DO STRONGER INTELLECTUAL PROPERTY RIGHTS INCREASE INTERNATIONAL TECHNOLOGY TRANSFER? EMPIRICAL EVIDENCE FROM U. S. FIRM-LEVEL PANEL DATA*

LEE G. BRANSTETTER
RAYMOND FISMAN
C. FRITZ FOLEY

This paper examines how technology transfer within U. S. multinational firms changes in response to a series of IPR reforms undertaken by sixteen countries over the 1982–1999 period. Analysis of detailed firm-level data reveals that royalty payments for technology transferred to affiliates increase at the time of reforms, as do affiliate R&D expenditures and total levels of foreign patent applications. Increases in royalty payments and R&D expenditures are concentrated among affiliates of parent companies that use U. S. patents extensively prior to reform and are therefore expected to value IPR reform most. For this set of affiliates, increases in royalty payments exceed 30 percent.

I. INTRODUCTION

Over the past twenty years, there has been a global trend toward stronger intellectual property rights (IPR).[1] By the mid-1990s, a minimum standard set of globally enforced intellectual property rights had been enshrined in the WTO Charter through

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1. Maskus [2000] provides an extremely useful summary of this policy history.

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the incorporation of the Agreement on Trade-Related Aspects of Intellectual Property Rights. The shift in international economic policy-making from its traditional postwar focus on the lowering of tariff and nontariff trade barriers to the embrace of strong IPR is deeply controversial. Lanjouw [1997] and McCalman [2001], among others, have argued that the move toward stronger IPR in developing countries may work against national economic interests, transferring rents to multinational corporate patent holders headquartered in the world's most advanced countries, especially the United States. IPR advocates counter that strengthening IPR will induce more innovation in the global economy, thereby fostering more rapid economic growth.[2] Furthermore, these advocates claim that even if the additional innovation is mostly concentrated in advanced countries, a strengthening of IPR will accelerate the transfer of technology between countries, ensuring that all countries benefit.

In this paper we attempt to assess this latter claim. We use affiliate-level data on U. S. multinational firms and aggregate patent data to test whether legal reforms that strengthen IPR increase the transfer of technology to multinational affiliates operating in reforming countries. Throughout the 1980s and 1990s a number of countries undertook substantial reforms of their patent systems. We find that royalty payments for the use or sale of intangible assets made by affiliates to parent firms, which reflect the value of technology transfer, increase in the wake of strengthened patent regimes. This increase is concentrated among the affiliates of firms that make extensive use of U. S. patents prior to reform and is more than 30 percent for this subsample.

The interpretation that IPR reform results in an increase in technology transfer among U. S. multinationals is strengthened by the fact that R&D spending by affiliates—usually viewed as a complement to technology imports from the parent—increases after IPR reform. Both the level and growth rate of nonresident patenting also increase in the postreform period, and these changes provide additional indications that at least one component of the observable increase in licensing flows is associated with the introduction of new technology following patent reform.

2. Theoretical work by Helpman [1993], Lai [1998], Glass and Saggi [2002], and Grossman and Lai [2005] demonstrates that this may not occur. The ultimate impact of stronger IPR on the global rate of innovation depends very much on how multinational firms respond to it.

Consistent with earlier work, we find no corresponding reaction in resident patent filings. Collectively, our results provide evidence that improvements in IPR result in real increases in technology transfer within multinational enterprises.

Existing empirical work that analyzes the impact of IPR reforms has a number of shortcomings. Many studies consider reactions to specific changes in the IPR regime of a single country, which raises concerns about whether their results generalize. In addition, these studies focus on the impact of stronger IPR on domestic innovation, omitting analysis of technology transfer.[3] Lerner [2002a, 2002b] analyzes changes in patenting activity of foreign and domestic issuers following patent reforms in 60 countries over a 150-year period. He finds an increase in patenting activity among foreigners, which is suggestive of increased technology transfer, but he does not directly examine technology transfer, nor does he study the heterogeneity of responses across firms.

Other empirical work has tried to identify the effects of IPR reform by analyzing the cross-sectional relationship between IPR and measures of international trade and investment at the country level, finding a strong positive effect of IPR on trade, but a less clear effect of IPR on FDI.[4] This work suffers from the usual problems that affect cross-country regressions. The measures of IPR utilized do not generally take into account the effectiveness of enforcement, they are highly correlated with other important country characteristics, and they have limited time-series variation. Since FDI data are typically not disaggregated, even by industry, it has also not been possible to look at the impact of IPR reform on the composition of multinational activity.[5] Further-

3. Evidence on the impact of stronger IPR on domestic innovation is mixed. Scherer and Weisburst [1995], Bessen and Maskin [2000], Sakakibara and Branstetter [2001], and Lerner [2002a, 2002b] find no positive impact, while Kanwar and Evenson [2001] and Chen and Puttitanum [2005] do find such an effect.

4. For example, Maskus and Penubarti [1995] found a strong positive effect of IPR on imports, and Smith [1999, 2001] reports results that are consistent with a role for IPR in encouraging U. S. exports. In looking at the effect of IPR on FDI, Maskus and Eby-Konan [1994] find no effect; Maskus [1998], however, points out that studies that consider FDI in isolation may not be conclusive because investment is only one part of the broader set of decisions that a multinational firm makes in entering a market. He reports regressions that are consistent with a positive effect of IPR on FDI, but only for more developed countries. Yang and Maskus [2001] examine the impact of IPR on technology licensing.

