing and developed countries). Standard errors in parentheses. ***, **, * indicate statistical significance at the 1%, 5% and 10% levels.

Table A8: Patent Protection and Patents Granted by USPTO - All Sectors

Variable	All Countries: Base Model	All Countries: Developing Interaction	All Countries: Country Breakdown	All Countries: Sector Interaction	Developing Countries: Base Model	Developing Countries: Country Breakdown	Developing Countries: Sector Interaction
Constant	-7.347***	-7.337***	-4.901***	-7.387***	-7.107***	-4.501***	-7.138***
	(0.683)	(0.683)	(0.681)	(0.682)	(0.685)	(0.672)	(0.684)
IP index	0.009	0.060	0.060	0.023	0.005	-0.114***	0.017
	(0.028)	(0.064)	(0.061)	(0.028)	(0.029)	(0.030)	(0.030)
IP*developing countries		-0.061					
		(0.070)					
IP*Asian tigers			0.744***			0.915***	
			(0.098)			(0.071)	
IP*emerging 8			0.162**			0.352***	
			(0.075)			(0.042)	
IP*other developing			-0.180***				
			(0.068)				
IP*Medical				-0.082***			-0.073**
				(0.026)			(0.034)
Ln per cap GDP	1.011***	1.013***	0.712***	1.011***	0.994***	0.669***	0.994***
	(0.094)	(0.094)	(0.093)	(0.093)	(0.094)	(0.092)	(0.094)
Openness index	-0.062***	-0.064***	-0.041**	-0.062***	-0.093***	-0.067***	-0.093***
	(0.018)	(0.018)	(0.017)	(0.018)	(0.018)	(0.018)	(0.018)
Observations	2,472	2,472	2,472	2,472	1,848	1,848	1,848
Adjusted R^2	0.948	0.948	0.952	0.948	0.847	0.863	0.847

Table A9: Patent Protection and USPTO Patents - Pharma & Biotech

Variable	All Countries: Base Model	All Countries: Developing Interaction	All Countries: Country Breakdown	All Countries: Sector Interaction	Developing Countries: Base Model	Developing Countries: Country Breakdown	Developing Countries: Sector Interaction
Constant	-6.394***	-6.411***	-3.898***	-6.065***	-6.182***	-3.515***	-6.050***
	(1.044)	(1.044)	(1.021)	(1.001)	(0.902)	(0.833)	(0.896)
IP index	0.012	-0.077	-0.074	-0.100**	0.039	-0.089**	-0.011
	(0.042)	(0.107)	(0.092)	(0.043)	(0.039)	(0.037)	(0.042)
IP*developing countries		0.108					
		(0.107)					
IP*Asian tigers			0.874***			0.876***	
			(0.147)			(0.088)	
IP*emerging 8			0.372***			0.405***	
			(0.112)			(0.052)	
IP*other developing			-0.023				
			(0.102)				
IP*Pharma				0.224***			0.102
				(0.028)			(0.033)
Ln per cap GDP	0.828***	0.824***	0.518***	0.827***	0.825***	0.496***	0.825***
	(0.143)	(0.143)	(0.139)	(0.137)	(0.124)	(0.114)	(0.123)
Openness index	-0.002		0.021	-0.002	-0.043*	-0.021	-0.043*
	(0.027)		(0.026)	(0.026)	(0.024)	(0.022)	(0.024)
Observations	824	824	824	824	616	616	616
Adjusted R^2	0.924	0.924	0.932	0.930	0.709	0.770	0.714

Note: The dependent variable is the logarithm of patent counts in a given industrial sector, country, and year. All models include country and industry fixed effects, and a linear time trend (allowing for different trends in developing and developed countries). Standard errors in parentheses. ***, **, * indicate statistical significance at 1%, 5% and 10% levels.

Table A10: Patent Protection and Co-Inventions Filed with EPO

Variable	All Countries: Base Model	All Countries: Developing Interaction	All Countries: Country Breakdown	All Countries: Sector Interaction	Developing Countries: Base Model	Developing Countries: Country Breakdown	Developing Countries: Sector Interaction
Constant	-4.678***	-4.775***	-3.170***	-4.682***	-5.681***	-4.041***	-5.697***
	(0.601)	(0.589)	(0.597)	(0.601)	(0.501)	(0.499)	(0.500)
IP index	-0.048*	-0.543***	-0.538***	-0.046*	0.054**	-0.033	0.060***
	(0.024)	(0.055)	(0.054)	(0.025)	(0.021)	(0.022)	(0.022)
IP*developing countries		0.601***					
		(0.060)					
IP*Asian tigers			0.994***			0.459***	
			(0.086)			(0.053)	
IP*emerging 8			0.817***			0.306***	
			(0.065)			(0.031)	
IP*other developing			0.506***				
			(0.060)				
IP*Medical				-0.008			-0.036
				(0.023)			(0.025)
Ln per cap GDP	0.651***	0.631***	0.441***	0.651***	0.757***	0.561***	0.757***
	(0.082)	(0.081)	(0.081)	(0.082)	(0.069)	(0.068)	(0.069)
Openness index	-0.026*	-0.009	-0.001	-0.026*	-0.027**	-0.018	-0.027**
	(0.015)	(0.015)	(0.015)	(0.015)	(0.013)	(0.013)	(0.013)
Observations	2,472	2,472	2,472	2,472	1,848	1,848	1,848
Adjusted R^2	0.714	0.726	0.737	0.714	0.523	0.561	0.523

