Doing R&D in Countries with Weak IPR Protection: Can Corporate Management Substitute for Legal Institutions? *

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ABSTRACT

Multinational enterprises (MNEs) are increasingly conducting R&D in countries such as India and China, where intellectual property rights (IPR) protection is still weak. This paper examines the puzzle. The argument is that weak IPR leads to low returns to innovation and thus underutilization of innovative talents. MNEs who possess not only the capabilities to utilize these talents, but also the internal organizations to protect the intellectual properties will therefore find it attractive to conduct R&D at those locations. Following a series of interviews in major multinational R&D centers in China, a theoretical framework is presented to capture the interaction between firm strategies and institutional environment. Empirical findings from a sample of 1,567 U.S.-headquartered innovating firms are consistent with the hypotheses that (i) technologies developed in weak IPR countries are used more internally, and (ii) firms doing R&D in weak IPR countries have tighter internal technology structures. The results suggest that firms may be using strong internal linkages to substitute for the inadequate external institutions. By doing so, they are able to take advantage of the arbitrage opportunities presented by the institutional gap across countries.

Keywords: R&D, intellectual property rights, MNE, arbitrage

> Intellectual property is still an extremely vague concept in China, where fake DVDs are sold on street corners and even the Government uses pirated software.
>
> –– The Times (London), Dec. 12, 2002

> A significant number of multinationals are increasingly combing the mainland [China] for engineers and researchers to handle projects for global applications that, in recent years, would have been performed in labs in the United States or Europe.
>
> –– ZDNet News, Jul. 10, 2002

I. INTRODUCTION

The recent years have witnessed a surge of multinational R&D activities in countries such as India and China, where the intellectual property rights (IPR) protection is still far from satisfactory. Technology giants such as Microsoft, IBM, Intel, and GE are in the lead, but more firms are following. (Financial Times 4/19/02; New York Times 4/21/02; BusinessWeek 2/03/03) Moreover, the R&D conducted in these Indian and Chinese labs is in excess of that required for localization or government-enforced technology transfers.

This trend is in apparent contradiction of conventional wisdom. Because poor institutional environment erodes the appropriable value of innovation, firms have been advised to keep their knowledge-intensive activities away from weak IPR countries. What has enabled some firms to act differently?

To understand this puzzle, I began with a series of interviews with the researchers and managers in some of the multinational R&D labs in China. Some common practices emerged, including intensive communications and collaborations with headquarters, patent applications in the home country, and internal project transfers across countries. In particular, the projects are often closely integrated in the firms' global research agendas. The research labs report directly to the technology department at headquarters, connected with the firm's other labs by intranet, conference calls and project collaborations. Because the resultant technologies are aimed at global applications, intellectual property issues are mostly handled in the home country.

The "carved-out expertise" – as called by some labs – is valuable only when combined with the complementary knowledge and resources within the firm. For example, by 2002 Microsoft Research (MSR) Asia had developed AutoMovie for Movie Maker, Mobile HTML Optimizer for FrontPage, and the Ink Parsing technology for Tablet PCs. They are all considered major contributions in the field, but they themselves do not bring direct commercial value to potential imitators. The closely-knit internal innovation structure, therefore, serves as an immune system against the adverse external environment.

This observation suggests a framework to examine the original puzzle. In countries with poor IPR protection and poor institutional environment overall, local firms would find it difficult to appropriate value from intellectual products. As a result, R&D is discouraged and human capital is undervalued. This is in spite of the fact that these countries have a large pool of potentially valuable talent to conduct R&D. MNEs are in a unique position to arbitrage the difference in factor prices across national borders; their ability to do so stems from their internal organizations that can be viewed as a substitute for the inadequate external institutions. I call it *internalization-arbitrage*.

To articulate the interaction between firm organizations and external environment, I map the observations to a very simple, but logically contestable framework. It shows that MNEs may find it desirable to conduct R&D across borders when technologies are complementary internally. By keeping the complementary resources well protected, MNEs are able to leverage the strong institutions in the home country for their operations overseas. The viability of this strategy depends on a set of firm-specific and knowledge-specific characteristics.

I then seek empirical evidence of the theoretical conjecture, using U.S. patent data and the Directory of Corporate Affiliations. I find supportive results that patents developed in weak IPR countries are cited more internally than those developed in other foreign countries. In addition, firms doing R&D in weak IPR countries feature significantly stronger internal linkages among their technologies than those who do not. The results are consistent with the thought that the internal linkages allow firms to appropriate value from their knowledge even in weak institutional environments.

The next section sets up the theoretical framework and analyzes the potential arbitrage opportunities between different institutional environments. Section III brings the theoretical conjecture to the data and sets up the stage for empirical analysis. The results are presented in Section IV. Section V concludes and discusses future extensions.

II. THE FRAMEWORK

The observations of multinational R&D suggest that firms may use internal organizations to protect knowledge, hence realizing the potential value of human capital in weak IPR countries. In this section, I map this idea to a logically contestable framework and show how technology complementarities, firm organizations, and legal institutions interact with one another.

2.1 The Nature of Knowledge Diffusion

There are three critical steps in imitation: the motivation to imitate, the ability to imitate, and the possibility of getting around legal restrictions against imitation. In an institutional environment where the legal restrictions barely exist or are not effectively enforced, the first two factors can play a critical role in firms' IPR protection. They both stem from the very nature of knowledge flow.

First, the motivation to imitate is low when the value of the technologies is highly dependent on internal resources. Imitation is costly (Mansfield et al. 1981), so it will happen only when imitators can profit from the technologies. Teece (1986) points out that specialized and co-specialized complementary assets are critically important to the successful commercialization of an innovation. Thus, innovators can discourage imitation by developing technologies that require complementary knowledge not readily available to imitators. For example, basic researches still far from commercialization, or technologies that are firm specific, are usually less attractive to imitators.

Second, the acquisition of complementary knowledge is subject to the constraints of geographic distance. It has long been realized that a multinational corporation is a geographically distributed innovation network, with the capacity to assimilate, generate and integrate knowledge on a worldwide basis (Bartlett and Ghoshal 1990). Knowledge that is difficult to codify or teach can be more efficiently transferred within the firm (Kogut and Zander 1993). Therefore, outside firms would have to face much higher costs to obtain complementary knowledge across country borders, if not altogether impossible.