5. One recent exception is Javorcik [2004], who examines the composition of FDI in Eastern Europe in the 1990s and relates this composition to differences across countries in IPR regimes. Because this study focuses on a small number of countries in a single region of the developing world, natural questions arise about the extent to which these findings can be generalized outside the regional context.

more, much of this literature addresses the crucial issue of the impact on technology transfer only indirectly, if at all.[6]

In our examination of the impact of stronger IPR on international technology transfer within multinational firms, we are able to bring to bear considerably richer data than have been used by prior researchers. Firm and affiliate-level data for multinationals operating in multiple countries allow us to deal more effectively with issues of causality and identification. As a consequence, we are able to offer the strongest evidence to date for the proposition that stronger IPR enhances at least one kind of international technology transfer.

The rest of this paper is structured as follows: Section II puts forth the hypotheses we test and our empirical specifications. Section III describes the data, and Section IV discusses the results. Section V concludes with a brief explanation of the implications of our results for the ongoing international policy debate as well as the economics literature.

II. Intellectual Property Rights and Technology Transfer

One of the potential benefits of strengthening intellectual property rights is that such protections may induce foreign firms to produce and sell technologically advanced goods in the reforming country. Surveys of multinational managers suggest that technology transfer within multinational firms is sensitive to the perceived strength of IPR protection.[7] When a firm transfers sensitive technology to an affiliate, it generally has to instruct local engineers and other local skilled workers concerning key elements of its technology. Some of these elements may have been deliberately withheld from the firm's patents, in the United States and in the foreign country, in order to prevent other parties from being able to copy its technology simply by reading its patents. When it transfers this knowledge to local employees,

6. Much of the recent literature on international technology diffusion, reviewed in Keller [2004], ignores the potential impact of changes in intellectual property rights on knowledge spillovers.

7. We note, among other studies, the survey research of Lee and Mansfield [1996] in which a large sample of U. S. multinationals identified countries to which they would not transfer their latest, most useful technologies, even if the transfer was done within the firm. In the same study, managers made it clear that they generally sought to avoid the transfer of strategically sensitive technology to unaffiliated parties, regardless of the perceived strength of the IPR regime. The reluctance to license strategically sensitive technology outside the firm has been confirmed in our own conversations with multinational managers.

there is a risk that these employees will defect to a local manufacturer, taking sensitive technology with them. These employees are able to combine the patented and unpatented elements of the firms' technology, effectively competing with it in the local market.[8]

In a weak IPR environment the multinational firm has little recourse. In the context of a stronger IPR environment with good patent protection, the firm can prevent the infringing firm from using the patented components of its technology. In addition, a number of the patent reforms examined below explicitly included new protection of trade secrets or strengthened existing protection.

Basic intuition suggests that if IPR regime shifts have a material impact on true intellectual property protection, then there should be an increase in the value of technology flows from parents to affiliates following regime changes. It is possible to test for this effect using regressions of the form,

$$(1)\quad Transfer_{ilt} = \alpha_0 + \alpha_{il} + \alpha_t + \beta_0 y_{jt} + \beta_1 P_{it} + \beta_2 H_{jt} + \beta_3 A_{ilt} + \beta_4 R_{jt} + \beta_5 R_{jt} * Pat_{il} + \varepsilon_{ilt},$$

where l indexes the individual affiliate, i the affiliate's parent firm, j the affiliate's host country, and t the year. The dependent variable measures the volume of intrafirm royalty payments for intangible assets—our proxy for technology transfer. The key variable of interest is R_{jt}, the postreform dummy variable, equal to one in the year of and years following patent reform in country j. The specification contains a number of controls including time-invariant fixed effects for the parent-affiliate pair (α_{il}), year fixed effects for the entire sample (α_t), and a vector of country-specific time trends (y_{jt}).[9] P_{it}, H_{jt}, and A_{ilt} are vectors of time-varying

8. There are many anecdotes that illustrate this point. For example, in late 2003 the world's leading contract semiconductor manufacturing firm, Taiwan Semiconductor Manufacturing Co. (TSMC), charged mainland Chinese rival Semiconductor Manufacturing International Corp. (SMIC) with theft of its intellectual property. According to public statements by TSMC representatives, SMIC hired away more than one hundred TSMC employees, who brought with them valuable trade secrets. SMIC was later sued for infringing multiple TSMC patents. Conversations with parties familiar with this lawsuit confirmed that TSMC had not transferred its most advanced technology to its mainland Chinese operations, in anticipation of the possibility of such an outcome.

9. The parent-affiliate pair fixed effect is generally indistinguishable from an affiliate fixed effect, except in the few cases where an affiliate moved from one parent system to another through mergers or acquisitions. Because an affiliate that has undergone such a move has access to a different portfolio of technologies, we treat it as a different entity.

parent, host country, and affiliate characteristics, respectively. P_{it} includes measures of parent firm sales and R&D investment. H_{jt} includes measures of income per capita, trade and FDI openness, corporate income tax rates, and withholding tax rates.

If any observed increase in the value of technology flows from parent firms to affiliates results from improved IPR protection (and not, for example, from correlated reforms), the effect should be largest for firms that value patent protection the most. In order to study the differential effects of patent reforms across firms, affiliates are split into two groups according to the extent to which their parents use U. S. patents prior to the reform. Affiliates of parents that, over the four years prior to a particular reform, average at least as many U. S. patent applications as the parent of the median affiliate in the reforming country over the same period are assigned a high patent use dummy, Pat_{il}, equal to one. For other affiliates that have parents that can be matched to the NBER patent database, Pat_{il} equals zero.[10] This dummy variable is interacted with the postreform dummy variable to assess the differential effect of reform on the affiliates of high patent parents.

Changes in the value of licensing payments could reflect changes in the volume of technology transferred or merely changes in the price charged for that technology. Analyzing changes in the R&D expenditures of affiliates is helpful in distinguishing between these two possibilities. There is a considerable body of work that details the relationship between affiliate and parent-firm R&D.[11] U. S.-based multinationals do undertake some basic and applied research abroad. However, this is concentrated in only the most advanced countries where the local scientific and engineering community is highly accomplished and the infrastructure for frontier research is well-developed. R&D conducted by affiliates in less developed countries, which account for almost all of the countries in our sample, is focused on the absorption of parent firm technology and on its modification for local markets.[12] The literature review presented in Kuemmerle

10. Alternative ways of specifying Pat_{il} yield similar results. A four-year window is used in these calculations because the sample begins in 1982 and the first reform occurs in 1986.