Table A11: Patent Protection and Co-Inventions Granted by USPTO

Variable	All Countries: Base Model	All Countries: Developing Interaction	All Countries: Country Breakdown	All Countries: Sector Interaction	Developing Countries: Base Model	Developing Countries: Country Breakdown	Developing Countries: Sector Interaction
Constant	-3.355***	-3.405	-1.622***	-3.350***	-4.048***	-2.200***	-4.052***
	(0.489)	(0.485)	(0.482)	(0.489)	(0.459)	(0.448)	(0.459)
IP index	-0.041**	-0.298***	-0.296***	-0.042**	0.013	-0.075***	0.015
	(0.02)	(0.045)	(0.043)	(0.020)	(0.020)	(0.020)	(0.020)
IP*developing countries		0.312***					
		(0.05)					
IP*Asian tigers			0.495***			0.274***	
			(0.053)			(0.028)	
IP*emerging 8			0.865***			0.616***	
			(0.069)			(0.047)	
IP*other developing			0.221***				
			(0.048)				
IP*Medical				0.009			-0.008
				(0.018)			(0.023)
Ln per cap GDP	0.470***	0.460***	0.242***	0.470***	0.558***	0.329***	0.558***
	(0.067)	(0.066)	(0.066)	(0.067)	(0.063)	(0.061)	(0.063)
Openness index	-0.016	-0.007	0.008	-0.016	-.034***	-0.018	-0.034***
	(0.013)	(0.013)	(0.012)	(0.013)	(0.012)	(0.012)	(0.012)
Observations	2,472	2,472	2,472	2,472	1,848	1,848	1,848
Adjusted R^2	0.689	0.694	0.718	0.704	0.535	0.589	0.534

Note: The dependent variable is the logarithm of patent counts in a given industrial sector, country, and year. All models include country and industry fixed effects, and a linear time trend (allowing for different trends in developing and developed countries). Standard errors in parentheses. ***, **, * indicate statistical significance at 1%, 5% and 10% levels.

Table A12: Patent Protection and R&D Expenditures - All Sectors

Variable	All Countries Base Model	Developing Interaction	Country Breakdown	Sector Interaction	Developing Countries Base Model	Country Breakdown	Sector Interaction
Constant	-10.41**	-6.616	-7.712	-5.817	-1.864	-0.552	-1.087
	(4.766)	(5.490)	(5.559)	(4.474)	(8.030)	(8.039)	(7.196)
IP index	-0.201	-0.536	-0.529	-0.248	0.283	0.191	0.230
	(0.162)	(0.352)	(0.352)	(0.155)	(0.240)	(0.456)	(0.234)
IP*developing countries		0.351					
		(0.328)					
IP*Asian tigers			1.363*			0.254	
			(0.723)			(0.528)	
IP*emerging 8			0.494			0.150	
			(0.341)			(0.459)	
IP*other developing			0.636				
			(0.674)				
IP*Drugs				0.623***			
				(0.098)			
Ln Lagged sales	0.312***	0.312***	0.312***	0.347***	0.680***	0.709***	0.699***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.023)	(0.025)	(0.024)
Ln per cap GDP	2.063***	1.839***	1.947***	1.579***	0.464	0.538	0.599
	(0.477)	(0.520)	(0.528)	(0.457)	(0.973)	(1.043)	(0.939)
Openness index	-0.038	0.014	0.017	-0.025	-0.305	-0.335	-0.028
	-(0.075)	(0.090)	(0.090)	-(0.072)	(0.208)	(0.207)	(0.202)
Observations	8,539	8,539	8,539	8,539	1,126	1,126	1,126
Adjusted R^2	0.415	0.415	0.415	0.468	0.627	0.682	0.660

Table A13: Patent Protection and R&D Expenditures - Pharma & Biotech

Variable	All Countries Base Model	Developing Interaction	Country Breakdown	Sector Interaction	Developing Countries Base Model	Country Breakdown	Sector Interaction
Constant	-28.21	-16.57	-13.68	-30.27**	6.043	23.62	8.808
	(14.48)	(16.02)	(16.94)	(14.16)	(24.34)	(23.32)	(18.80)
IP index	0.435	-1.105	-1.172	1.044*	0.745	-1.156	-1.353
	(0.467)	(1.002)	(1.016)	(0.593)	(0.952)	(1.786)	(1.943)
IP*developing countries		1.622*					
		(0.934)					
IP*Asian tigers			-2.733			-1.982	
			(4.413)			(1.979)	
IP*emerging 8			0.984			1.594	
			(1.150)			(1.417)	
IP*other developing			-0.0138				
			(2.211)				
IP*Pharma				-0.572			2.301
				(0.369)			(1.839)
Ln Lagged sales	0.079***	0.078***	0.078***	0.082***	0.799***	0.911***	0.892***
	(0.010)	(0.010)	(0.010)	(0.010)	(0.101)	(0.096)	(0.098)
Ln per cap GDP	4.417***	3.576**	3.290**	4.440***	-0.703	-4.032	-1.303
	(1.501)	(1.576)	(1.667)	(1.483)	(2.899)	(3.500)	(2.632)
Openness index	-0.341	-0.118	-0.099	-0.366	-0.525	-0.722	-0.760
	(0.232)	(0.265)	(0.270)	(0.229)	(0.767)	(0.710)	(0.705)
Observations	936	936	936	936	119	119	119
Adjusted R^2	0.366	0.367	0.367	0.381	0.502	0.590	0.591

Note: The dependent variable is the logarithm of firm-level R&D expenditures in a given industrial sector, country, and year. All models include country and industry fixed effects, and a linear time trend (allowing for different trends in developing and developed countries). Standard errors in parentheses. ***, **, * indicate statistical significance at 1%, 5% and 10% levels.