From this perspective, the nature of knowledge creation and diffusion presents an opportunity for MNEs to overcome the weak institutional environment in the host country. On one hand, the internal complementarity of technologies makes the leakage of individual components less threatening. On the other hand, the constraints on cross-border knowledge flows enable MNEs to keep the critical knowledge under the protection of home institutions. The combination of these two makes R&D in weak IPR countries a feasible strategy. I will elaborate this idea in the following model.

2.2 Internalization-Arbitrage

In essence, there are two boundaries in multinational R&D: the *firm boundary* and the *national boundary*. Within a firm, complementary technologies create synergy in a way that is hard to duplicate outside the firm. Within a country, R&D activities are subject to a certain institutional environment distinct from that of other countries. MNEs are of particular interest because they expand their boundaries across multiple institutions, and create value from technologies that are exposed to different external environments.

Suppose that firm A has two technologies under development: a_1 and a_2. Standing alone, in the absence of the other, each a_i ($i = 1, 2$) has value $V(a_i)$. At the same time, a_1 can be integrated with a_2 inside the firm. The *joint value* of two complementary technologies $V(a_1 \& a_2)$ can be larger than the sum $V(a_1) + V(a_2)$ because of internal complementarity. In the following analysis, I will use the phrase *internalized value* to describe the difference between the $V(a_1 \& a_2)$ and $V(a_1) + V(a_2)$.

Depending on the legal and social institutions, there is certain imitation risk p ($0 \leq p \leq 1$) in the economy, which firms take as given. With probability p, imitation would happen to a_i and the value $V(a_i)$ would be taken away from the firm. This is independent of what might happen to the other technology. Only when a_1 and a_2 are both imitated will firm *A* lose the whole value $V(a_1 \& a_2)$.

Suppose there are two countries. Country *X* has strong IPR protection (small p_x), hence high price of human capital (large c_x); country *Y* is just the opposite: large p_y and small c_y. Firm *A*, with its two complementary projects, can now choose from the following three strategies, as shown in Figure 1:

- Having both projects developed in country *X*;
- Having both projects developed in country *Y*;
- Having one project developed in country *X* and the other developed in country *Y*.

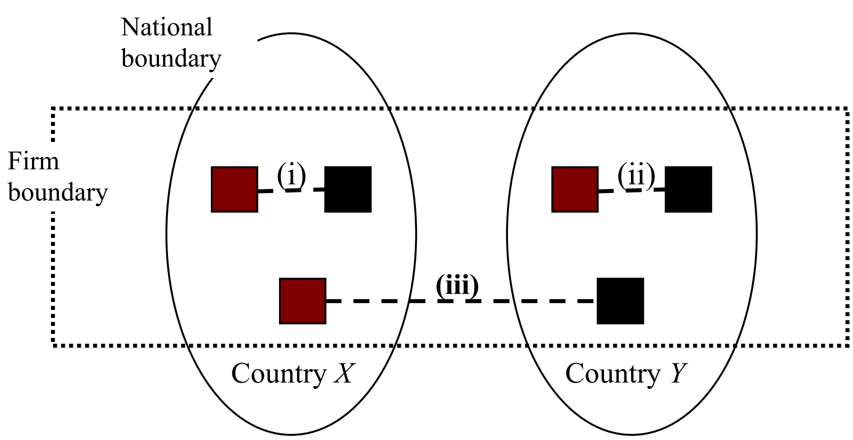

Figure 1. Organizational Strategies of R&D Projects

Now we are ready to analyze the potential arbitrage opportunities of strategy (iii), in which the two complementary components are developed in two different environments with an institutional gap $\Delta p \equiv p_y - p_x > 0$ and a factor price difference $\Delta c \equiv c_x - c_y > 0$. Due to the poor IPR protection in some countries, human capital is underutilized and underpriced. Such low cost human capital is attractive to R&D intensive firms if the firms possess alternative mechanisms to protect their intellectual property. One of the mechanisms, as identified above, is the substitution of *internal* organizations for external institutions, which allows firms to *arbitrage* the difference across countries. I call it *internalization-arbitrage*.

There are two main factors involved in internalization-arbitrage.

First, different R&D projects are different in their internal dependence. The strategy of differentiated project assignment, in essence, is to tailor and allocate projects so that the firm can capitalize on the strengths of particular locations while minimizing the costs and risks. In particular, firms can examine their R&D portfolios and allocate R&D projects with stronger internal dependence in weak IPR countries.

Second, MNEs are in a unique position to protect the internalized value arising from internal complementarities. With small imitation risk in the home country, having one project developed overseas brings little damage to the internalized value. Meanwhile, when the imitation risk in country *Y* is high, keeping the complementary components in the home country becomes critically important. Therefore, firms can actually leverage the home institutions for their operations overseas. The higher internalized value can also be considered higher leverage across countries.

III. EMPIRICAL DESIGN

The observations seem to be supportive of the internalization-arbitrage conjecture, but they are silent on how general the phenomenon is. In this step, I bring the idea to the U.S. patent data and construct empirical measures for the theoretical concepts.

3.1 Empirical Implications of Internalization-Arbitrage

The key insight that emerges from the qualitative analysis is the interaction between firms' internal organization and the external environments. This lends a natural framework to the empirical analysis.

First, I focus on firms that conduct R&D in weak IPR countries and examine the *strategies* they use: how do firms arbitrage? If firms strategically allocate their R&D projects in response to the external environment, as suggested by the theoretical analysis, then we should be able to observe systematic differences among technologies developed under different IPR regimes. Specifically, technologies developed in weak IPR countries should have stronger internal linkages, controlling for firm characteristics.

Second, I compare across all firms and examine firm *capabilities*: who is doing the arbitrage? Internalization-arbitrage is a viable strategy only for firms with strong organizational capabilities. Hence, we should be able to observe systematic differences between firms that do R&D in weak IPR countries and those that stay away. Specifically, firms who are able to do so should have tighter organization of their innovative activities, controlling for locations.