11. For an early study on this topic, see Mansfield, Teece, and Romeo [1979]. Kuemmerle [1999] provides a survey of the literature as of 1999.

12. Our patent data allow us to identify where inventions for which U. S. patent protection is sought were generated. We can thus get a rough sense of the extent to which R&D in affiliates based in our sample of countries was devoted to

[1999] lists a number of studies that provide evidence that the co-location of R&D with foreign manufacturing facilitates the "transfer of knowledge and prototypes from the firm's home location to actual manufacturing." Affiliate R&D and technology transfer from the parent may thus be considered complements, so that IPR reform should also generate an increase in R&D spending. To test whether this is the case, we use variations of specification (1) that employ measures of the level of R&D spending conducted by individual affiliates as dependent variables.

If multinationals do change the volume of technology transferred in a sustained manner and if these changes are a consequence of stronger IPR, then this should also be reflected in the data on foreign patenting in reforming countries.[13] A foreign multinational has little incentive to incur the costs of preparing and filing patent applications in a country where patent law or enforcement is weak—and firms anticipate this. After IPR reform, multinationals may have an incentive to file patents primarily for the technologies already employed in the country. This would imply that reform would only generate a temporary increase in foreign patent filing that falls off as firms completed protecting the portfolio of technologies used prior to reform. However, if reforms induce multinationals to transfer new technologies into the country on an ongoing basis, both the level and growth rate of foreign patenting should increase after reform. Specifications that test these predictions take the form,

$$(2) \qquad Patent_{jt} = \alpha_0 + \alpha_j + \alpha_t + \beta_0 y_{jt} + \beta_1 H_{jt} + \beta_2 R_{jt} + \beta_3 R_{jt} * T_{jt} + \varepsilon_{jt}.$$

The dependent variable measures the number of patents filed by domestic or foreign applicants in country j in year t. We estimate (2) separately for domestic and foreign patenting in the countries that underwent IPR reform. Patent applications in year t are a function of country (α_j) and year (α_t) fixed effects, a vector of

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modification of existing products (which would produce few patents) as opposed to research designed to advance the technological frontier (which would produce many patents). We find that the ratio of R&D spending to U. S. patents produced for foreign affiliates in countries other than Japan (a highly advanced country) is 8.4 times higher than the ratio for the domestic R&D operations of the parent firm. This strongly suggests that the nature of R&D at home and abroad is qualitatively very different and confirms that the characterization of affiliate R&D activity in the literature holds for our sample firms. We also note that our results on affiliate R&D are robust to dropping Japan from the sample of reforming countries.

13. In an influential paper, Eaton and Kortum [1996] use international patenting data to measure international technology transfer.

country-specific time trends (y_{jt}), as well as host country characteristics (H_{jt}). This specification yields estimates of the effect of reform on both the level of patenting and its growth rate, which is captured by the coefficient on the interaction term of the reform dummy and a time trend that is equal to the number of years that have passed relative to the reform year (T_{jt}).

III. Data Sources

III.A. Data from BEA Surveys

Annual data on U. S. multinational firms over the 1982–1999 period come from the U. S. Bureau of Economic Analysis (BEA) Survey of U. S. Direct Investment Abroad and the Balance of Payments Survey.[14] In addition to reporting extensive information on measures of parent and affiliate operating activity including R&D expenditures, multinationals must also report the value of royalties paid by affiliates to parents for the sale or use of intangible property. Royalty payments are reported at the affiliate level, and they include payment for industrial products and processes, which capture technology licensing fees, as well as franchise fees, fees for the use of trademarks, and payments for other intangibles. In 1989 the BEA collected data on technology licensing fees specifically. In that year the value of technology licensing fees accounted for more than 88 percent of total royalty payments, indicating that it is appropriate to use aggregate royalty payments as a proxy for the value of technology transfers.[15]

One concern with the use of royalty payments to proxy for the transfer of technology worth noting is that it only captures the value of transfers that firms report. If firms have discretion with respect to reporting when IPR is weak, any observed increases in royalties

14. The forms that firms are required to complete vary depending on the year, size of the affiliate, and U. S. parent's ownership stake. The most extensive data are collected in benchmark years: 1982, 1989, 1994, and 1999. BEA uses reported data to estimate universe totals when surveys cover only larger affiliates or when only certain affiliates provide information on particular survey forms. To avoid working with estimated data, only affiliates required to provide all the information associated with a particular analysis are considered in this paper. Additional information on the BEA data can be found in Mataloni [1995].

15. It is important to note that our methodology does not require that the recorded intrafirm technology transfers be a full, complete accounting of the value of technology, broadly defined, that is provided by the parent to the affiliate. Recall that we are basing our identification on changes over time for individual affiliates. It is only necessary that the recorded numbers be roughly proportional to actual transfers, and that the factor of proportionality not change at the time of patent reform.

could merely reflect increases in the extent to which firms report royalties at the time of patent reform. There are three main reasons such changes in reporting are unlikely to affect our results.

First, Section 482 of the U. S. tax code and similar legislation in countries abroad require U. S. multinationals to make royalty payments for the transfer of technology and impose constraints on how transfers are valued. These laws generally demand that firms ascribe a value to transfers that would be realized in an arm's-length setting, and U. S. and foreign governments have opposing incentives to ensure that royalties are not set at rates that are excessively high or low.