Before getting to the empirical tests, I need to (1) quantify the IPR regimes, (2) describe the data sources and the sample, and (3) construct variables from the sample data.

3.2 Weak IPR Countries

Arbitrage opportunities exist in a country that has a substantial reserve of human capital, yet suffers from weak IPR protection. Referring to the *World Development Indicators*, I exclude countries and areas that have under two million population, less than 1% of gross tertiary school enrollment rate, or less than five patents filed with U.S. Patent and Trademark Office (USPTO) in the 1990s.

Six indices are considered to proxy for the institutional environment for IPR. The first three apply to the general legal and political environment: the Law and Order index in the *ICRG Risk Rating System* (1997), the O-Factor in the *PricewaterhouseCoopers Opacity Survey* (2000), and the Property Protection index in the *Index of Economic Freedom* (1995). The second set of indices apply specifically to IPR protection: the Rapp and Rozek (1990) index, the Ginarte and Park (1997) index, and United States Trade Representative's Special 301 watch list and priority watch list (1999). I also supplement the indices with the Rule of Law index developed by Kaufmann, Kraay and Zoido-Lobatón (1999, 2002), and with the piracy index developed by the International Planning and Research (IPR). These indices turn out to be quite consistent. Whether I use each single index, or a composite index with various weights, I get a reasonably stable list of 34 countries with weak IPR protection. The countries and the corresponding indices are listed in Appendix A.

3.3 Patent Data

Despite the various criticisms of patent data, I choose to use the U.S. patent data for three reasons (in addition to Griliches 1990; Patel and Pavitt 1995). First, using patent data allows me to eliminate the localization/adaptation type of R&D specific to the host countries, and instead focus on overseas innovations that can bring value to the whole firm. Moreover, because patents are the output of R&D, they capture the projects that *fruitfully* utilize human capital in various countries. Second, patent citation is one of the most traceable evidences of knowledge flows (Jaffe et al. 2000). The systematic documentation of patent citations tracks the knowledge flows within and across the firms' global innovation networks. Finally, the detailed location information of patent inventors can help me identify the geographic distribution of talents utilized by the U.S. firms, as well as the collaboration among them.

I decide to focus on U.S.-headquartered firms in the empirical study. The reason is that I can obtain the most comprehensive data for U.S. firms, and at the same time avoid the potential administrative biases in cross-country comparisons. The sample period is from 1993 to 2001, and I study all the patents applied during this period (and granted up to August 2003). Information on patents granted between January 1993 and December 1999 is obtained from the NBER patent data (Hall et al. 2001). Patents granted between January 2000 and August 2003 are extracted from the Grant Red Book V2.5 bibliographic data of USPTO. Every field is closely examined to ensure consistency when the two datasets are merged.

Since patents may be assigned to parent companies or their subsidiaries for unobservable reasons, I study each multi-unit firm as an integrated strategic agent. The Directory of Corporate Affiliation (DCA) allows me to build family trees for each *firm* in my sample. An American firm in this study refers to an ultimate parent registered in the U.S., plus all its branches, subsidiaries and affiliates, home as well as abroad, that are owned by the same ultimate parent, directly or indirectly, by more than 10%. After aggregation, the number of firms in my sample is only half that of assignees.

3.4 The Sample

Industries vary widely in their propensity to patenting and the usefulness of patents as the measure of innovative activities (Cohen, Nelson and Walsh 2000). To reduce unrelated noises, I remove industries where patents are a very weak indicator of innovations (e.g., insurance), industries that are heavily influenced by public policies (e.g., utilities), industries that are mostly domestic (e.g., retailing), or industries whose geographic locations are dictated by some exogenous factors (e.g., mining). The main sample includes the following two-digit SIC industries: 28 (chemical), 29 (petroleum and coal products), 30-39 (manufacturing), 48 (communications), 73 (business services), and 87 (engineering and management services). I vary the industry selection in robustness checks and make sure that the findings do not depend on specific industries.

Compustat data are used to capture other firm characteristics, such as assets and sales. To avoid noise from small or instable firms, I drop companies with less than $0.1 million assets, as well as those that are traded for less than three years in the sample period.

The challenge in the data preparation is to match the records in the large datasets, where the only link among them is the company names. Matching is conducted year by year to accommodate possible organizational changes, which are not unusual during this period. An elaborate computer program was developed for this purpose, and all the results are manually checked. Ambiguous matches are further verified via Dun & Bradstreet Million Dollar Database, company websites and industry publications. The data cleaning procedure is illustrated in Appendix B. I drop those firms that do not have any patents during the entire sample period and those three-digit SIC industries that contain less than three innovating firms. After data cleaning, the main sample consists of 1,567 firms in 92 three-digit SIC industries, whose patent output during the nine-year period ranges from one to more than 20,000 (IBM), averaging at more than 100 per firm.

3.5 Location and Internal Linkages

Given my focus on human capital utilization, I want to be very careful with the locations of inventions. For each patent, I tracked the addresses of all the inventors, and calculated the percentage contribution from different countries. If more than half of the inventors are from weak IPR countries, then the patent is considered to have been developed in weak IPR countries. If more than half of the inventors are from the U.S., then it is considered to have been developed in the home country. The rest are patents developed in other (strong IPR) foreign countries. Accordingly, a firm is considered to have R&D in weak IPR countries if at least one of its patents is developed in those countries. The firm is considered to have foreign R&D if at least one of its patents is developed in a foreign country.

The 227,034 patents in the full sample are described in Table 1. The share of patents developed in weak IPR countries, small as it still is, has been steadily increasing over the last decade. Table 2 presents summary data for the 1,567 firms included in the sample.

There is no direct measure for the internalized value of technologies, but value can be proxied by usage. Technologies whose values are highly dependent on internal resources are more likely to be utilized within the firm. Since self-citations represent internalized knowledge transfers (Hall et al. 2001; 2003), I use self-citations to proxy for the internalized value of each technology. Presumably, the more a patent is cited by the same firm, the more its value is being retained inside the firm boundary. Because I am more interested in the firm as an integrated organization, any citations that occur among affiliated entities are considered self-citations.

Inevitably, my citation calculation is subject to the truncation problem in the time series. The patents filed in the 1993-2001 sample period had only received a fraction of the citations by the end of August 2003. However, I believe that this problem will not significantly affect my results, as patents in the same firm or industry tend to be affected similarly and I will certainly control for the between-group variations in my analysis. Even if there are significant within-group variations in citation lags, this measure is still consistent with my objective of capturing the efficiency in internal knowledge utilization: *speed* as well as *scale*. A self-citation ratio is high either because the technology is used more internally, or because the internal inventors are able to build on the technology faster, before the external citations take place.

IV. EMPIRICAL RESULTS

In this section, I seek empirical evidence of the internalization-arbitrage conjecture by analyzing the within- and across-firm variations in the technology structures.

4.1 The Econometric Model

Let N_k be the number of citations received by patent k, among which n_k are self-citations. As discussed previously, the self-citation ratio n_k/N_k, which proxies for internal linkages, depends on the external IPR environment as well as the internal firm characteristics.

Econometrically, I choose the zero-inflated negative binomial (ZINB) model to reflect three features of the data. First, most patents received only a small number of citations during the short sample period. Second, a negative binomial (NB) model is preferred to a simple Poisson model due to the large variance in the number of citations and self-citations received by each patent. Third, the frequent occurrence of zero self-citations may well arise from a different mechanism. Because many patents have yet to receive any citations by the end of the sample period, $n_k = 0$ does not necessarily mean a low level of internalization. It may simply be constrained by a small N_k. The Vuong statistic (Vuong 1989) for non-nested models shows large positive values (z = 12.49 and $pr > z$ = 0.000 in the baseline model) favoring the ZINB model versus the standard NB model.

In the first step, I focus on the 227 firms that conduct R&D in weak IPR countries and study the within-firm variations. The regression takes the following form:

Regime 1: $E(n_k) = N_k \cdot exp\ (\beta_0 + \beta_1 \cdot foreign + \beta_2 \cdot weak + \beta_3 \cdot i.firm + \Lambda_k)$

Regime 2: $E(n_k) = 0$

$Prob$ (Regime 1) = $exp\ (\gamma_0 + \gamma_1 \cdot N_k)/[1 + exp\ (\gamma_0 + \gamma_1 \cdot N_k)]$

Here *foreign* and *weak* are two dummy variables to indicate, respectively, whether the technology is developed in a foreign country and a weak IPR country. *i.firm* represents 226 dummy variables for firm fixed effects. The exposure variable N_k serves as the scope in which self-citations can be observed for each patent. Finally, Λ_k represents a list of control variables such as application years and patent classes. A cluster model is used to allow the possibility that the observations are independent across firms but not necessarily within firms.

The coefficient on the variable *foreign* is expected to be negative. Previous studies have shown that knowledge diffusion is geographically concentrated in nature (Almeida 1996, Jaffe and Trajtenberg 1998). Cross-country knowledge transfer is difficult even within the firm (Teece 1977). Therefore, I expect the foreign developed patents to be less intertwined with the parent company's knowledge base.

Meanwhile, I expect a positive coefficient on the variable *weak*. The purpose of R&D in weak IPR countries is to tap the underutilized human capital, and internalization is used as a barrier against imitation. Hence, the internal linkages would be stronger in countries with weak external institutions.

In the second step, I compare across all the firms in my sample and examine whether firms doing R&D in weak IPR countries manifest stronger internal linkages:

$$\text{Regime 1: } E(nk) = Nk \exp(\beta 0 + \beta 1 \cdot f\_foreign + \beta 2 \cdot f\_weak + \beta 3 \cdot foreign + \beta 4 \cdot weak + \Lambda k)$$

$$\text{Regime 2: } E(nk) = 0$$

$$\text{Prob (Regime 1)} = \exp(\gamma 0 + \gamma 1 \cdot Nk)/[1 + \exp(\gamma 0 + \gamma 1 \cdot Nk)]$$

Here *foreign* and *weak* are the same as defined in the within-firm analysis. *f_foreign* and *f_weak* are two dummy variables to indicate whether the firm that owns patent *k* has any patents developed in foreign countries and in weak IPR countries. Λ_k represents other control variables such as firm sizes and patent portfolios. Again, a cluster model is used to allow the possibility that the observations are not independent within firms.

According to the discussion in Sections II, firms need to have strong organizational capabilities to implement successful internalization across borders, even more so if they want to conduct R&D in weak IPR countries. Therefore, I expect positive coefficients on both *f_weak* and *f_foreign*.

The variables *weak* and *foreign* remain in the regression because locations significantly affect the degree of internalization. For example, a patent developed by IBM in Japan would probably have a lower self-citation ratio than a patent developed by Motorola in the U.S.. However, this comparison does not say much about the R&D organizations of IBM and Motorola. By controlling for the location effect, I am able to examine whether, among the technologies developed under similar environment, a firm's R&D presence in weak IPR countries is associated with stronger internal linkages among its technologies.

In both models, the marginal effect (economic significance) of the independent variables can be calculated as follows:

$$E(n_k) = N_k \exp(\boldsymbol{\beta}'\mathbf{x}) \;\Rightarrow\; \frac{\partial E(n_k)/N_k}{\partial x_i} = \frac{E(n_k)}{N_k} \cdot \beta_i$$

When the independent variables are dummy variables, the coefficients can be roughly interpreted as the percentage change in the self-citation ratio if the corresponding independent variable changes from 0 to 1.

4.2 Within Firms: Differentiated Project Assignment

In this step, I look into the 227 firms that conduct R&D in weak IPR countries, and compare the technologies they develop under different IPR regimes. Table 3 gives the average self-citation ratios for three groups of patents: those developed in weak IPR countries, those developed in strong IPR foreign countries and those developed in the home country (U.S.). As expected, the first group consistently shows higher self-citation ratios than the second, highlighting the effect of external environment. The increasing self-citation ratios over time simply reflect the fact that self-citations happen faster than citations across organizations, and this difference becomes more salient when the observation window gets narrower.