Second, U. S. multinationals typically transfer similar technology to different parts of the world, and they charge the same royalties for transfers going to different locations, irrespective of the strength of patent law, to avoid IRS scrutiny. In most multinationals, transfers of technology and the royalty payments they trigger are centrally managed, and parent firms keep careful internal records in order to track how their technology is being deployed around the world. Audits by tax authorities are common, and if a U. S. audit is undertaken, the IRS carefully examines any cases in which a firm receives royalty flows that imply that similar transfers receive distinct reporting treatment in different countries. To avoid such scrutiny, firms generally apply the same royalty charges for transfers regardless of where the transfers occur.[16]

Finally, to the extent firms do have discretion in reporting royalties, tax considerations would factor prominently in reporting decisions, and these considerations would not necessarily encourage firms to report lower royalties before reform. To avoid tax payments, multinationals prefer to report profits in low tax jurisdictions. Parent companies therefore have the incentive to set low royalty rates for transfers to low tax countries. However, they also have the incentive to set high royalty rates for transfers to high tax jurisdictions, thereby shifting profits back to the relatively low-taxed U. S. parent. Hines [1995], Grubert [1998], and Collins and Shackelford [1998] present evidence that firms respond to the tax incentives to keep royalties off the books in low tax jurisdictions by adjusting their real activity or their reporting.

16. We thank accountants at the Big Four accounting firms for providing us with a detailed understanding of the accounting treatment of royalties and technology transfers.

These papers indicate that host country income tax rates and withholding tax rates can be used to control for the effects of tax incentives on reported intrafirm royalties; we use these tax variables as controls in our econometric specifications. In addition, robustness tests described in subsection IV.A provide evidence against the hypothesis that increases in royalties around the time of patent reform are focused in low tax countries where the incentives to underreport prior to reform are strongest.

The use of reported R&D expenditures from different countries also raises some important issues. Although data on R&D expenditures from firms based in different countries are subject to concerns about comparability, the BEA survey requires all affiliates, regardless of location, to account for R&D expenditures in the same way. FASB guidelines for reporting R&D were set in the early 1970s and have not been substantively changed over the course of our sample period. A second issue is that scientific and engineering labor costs or other factor prices might differ across countries, and these differences might distort international comparisons of the level of R&D expenditure at a point in time. Our analysis below examines changes over time in affiliate R&D spending in the aftermath of IPR reform, controlling for country and year fixed effects as well as country-specific time trends. Since factor price differentials typically evolve slowly over time, it is unlikely that our results merely capture a sharp contemporaneous movement in the local price of R&D inputs.

III.B. Data from Other Sources

A number of other databases are used to augment the information on U. S. firms in the BEA data. In order to obtain information on parent firm R&D expenditures in years in which this item was not captured in BEA surveys, the BEA data on publicly traded parents are linked to COMPUSTAT using employee identification numbers. To characterize the extent to which firms use the U. S. patent system, parent firm data are also linked to data on patenting activity captured in the NBER patent citation database.[17] This comprehensive database covers all patents granted by the U. S. Patent and Trademark Office (U. S. PTO) throughout the 1982–1999 sample period. Data on patent filings in the countries that undergo patent reform provide additional information on the level of technology being transferred. Data on patent

17. This data set is documented in Hall, Jaffe, and Trajtenberg [2001].

applications, broken out for foreign and domestic applicants over the 1982–1999 period, are primarily drawn from the World Intellectual Property Rights Organization (WIPO).[18]

We also utilize host country controls from a variety of sources. Corporate tax rates and withholding tax rates are imputed from the BEA data.[19] Measures of inward FDI restrictions are taken from Brune [2004], and measures of capital controls come from Shatz [2000].[20] The trade openness index is drawn from Heston, Summers, and Aten [2002] and GDP per capita from the World Bank, *World Development Indicators* [2003].

Table I displays descriptive statistics of variables used in the analysis that follows for the benchmark survey years as well as for the entire 1982–1999 period.[21] The sample only includes firms in countries that undertook the IPR regime changes described below. In the most recent benchmark year, 1999, the sample includes more than 5,000 affiliates of more than 1,000 parent companies.

III.C. Patent Reforms

Details of the sample construction, including descriptions of our discussions with local patent experts in reforming countries, can be found in the Appendix associated with this paper, which is available online.[22] We provide an abbreviated discussion here in the interests of space. We began by constructing as exhaustive a

18. Eaton, Kortum, and Lerner [2004] point out that these data may double count some nonresident patent applications. To correct for this, WIPO data from 1991 forward are replaced with the data used in Eaton, Kortum, and Lerner for the sample of countries covered in that paper. We thank Sam Kortum for these data. In addition, we use data drawn from the OECD's *Basic Science and Technology Statistics* for all years for OECD countries not covered by Eaton, Kortum, and Lerner and for the years prior to 1991 for countries in the Eaton-Kortum-Lerner sample.

19. Corporate tax rates are calculated from BEA data by taking the ratio of foreign income taxes paid to foreign pretax income for each affiliate, and using the medians of these rates as country-level observations for each country and year. Affiliates with negative net income are excluded for the purposes of calculating country tax rates. Withholding tax rates are calculated by taking the ratio of withholding taxes paid to royalty payments made for each affiliate, and using medians of these rates as country-level observations for each country and year.

20. The Brune [2004] measure is drawn from the 2001 version of the index she creates. Host Country Capital Controls is a dummy equal to one when Shatz [2000] classifies openness with respect to both capital and profit remittances at less than 3.

21. Since the size reporting requirements are higher in nonbenchmark years than in benchmark years, means and standard deviations of variables like affiliate sales are larger for the full sample than for each of the benchmark years.