The regression results are shown in Table 4. Column (1) is the baseline model with 226 firm dummies and eight year-dummies to remove the time effect. Replacing the year-dummies with a trend variable generates similar results. In column (2), I only include firms that have more than 50 patents over the nine-year period. Since the theoretical conjecture is on firms' internal complementarities, firms above certain R&D scales should be the more appropriate group to study. Statistics show that over half of the citations by US patents are imposed by examiners, rather than voluntarily filed in patent applications (Alcacer and Gittelman 2003). It would be far-fetched to interpret the examiner-imposed citations as knowledge flows. In column (3), I conduct the test using only voluntary citations made by post-2000 patents.[1] In Column (4), I control for patent classes to test whether the difference in internal linkages are driven purely by the distribution of technology fields across countries. Column (5) reports the results for Computers and Communications,[2] an industry I conducted most of my interviews in. Separate tests are also conducted in other technology categories.

Throughout the specifications the coefficient on the *foreign* dummy is significantly negative, which confirms the distance effect. Within the same firm, foreign developed

[1] The distinction between inventor-filed and examiner-imposed citations is available only for patents granted after 2000.

[2] As defined in Hall et al. (2001), this category covers 35 primary patent classes spanning communications, computer hardware & software, computer peripherals, and information storage.

patents are 20-30% less likely to be cited by the same firm, compared with those developed in the home country. The difference is even larger in the computer industry. However, the positive coefficient on the *weak* dummy nearly offsets all the negative distance effect. This is not trivial if we believe that the weak IPR countries are even further away from the home country in terms of culture, institutions and technological development. The net effect of *weak* and *foreign* indicates that technologies developed in weak IPR countries are intertwined in the firms' internal knowledge base as if they were right at U.S. headquarters!

4.3 Across Firms: Organizational Structure

In this step, I compare across firms and examine firm capabilities. Do firms that conduct R&D in weak IPR countries differ systematically from others regarding their knowledge organization? Table 5 gives the average self-citation ratios for three groups of firms: those with positive patent output in weak IPR countries, those with positive patent output in foreign – but not weak IPR – countries, and those whose R&D is in the home country (U.S.) only. Statistics for large R&D firms are also shown in the table. Consistently, firms with R&D in weak IPR countries show much higher self-citation ratios.

The regression results are shown in Table 6. Column (1) is the baseline model on the full sample, with fixed year effect. Column (2) constrains the sample to firms with more than 50 patents during the nine-year period. Same as in the within-firm analysis, column (3) removes examiner-imposed citations and limits the sample to voluntary citations received after January 2000. Patent classes are controlled for in Column (4). Column (5) gives the results for the field of Computer and Telecommunications.

Across all specifications, the coefficients on *f_weak* and *f_foreign* are positive and significant. The results show that firms who are able to conduct R&D overseas generally have more internalized technology structures compared with purely domestic firms. In addition, among firms with foreign R&D, those who are able to do R&D in weak IPR countries manifest even stronger internal linkages. Since location effects are controlled for throughout the analysis, the results are not driven by the geographic distribution of firms' patent portfolios.

Arguably, firms with R&D in weak IPR countries have proportionally more self-citations simply because they are larger firms. I would like to examine more closely whether the degree of internalization is fully explained by firm size. In Table 7, I report the regression results controlling for assets (1), sales (2), and the total number of patents owned by the firm (3). The coefficients on *f_weak* and *f_foreign* remain positive and significant, although a large patent pool does offer some explanation power to the high degree of self-citations. Similar results are obtained when I use the logarithms of these variables. Therefore, the data provide supportive evidence that firms with R&D in weak IPR countries feature stronger internal linkages, even after controlling for firm sizes.

V. CONCLUSION AND DISCUSSION

Doing R&D in countries with weak IPR protection appears to contradict the comparative advantage theory. With poor institutional environment, these countries are not known for their R&D or technology strengths. This study is an attempt to address the puzzle.

The interviews, the theoretical analysis, and the empirical evidence consistently point to one potential explanation: MNEs may be substituting their internal innovation organizations for the external environment. Thus, firms with closely-knit internal knowledge structures are able to take advantage of the underutilized human capital in weak IPR countries without exposing themselves to too much risk.

This adds to our understanding of a fundamental question in international strategy. Traditional views focus on firm-specific assets (intangibles, etc.) or location-specific endowment (natural resource, etc.) as the driving forces of internationalization. More recently, Ghemawat (2003) advocates that the foundation for international strategy should be built on the arbitraging of international differences, strategies made possible by internal firm capabilities. This study is a direct illustration of this point: institutional gaps across countries can be an important source of arbitrage opportunities. The study also reveals the internal capabilities required to take advantage of the opportunities. Just as globalization is not for everybody, neither is setting up R&D centers in China or India. To benefit from R&D internationalization, a firm's internal infrastructure matters.

Meanwhile, the analysis has important implications to the local firms in weak IPR countries. To survive the adverse institutional environment, and to compete effectively with MNEs, the local firms have the alternative of expanding beyond national boundaries and leveraging foreign institutions for value appropriation. In fact, we have already seen this possibility in a few high-tech firms from the emerging economies, although the organizational costs are still intimidating for most of them.

While identifying the potential opportunities in the adverse environments, I am by no means indicating that poor IPR protection is good either for firms or for the economy. In face of weak legal institutions, firms have to strategically internalize their knowledge-intensive activities, and only a small number of firms are able to do so. In other words, internalization-arbitrage is a strategic choice under the constraint of poor external environment. Removing this constraint is expected to improve both the channel and the direction of knowledge flows. For example, MNEs would feel more comfortable transferring technologies that are more readily applicable to the host countries. Indeed, Branstetter et al. (2002) show that U.S. MNEs responded to IPR reforms in the host countries with more technology transfers to the subsidiaries.

This paper also opens a whole line of further research.

First, the essential message in this study is that sustainable advantage does not come from the most favorable environment, but from the right interaction between firm capabilities and external idiosyncrasies. Since the external environment varies along many dimensions such as competition, technology changes and government regulations, there are many interesting questions worth exploring. For example, do firms conduct a specific subset of R&D at technology clusters, where they face close interaction with competitors? What is the relationship between this subset and the technologies they develop elsewhere? How does this relationship affect firms' location choices?

Second, efficient coordination is shown to be a crucial condition for synergy. Several alternative measures have been developed in this study to proxy for firms' internal coordination. In the next step, I would like to examine the effect of coordination efficiency on firms' diversification behaviors, the benefit from diversification, and their overall performance.

Finally, the arbitrage-internalization mechanism should not be limited to innovation only. Similar arguments can also be found in the mainstream internalization theories (Buckley and Casson 1976) and in the line of work on "business groups" (Khanna 2000). While the intangibility of knowledge makes R&D the ideal field for institutional arbitrage, we have reason to believe that the mechanism applies to other fields too. A study with a broader view would surely deepen our understanding of firms and institutions.

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TABLES

Table 1. Description of the Sample Patents

Year	Patents developed in weak IPR countries		Patents developed in all foreign countries		Total number of patents
	Number	Percentage	Number	Percentage	
1993	118	0.60%	2,070	10.53%	19,652
1994	209	0.98%	2,219	10.41%	21,313
1995	244	0.81%	3,259	13.50%	24,143
1996	277	0.95%	3.039	11.48%	26,474
1997	385	1.12%	3,406	9.91%	34,357
1998	386	1.22%	3,203	10.10%	31,708
1999	505	1.70%	3,332	11.21%	29,716
2000	437	1.79%	2,982	12.20%	24,434
2001	267	1.75%	1,820	11.94%	15,238
Total	**2,828**	**1.20%**	**25,330**	**11.16%**	**227,034**

Table 2. Description of the Sample Firms

Variables	Firms that do R&D		All firms (1567 obs)
	in weak IPR countries (227 obs)	in any foreign countries (681 obs)	
Assets (million dollars)	10,414.65	4,981.98	2,687.09
Sales (million dollars)	8,088.27	3,813.81	1,931.97
Number of patents[1]	750.14	298.60	137.61
Number of subsidiaries[1]	45.69	31.99	19.36
Number of assignees[1]	4.98	3.34	2.27
Countries with presence[1]	13.56	8.92	4.55
H-index for tech class[2]	0.08	0.12	0.28

[1] count per firm

[2] concentration of technology field, calculated as a Herfindahl index of the firm's patents across patent classes. Smaller numbers indicate more technology diversification.

Table 3. Self-Citation Ratios of Patents Developed under Different Environments

Year	Patents developed in weak IPR countries		Patents developed in other foreign countries		Patents developed in the home country	
	mean	s.d.	mean	s.d.	mean	s.d.
1993	0.124	0.183	0.123	0.250	0.166	0.257
1994	0.145	0.241	0.141	0.254	0.171	0.263
1995	0.170	0.257	0.120	0.247	0.175	0.274
1996	0.177	0.289	0.158	0.283	0.187	0.294
1997	0.175	0.295	0.153	0.288	0.206	0.318
1998	0.195	0.319	0.191	0.339	0.237	0.357
1999	0.242	0.385	0.241	0.389	0.279	0.392
2000	0.352	0.462	0.264	0.409	0.332	0.435
2001	0.556	0.498	0.458	0.502	0.391	0.463
Average	**0.191**	0.308	**0.161**	0.296	**0.205**	0.317

Table 4. Zero-inflated Negative Binomial Regression on Within-Firm Difference

	The Full Sample (1)	Firms with >50 patents (2)	Voluntary citations (3)	Control for patent class (4)	Computer & Telecom (5)
Foreign country	-0.2838*** (0.0476)	-0.2849*** (0.0477)	-0.2248*** (0.0397)	-0.2832*** (0.0424)	-0.4496*** (0.0503)
Weak IPR country	**0.2055****** **(0.0703)**	**0.2033****** **(0.0707)**	**0.2128****** **(0.0865)**	**0.2207****** **(0.0723)**	**0.3941****** **(0.1059)**
Constant	-1.6743*** (0.2069)	-1.6755*** (0.2068)	-1.9263*** (0.1803)	-1.4925* (0.7644)	-1.6564** (0.9354)
Total citation	- exposure				
Inflate					
Total citation	0.0118*** (0.0029)	0.0118*** (0.0028)	0.0883*** (0.0107)	0.0137*** (0.0027)	0.0178*** (0.0052)
Constant	-2.4389*** (0.2678)	-2.4405*** (0.2678)	-2.9442*** (0.2682)	-2.4975*** (0.2630)	-3.2100*** (0.2711)
Obs	125,796	125,036	95,302	117,120	42,801
log_likelihood	-153,479.80	-153,106.10	-66,659.79	-147, 920.87	-52,536.13

*** significant at 1% level ** significant at 5% level * significant at 10% level

Numbers in parentheses ( ) are robust standard errors adjusted for clustering.

Table 5. Self-Citation Ratios of Patents Developed by Different Firms

Year	Firms with positive patent output in the 10-year period			Firms with >50 patents in the 10-year period	
	w/ R&D in weak IPR countries	w/ R&D in other foreign countries	w/o any foreign R&D	w/ R&D in weak IPR countries	w/o R&D in weak IPR countries
1993	0.175	0.129	0.083	0.180	0.129
1994	0.180	0.130	0.076	0.185	0.109
1995	0.163	0.117	0.070	0.167	0.134
1996	0.195	0.109	0.078	0.201	0.105
1997	0.219	0.140	0.101	0.226	0.164
1998	0.249	0.179	0.166	0.254	0.185
1999	0.294	0.216	0.212	0.299	0.281
2000	0.340	0.251	0.365	0.347	0.273
2001	0.410	0.315	0.396	0.408	0.348
Average	**0.211**	**0.144**	**0.125**	**0.216**	**0.153**