22. Please see http://www.gsb.columbia.edu/faculty/lbranstetter/research/tech_transfer_appendix.

TABLE I
DESCRIPTIVE STATISTICS FOR U. S. MULTINATIONAL ACTIVITY IN REFORMING COUNTRIES

	Benchmark years				Full sample
	1982	1989	1994	1999	1982–1999
Number of Affiliates	3,970	4,115	4,888	5,785	12,961
Number of Parents	836	902	1,114	1,132	2,156
Intrafirm Royalty Payments					
Mean	157	552	932	988	997
Standard deviation	2,335	13,873	14,989	14,870	16,622
R&D Expenditures					
Mean	117	407	482	570	635
Standard deviation	911	9,470	4,397	6,595	6,538
Sales					
Mean	57,129	77,604	90,229	106,866	115,406
Standard deviation	299,376	460,023	517,553	463,536	534,787
Parent R&D Expenditures					
Mean	80,836	81,805	72,647	94,310	109,491
Standard deviation	282,188	358,908	338,329	392,521	398,687
Parent System Sales					
Mean	3,262,647	3,940,225	4,151,990	6,007,838	5,512,638
Standard deviation	9,552,341	11,500,000	13,100,000	17,300,000	14,800,000
Number of Nonresident Patent Filings					
Mean	4,669	8,276	13,953	41,482	13,761
Standard deviation	7,035	12,281	15,488	29,231	18,543
Number of Resident Patent Filings					
Mean	19,805	23,973	26,239	33,896	26,461
Standard deviation	63,383	84,541	84,956	99,531	83,687

Descriptive statistics for all affiliate years	Mean	St. dev.
Host Country Corporate Tax Rate	0.3375	0.1309
Host Country Withholding Tax Rate	0.0707	0.0889
Host Country Inward FDI Restrictions	0.0661	0.2485
Host Country Capital Controls	0.1125	0.3160
Host Country Trade Openness	36.7459	22.8795
Log of Host Country GDP per Capita	8.9843	0.6759

The top panel provides descriptive statistics for the data obtained from BEA surveys and from WIPO. Intrafirm royalty payments are royalty payments made by affiliates to their parents, and like the other financial data are measured in thousands of dollars. Parent R&D Expenditures are the R&D expenditures of the domestic operations of the parent. Parent System Sales are the total sales of the parent and its affiliates. The Number of Nonresident Patent Filings and the Number of Resident Patent Filings are counts of patent applications by nonresidents and residents in a particular country and year. The bottom panel provides descriptive statistics for the country level control variables that are used in the analysis. The Host Country Corporate Tax Rate and the Host Country Withholding Tax Rate are annual median tax rates paid by affiliates in a host country. Host Country Inward FDI Restrictions and Host Country Capital Controls are dummies equal to one when inward FDI restrictions and capital controls exist, and they are drawn from Brune [2004] and Shatz [2000], respectively. Host Country Trade Openness is the index of constant price openness taken from Heston, Summers, and Aten [2002]. The Log of Host Country GDP is derived from data provided in the World Bank, *World Development Indicators* [2003].

list as possible of patent reforms over the 1982–1999 sample period. This initial list drew upon the reforms identified by Maskus [2000] and Qian [2004], as well as countries for which the widely used Ginarte and Park [1997] index of the strength of patent protection showed a significant change.[23] These sources identified an initial list of 42 nations.

Unfortunately, data limitations sharply constrain the number of reform episodes we can examine using our empirical methodology. We require both pre- and postreform data, and since our affiliate-level data are only available for the period 1982–1999, reforms that fall outside this window must be omitted. We also distinguish the responses of affiliates to IPR reform based on the extent to which their parent firms make use of the U. S. patent system. In order to ensure that such a comparison is meaningful in each reform we examine, we required that there be at least twenty affiliates in manufacturing that report before and after a reform and that can be linked to the patenting entities in the NBER patent citation database.

These data restrictions excluded all but eighteen countries. Extremely poor countries like Ghana, small economies like Iceland, and formerly communist countries like Russia failed to attract sufficient U. S. FDI. Finally, as discussed at length in the Appendix, Canada and Singapore were excluded due to the limited significance of the actual patent reforms undertaken. This leaves us with sixteen countries with sufficient data to estimate the impact of reform. Table II displays the list of patent reforms used in the analysis that follows.[24]

Each reform can be classified according to whether or not it expanded or strengthened patent rights along five dimensions: 1) an expansion in the range of goods eligible for patent protection, 2) an expansion in the effective scope of patent protection, 3) an increase in the length of patent protection, 4) an improvement in the enforcement of patent rights, and 5) an improvement in the admin-

23. We thank Walter Park for providing us with an update to the data used in his paper.

24. To test whether sample selection decisions affect the results, the main tests of the paper have also been conducted with a broader sample generated by reducing the affiliate count cutoff from twenty to ten affiliates and including Canadian affiliates of firms in the pharmaceutical and foodstuffs industries. As indicated in the Appendix, some might argue that the 1987 reform in Canada was a meaningful reform in these sectors. The main results are robust to using this alternative sample.

TABLE II
TIMING OF MAJOR PATENT REFORMS

Country	Year of reform
Argentina	1996
Brazil	1997
Chile	1991
China	1993
Colombia	1994
Indonesia	1991
Japan	1987
Mexico	1991
Philippines	1997
Portugal	1992
South Korea	1987
Spain	1986
Taiwan	1986
Thailand	1992
Turkey	1995
Venezuela	1994

This table provides information about the timing of reforms in the countries that strengthen their intellectual property rights and are included in the sample.

istration of the patent system. There is a surprising degree of similarity in the sixteen reforms, with fifteen out of sixteen exhibiting expansion of patent rights along at least four of the five dimensions listed above. These substantive reforms could have a material impact on intrafirm technology transfer and are well-suited to the empirical approach outlined in Section II. A detailed discussion of the individual reform episodes, their distinctive characteristics, and their common features, is provided in the Appendix.