Table 6. Zero-inflated Negative Binomial Regression on Cross-Firm Difference

	The Full Sample (1)	Firms with >50 patents (2)	Voluntary Citations (3)	Control for patent class (4)	Computer & Telecom (5)
Firms w/ R&D in foreign	0.3196** (0.1322)	-0.0963 (0.1946)	0.1016 (0.1677)	0.3112** (0.1212)	0.7188*** (0.2262)
Firm w/ R&D in weak IPR	**0.3950*** (0.1122)**	**0.3453*** (0.1168)**	**0.5337*** (0.1169)**	**0.3239*** (0.0812)**	**0.5256*** (0.1427)**
Developed in foreign	-0.3811*** (0.1526)	-0.3743** (0.1560)	-0.2753* (0.1453)	-0.4605*** (0.1118)	-0.6570** (0.2195)
Developed in weak IPR	0.0390 (0.1982)	0.0578 (0.2020)	0.0573 (0.2166)	0.2002 (0.1307)	0.4846 (0.3003)
Constant	-2.2573*** (0.1187)	-1.7852*** (0.1842)	-2.8044*** (0.3114)	-2.5436*** (0.5478)	-3.0136*** (0.2133)
Total citation	- exposure				
inflate					
Total citation	0.0102*** (0.0037)	0.0095*** (0.0039)	0.0830* (0.0045)	0.0097*** (0.0039)	0.0145*** (0.0032)
Constant	-2.0344*** (0.1977)	-2.0438*** (0.2057)	-1.9950 (1.3005)	-1.9433*** (0.2363)	-2.7041*** (0.2400)
Obs	153,950	146,018	116,138	153,950	49,733
log_likelihood	-191,527.2	-185,673.7	-83,201.8	-186,562.4	-62,134.3

*** significant at 1% level ** significant at 5% level * significant at 10% level

Numbers in parentheses ( ) are robust standard errors adjusted for clustering.

Table 7. Cross-Firm Regression with Size Effect

	Control for Assets (1)	Control for Sales (2)	Control for Patent Output (3)
Assets ($bn)	-0.0020*** (0.0010)		
Sales ($bn)		-0.0024* (0.0018)	
Patent Output (thousand)			0.0170* (0.0093)
Firms w/ R&D in weak IPR	**0.4761*** (0.1364)**	**0.4788*** (0.1474)**	**0.3018** (0.1343)**
Firms w/ R&D in foreign	0.3415*** (0.1657)	0.3422*** (0.1656)	0.2625** (0.1641)
Developed in weak IPR	0.0340 (0.1664)	0.0410 (0.1480)	0.0783 (0.2070)
Developed in foreign	-0.3655*** (0.1763)	-0.3686** (0.1745)	-0.4048** (0.1761)
Constant	-2.2574*** (0.1506)	-2.2638*** (0.1512)	-2.1047*** (0.1429)
Total citation	- exposure		
inflate			
Total citation	0.0089** (0.0047)	0.0088** (0.0048)	0.0138*** (0.0032)
Constant	-2.1412*** (0.3043)	-2.1321*** (0.3181)	-2.2353*** (0.2764)
Obs	126,636	126,636	153,950
log_likelihood	-160,355.50	-160,369.40	-192,347.00

*** significant at 1% level ** significant at 5% level * significant at 10% level

Numbers in parentheses ( ) are robust standard errors adjusted for clustering.

Table 8. Within- and Cross-Firm Regression with Stable Firm Affiliations

	Within-firm (1)		Across-firm (2)	
Firms w/ R&D in weak IPR			**0.4309*****	**(0.1356)**
Firms w/ R&D in foreign			0.3115**	(0.1776)
Developed in weak IPR	**0.2543*****	**(0.0831)**	0.0826	(0.2324)
Developed in foreign	-0.3034***	(0.1019)	-0.4131**	(0.1830)
Constant	-1.6456***	(0.1933)	-2.2466***	(0.1548)
Total citation	- exposure			
inflate				
Total citation	0.0105***	(0.0039)	0.0095***	(0.0038)
Constant	-2.5555***	(0.1899)	-2.1863***	(0.2452)
Obs	106,365		129,614	
log_likelihood	-130,730.00		-162,695.30	

*** significant at 1% level ** significant at 5% level * significant at 10% level

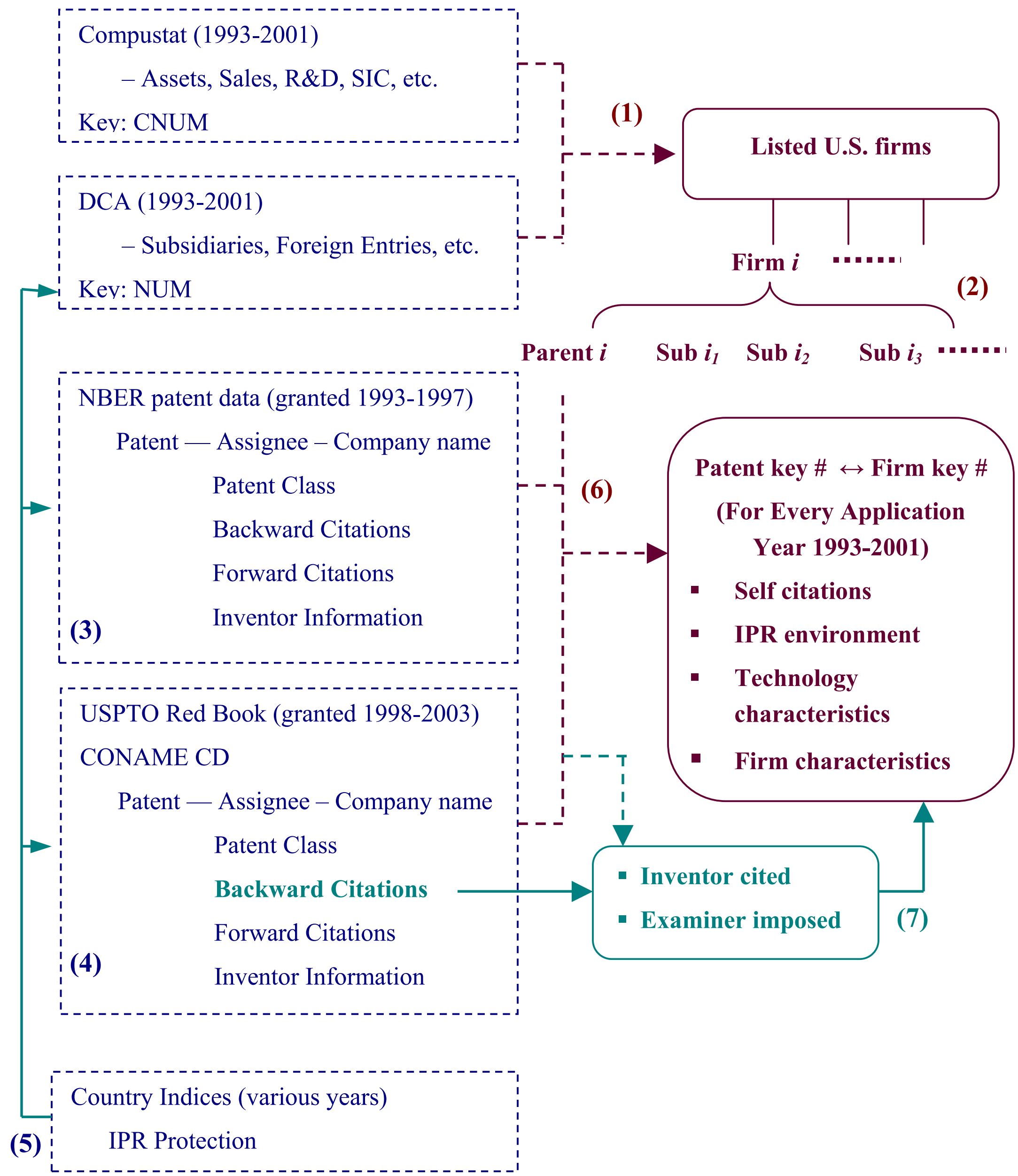
Numbers in parentheses ( ) are robust standard errors adjusted for clustering.