IV. RESULTS

IV.A. Technology Transfer to Affiliates

To provide a general sense of trends in technology transfer, Figure I displays pre- and postreform averages of the ratio of aggregate royalties to aggregate sales in each country and year. Each of the unshaded bars illustrates the average prereform ratios, and the shaded bars illustrate similar averages for the postreform period. These unconditional averages are suggestive of an increase in the value of royalty payments relative to sales around the time of IPR reform. Furthermore, it is clear that affiliates in the high patent

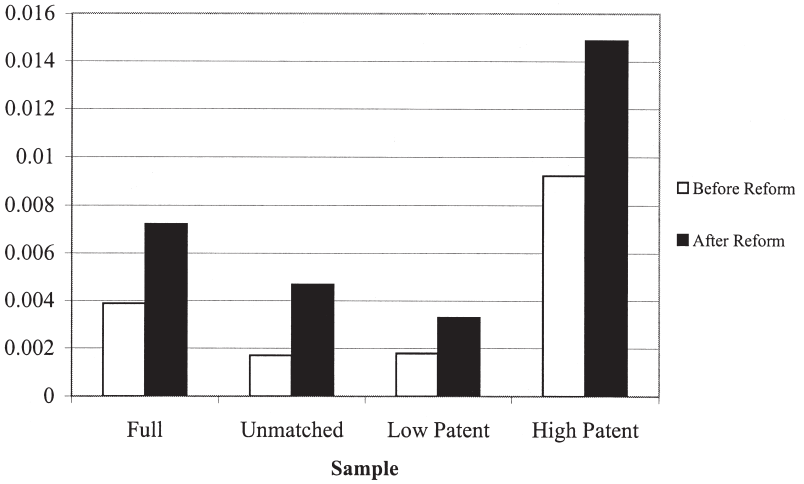

FIGURE I
Aggregate Royalty Payments/Aggregate Sales

The clear bars indicate the average annual aggregate royalty payment to sales ratio for various samples of affiliates in reforming countries before reforms occur. Averages are calculated as the mean of annual ratios in each country over all years in the prereform period. The shaded bars depict average ratios for the year of and years following reform. The first two bars are for the full sample; the next two for affiliates of parents that cannot be matched to the NBER patent citation database; the third pair of bars are for the sample of affiliates of parents that do not make extensive use of patents in the United States prior to reforms; and the final pair are for affiliates in the high patent use sample.

sample make more extensive use of technology provided by the parent and that the ratio of royalty payments to sales increases by the largest amount for this subsample after reform.

Results of regression analyses of royalty payments made by affiliates located in the reforming countries to their parents based on specification (1) are reported in Table III; standard errors allow for clustering by country. Columns (1)–(3) report the impact of IPR reform on the log of the value of royalty payments to the parent firm.[25] The specification in the first column is run on the full sample of affiliates; the coefficient on the postreform dummy is positive and significant at the 1 percent level, indicating that

25. A large number of affiliates, particularly those in low-tech industries, report zero values for technology transfer in most years. We thus add 1 to all observations and take the log of the resulting values. This transformation is standard in the older R&D and productivity literature. Robustness checks described in the text remove affiliates that do not make royalty payments from the sample.

TABLE III
INTRAFIRM ROYALTY PAYMENTS AND IPR REGIME CHANGES

Dependent variable:	Log of intrafirm royalty payments			100 × Log of intrafirm royalty payments/affiliate sales		
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	3.2650	16.5317	37.9012	−4.9088	−8.6826	−4.3862
	(33.9656)	(48.1874)	(49.8304)	(18.4389)	(30.9809)	(30.6403)
Postreform Dummy	0.1663	−0.0006	−0.0080	0.0788	−0.0095	−0.0025
	(0.0619)	(0.0856)	(0.0872)	(0.0333)	(0.0448)	(0.0459)
Postreform Dummy * High Patent Use Dummy		0.3362	0.3107		0.2043	0.1866
		(0.0850)	(0.1004)		(0.0483)	(0.0519)
Host Country Corporate Tax Rate	−0.0625	0.2083	0.0612	−0.0726	−0.0672	−0.1058
	(0.4482)	(0.5273)	(0.5753)	(0.1893)	(0.2491)	(0.2544)
Host Country Withholding Tax Rate	−0.1815	0.4360	0.3218	−0.3515	−0.3652	−0.3844
	(0.5124)	(0.7530)	(0.7408)	(0.3397)	(0.4438)	(0.4512)
Host Country Inward FDI Restrictions	−0.0644	−0.0470	−0.0514	0.0399	0.0342	0.0337
	(0.0445)	(0.1436)	(0.1387)	(0.0359)	(0.1243)	(0.1220)
Host Country Capital Controls	−0.2561	−0.4771	−0.4662	−0.0587	−0.1083	−0.1094
	(0.1163)	(0.1287)	(0.1454)	(0.0453)	(0.0359)	(0.0385)
Host Country Trade Openness	−0.0053	−0.0172	−0.0176	−0.0048	−0.0125	−0.0121
	(0.0043)	(0.0077)	(0.0080)	(0.0031)	(0.0056)	(0.0056)
Log of Host Country GDP per Capita	1.2070	1.8739	1.8584	0.5165	0.6821	0.7196
	(0.3213)	(0.4770)	(0.5060)	(0.1472)	(0.2754)	(0.2917)
Log of Affiliate Sales			0.0976			
			(0.0342)			
Log of Parent R&D Expenditures			0.0272			0.0121
			(0.0126)			(0.0035)
Log of Parent System Sales			0.0296			−0.0131
			(0.0428)			(0.0256)
Affiliate and Year Fixed Effects?	Y	Y	Y	Y	Y	Y
Country-Specific Time Trends?	Y	Y	Y	Y	Y	Y
No. of obs.	52,067	18,401	17,737	49,970	18,029	17,384
R^2	0.7408	0.7149	0.7155	0.6763	0.6751	0.6750

The dependent variable in the first three columns is the log of one plus the value of royalty payments made by affiliates to their parents, and the dependent variable in columns (4)–(6) is the log of one plus the ratio of intrafirm royalty payments to affiliate sales, multiplied by 100. The Postreform Dummy is a dummy equal to one in the year of reform and in the years following the reforms identified in Table II. The High Patent Use Dummy is a dummy that is equal to one for affiliates of parents that over the four years prior to a reform average at least as many patent applications as the parent of the median affiliate in the reforming country. Host Country Corporate Tax Rate and Host Country Withholding Tax Rate are annual median tax rates paid by affiliates in a host country. Host Country Inward FDI Restrictions and Host Country Capital Controls are dummies equal to one when inward FDI restrictions and capital controls exist, and they are drawn from Brune [2004] and Shatz [2000], respectively. Host Country Trade Openness is the index of constant price openness taken from Heston, Summers, and Aten [2002]. The Log of Host Country GDP per capita is derived from data provided in the World Bank, *World Development Indicators* [2003]. Log of Affiliate Sales is the log of the value of affiliate sales, and Log of Parent R&D Expenditures is the log of the affiliate's parent R&D expenditures. The Log of Parent System Sales is the log of total sales of the parent and its affiliates. All specifications include affiliate and year fixed effects as well as country-specific time trends. Heteroskedasticity-consistent standard errors that correct for clustering at the country level appear in parentheses.

intrafirm royalty payments increase at the time of reforms. As additional regressors, all specifications in the table include host country controls, including the corporate income tax rate, the withholding tax rate, indicators of FDI restrictions and capital controls, measures of openness to trade, and the log of GDP per capita.

The specifications in columns (2) and (3) examine the differential effect of IPR reform for affiliates of parents that make more extensive use of patents in the United States. Since these specifications require information on the patent activity of parents, only affiliates of firms that can be linked to firms in the NBER patent database are included. The high patent use dummy is equal to one for affiliates of parents that, over the four years prior to a particular reform, average at least as many U. S. patent applications as the parent of the median affiliate in the reforming country over the same period. The coefficient on the postreform dummy in column (2) is small and insignificantly different from zero, while the coefficient on the postreform dummy interacted with the high patent use dummy is positive, large, and significant at the 1 percent level.

These results imply that the increases in technology transfer as measured by royalty payments that occur around the time of IPR reform are concentrated among affiliates of parents that use patents extensively. These affiliates experience an increase in royalty payments of about 34 percent. This is an annual increase in technology flows from parents to affiliates which, cumulated over several years, implies a substantial increase in the technological intensity of affiliate activity. Similar results are obtained from the specification presented in column (3) that also includes the log of affiliate sales, the log of parent R&D expenditures, and the log of parent system sales. These collectively control for the expanding demand for technology of a growing affiliate and the expanding potential supply of technology of a parent as it invests in R&D and grows.[26]

The dependent variable in the specifications presented in columns (4)–(6) of Table III is 100 times the log of one plus the

26. We recognize the potential endogeneity of these variables in this context. The purpose here is not to derive structural estimates of, for instance, affiliate size on technology transfer. Rather, we only include these variables to control for parent-specific changes in technology supply and affiliate-specific changes in technology demand.

ratio of royalty payments to sales.[27] This dependent variable is used to assess whether affiliates use technology provided by the parent more intensively after reforms occur. We find results that parallel those reported in columns (1)–(3): there is a significant effect of reform on the rate of royalty payments, and this effect is concentrated among high patent use firms. To allow for a more direct comparison with the effects reported in columns (1)–(3), it is helpful to calculate the elasticity of the royalty to sales ratio with respect to reform. Defining ratio = royalties/sales and differentiating log (1 + royalties/sales) with respect to reform,

$$\frac{d \log (1 + ratio)}{dreform} = \frac{(dratio/dreform)}{1 + ratio} \cong \frac{(dratio/dreform)}{ratio} * ratio$$

$$= \varepsilon_{ratio} * ratio,$$

where ε_{ratio} is the elasticity of the royalty to sales ratio with respect to reform. From specification (1) we observe that $\varepsilon_{ratio} * ratio$ is given by $\beta_4/100$, or 0.0008. Since the mean value of $ratio$ is approximately 0.005, this implies that ε_{ratio} is approximately 16 percent. For the high patent subsample, the implied effect of reform on log $(1 + ratio)$, based on the last two specifications, is 0.0019, which implies an elasticity of 38 percent. These values are roughly comparable to those generated by the level regressions reported in columns (1)–(3).

We subject these results to a number of robustness checks. To ensure that measured responses to reforms do not simply reflect increased reporting of royalties by affiliates that face tax incentives to underreport royalties prior to reform, we include a dummy equal to one if the host country tax rate is below the U. S. tax rate and this dummy interacted with the postreform dummy.[28] We include region-year fixed effects in our regression using the five regions designated in the BEA data to control for regional factors. We drop all affiliates that report zero licensing payments. We expand the sample to incorporate affiliates in all countries—not just those that underwent reform during our sample period. We also repeat our analyses omitting Argentina and China, the countries where we have less confidence that patent reforms were effectively implemented. To address the concern that our results might be driven by pharmaceutical firms, we

27. This variable is scaled for expositional reasons.
28. We also include an interaction of the postreform dummy and the host country withholding tax rate.

drop all affiliates in that industry. None of these alternative specifications qualitatively change our results.