APPENDIX A. Countries with Weak IPR Protections

	Scientist &Engineers /mn people	Population (mn)	Tertiary School (gross %)	Opacity Factor 2000	Property Rights 1995	Law & Order 93-95	Rapp & Rozek	Ginarte & Park 1990	Special 301* 1999	KKZ Index 1998	Piracy Rate 2000
Argentina	711	35.22	41.80	60.60	2	4.58	1	2.26	1.5	0.24	58
Belarus	2,296	10.30	44.00		3				1.0	-1.08	
Brazil	168	161.52	11.70	60.85	3	3.25	1	1.85	1.0	-0.09	58
Bulgaria	1,289	8.36	41.20		3					-0.22	
Chile	370	14.42	30.30	35.65	1	4.58	2	2.41	1.0	1.26	49
China	459	1,215.30	5.70	87.16	4		1		2.0	-0.22	94
Costa Rica	533	3.40	33.10		3		3	1.47	1.0	0.88	
Czech Rep.	1,317	10.32	22.70	70.81	2				1.0	0.62	43
Egypt	493	59.27	22.60	57.97	4	3.61	2	1.99	1.5	0.17	
Greece	1,045	10.48	42.80	57.38	2	5.56	4	2.32	1.5	0.66	66
HKSAR, China	93	6.32	28.00	44.68	1	5.36		2.57		1.73	57
Hungary	1,249	10.19	25.10	50.07	2				1.0	0.78	51
India	158	945.78	6.90	63.74	3	3.83	1	1.48	1.5	0.21	63
Indonesia	..	197.18	11.30	75.16	3	4.22	0	0.33	1.5	-0.97	89
Israel	1,570	5.69	43.60	52.71	2	5.00	5	3.57	1.5	1.09	41
Korea, Rep.	2,139	45.51	60.30	73.46	1	5.00	3	3.94	1.0	0.82	56
Lithuania	2,031	3.71	31.40	58.45						0.19	
Malaysia	154	21.14	11.40		2	4.61	3	2.37		0.82	66
Mexico	213	92.71	16.10	47.64	2	3.00		1.63	1.0	-0.38	56
Pakistan	78	125.42	3.40	61.96	2	2.64		1.99	1.0	-0.71	
Peru	229	23.95	31.10	57.63	3	2.83	1	1.02	1.5	-0.44	61
Philippines	156	71.90	35.20		3	3.78	4	2.67	1.0	-0.04	61
Poland	1,460	38.62	24.30	63.93	3				1.0	0.57	54
Portugal	1,583	9.93	38.00		2	5.42	3	1.98		1.31	42
Romania	1,393	22.61	22.50	71.42	4				1.0	-0.25	
Russia	3,397	147.73	41.40	83.59	3				1.5	-0.78	88
Slovak Rep.	1,706	5.35	22.10		2					0.13	
South Africa	992	39.90	18.80	59.54	3	3.33	5	3.57	1.0	0.21	45
Spain	1,562	39.27	51.10		2	6.00	4	2.95	1.0	1.35	51
Taiwan, China	660	21.42	18.71	60.64	1	5.00			1.0	1.17	53
Thailand	102	60.00	20.90	66.95	1	5.00	1	1.85	1.0	0.40	79
Turkey	303	61.45	18.20	74.07	2	4.17	1	1.80	1.5	0.19	63
Ukraine	2,121	51.11	41.50		4				1.5	-0.76	
Venezuela	194	22.31	25.40	63.45	3	4.00	2	1.35	1.0	-0.62	58
United States	4,103	265.23	80.60	35.53	1	6.00	.	4.52	.	1.77	26

* The countries with a "1" are countries on the watch list, those with a "1.5" are on the priority watch list, and those with a "2.0" are section 306 monitoring countries.

APPENDIX B. Illustration of Data Sources



Notes:

- Dotted rectangular: data sources
- Rounded rectangular: processed datasets
- Dashed lines: data matching
- Solid lines: information reference

Steps:

(1) Match Compustat with DCA data, year by year, according to company names.

(2) For each matched firm, extract all the family members from DCA.

(3) Prepare data for patents applied on or after 1993, and granted between 1993 and 1997, using the NBER dataset.

(4) Prepare data for patents applied on or after 1993, and granted between 1998 and August 2003, using the USPTO data. Assignee names are modified according to the USPTO company name files.

(5) Country indices are used to describe the countries of the inventors.

(6) Patent assignee names are matched with all the company names –parents as well as subsidiaries and other family members –in the Compustat-DCA company list. Thus, every patent (with relevant information) is corresponding to a firm (with relevant information). Inventor locations are used to determine the IPR environment in which the technology is developed. Self-citations are used to proxy for internal linkages.

(7) Among the self-citations from (6), count the number of self-citations imposed by the examiner. Exclude those citations in the robustness check.