IV.B. Affiliate R&D Spending

As discussed in Section II, affiliate R&D is often focused on the absorption and modification of the parent firm's technology to meet local market conditions and is hence a complement to technology imports from the parent. If IPR reform stimulates an increase in the volume of technology deployed, then it should also stimulate an increase in affiliate R&D spending. To examine this hypothesis, the analysis in Table IV examines the impact of IPR reform on affiliate R&D activity. The specifications presented parallel those presented in Table III, with the only difference being that the log of affiliate R&D expenditures and 100 times the log of affiliate R&D expenditures scaled by sales are used as dependent variables.[29] The results presented in column (1) imply a positive effect of IPR reform on the R&D spending of the average affiliate in the full sample, but this effect is only significant at the 10 percent level.

The specifications in columns (2) and (3) include the postreform dummy interacted with the high patent use dummy to test whether the effects of IPR reform are particularly concentrated among firms that make more extensive use of patents in the United States. The large positive and significant coefficients on the interaction terms imply that this is the case. For instance, the results in column (2) imply that IPR reform leads to a 23 percent increase in R&D spending by the affiliates of patent-intensive parents, and a t-test that corrects for clustering at the country level indicates that this increase is significantly different from zero at the 5 percent level. Because R&D represents a cost borne by the parent system, the coincidence of the measured increase in R&D spending with the measured increase in royalty payments suggests that at least some component of the latter represents a real increase in the deployment of technology to affiliates. Columns (4)–(6) of Table IV provide the results of specifications in which R&D expenditure is scaled by affiliate sales. The results

29. It is important to make two caveats about the R&D data. First, data on affiliate R&D expenditures were not collected from 1983–1988, so the sample does not include data from these years. Second, since many affiliates report zero values for R&D expenditures in most years, we add 1 to all observations of affiliate R&D and affiliate R&D scaled by sales and took the log of the resulting values. Robustness checks described in the text remove affiliates that do not conduct R&D from the sample.

TABLE IV
AFFILIATE R&D EXPENSES AND IPR REGIME CHANGES

Dependent variable:	Log of R&D expenditures			100 × log of R&D expenditures/affiliate sales		
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	−22.5850	−14.5488	−17.7987	−11.3471	−6.3190	−6.4074
	(32.8691)	(53.1728)	(51.2915)	(12.0184)	(18.5573)	(18.5184)
Postreform Dummy	0.0908	−0.1079	−0.1277	0.0049	−0.0716	−0.0704
	(0.0512)	(0.1153)	(0.1191)	(0.0257)	(0.0475)	(0.0474)
Postreform Dummy *		0.3374	0.3250		0.1058	0.1026
High Patent Use Dummy		(0.1507)	(0.1510)		(0.0522)	(0.0516)
Host Country Corporate	0.8715	0.5898	0.4829	0.3968	0.1047	0.1041
Tax Rate	(0.3201)	(0.4738)	(0.4745)	(0.2189)	(0.1553)	(0.1547)
Host Country Withholding	1.1364	0.1351	0.0504	0.5258	0.1642	0.1632
Tax Rate	(0.3461)	(0.7787)	(0.8027)	(0.2757)	(0.3073)	(0.3058)
Host Country Inward FDI	−0.0506	0.0234	0.0235	−0.0528	−0.0899	−0.0902
Restrictions	(0.0573)	(0.1388)	(0.1402)	(0.0179)	(0.0330)	(0.0333)
Host Country Capital	−0.1948	−0.2725	−0.2613	−0.0145	−0.0479	−0.0476
Controls	(0.0932)	(0.1243)	(0.1196)	(0.0268)	(0.0230)	(0.0226)
Host Country Trade	0.0058	0.0073	0.0076	0.0022	0.0024	0.0025
Openness	(0.0045)	(0.0048)	(0.0050)	(0.0036)	(0.0040)	(0.0040)
Log of Host Country GDP	0.1796	−0.2321	−0.4775	0.0050	−0.0103	−0.0089
per Capita	(0.4405)	(0.6959)	(0.7283)	(0.0983)	(0.1937)	(0.1935)
Log of Affiliate Sales			0.1352			
			(0.0412)			
Log of Parent R&D			0.0311			0.0074
Expenditures			(0.0096)			(0.0024)
Log of Parent System Sales			−0.0645			−0.0029
			(0.0305)			(0.0053)
Affiliate and Year Fixed Effects?	Y	Y	Y	Y	Y	Y
Country-Specific Time Trends?	Y	Y	Y	Y	Y	Y
No. of obs.	31,739	10,238	10,238	31,588	10,182	10,182
R^2	0.7310	0.6838	0.6858	0.6684	0.6710	0.6710

The dependent variable in the first three columns is the log of one plus the value of affiliate R&D expenditures, and the dependent variable in columns (4)–(6) is the log of one plus the ratio of affiliate R&D expenditures to affiliate sales, multiplied by 100. The Postreform Dummy is a dummy equal to one in the year of reform and in the years following the reforms identified in Table II. The High Patent Use Dummy is a dummy that is equal to one for affiliates of parents that over the four years prior to a reform average at least as many patent applications as the parent of the median affiliate in the reforming country. Host Country Corporate Tax Rate and Host Country Withholding Tax Rate are annual median tax rates paid by affiliates in a host country. Host Country Inward FDI Restrictions and Host Country Capital Controls are dummies equal to one when inward FDI restrictions and capital controls exist, and they are drawn from Brune [2004] and Shatz [2000], respectively. Host Country Trade Openness is the index of constant price openness taken from Heston, Summers, and Aten [2002]. The Log of Host Country GDP per capita is derived from data provided in the World Bank, *World Development Indicators* [2003]. Log of Affiliate Sales is the log of the value of affiliate sales, and Log of Parent R&D Expenditures is the log of the affiliate's parent R&D expenditures. The Log of Parent System Sales is the log of total sales of the parent and its affiliates. All specifications include affiliate and year fixed effects as well as country-specific time trends. Heteroskedasticity-consistent standard errors that correct for clustering at the country level appear in parentheses.

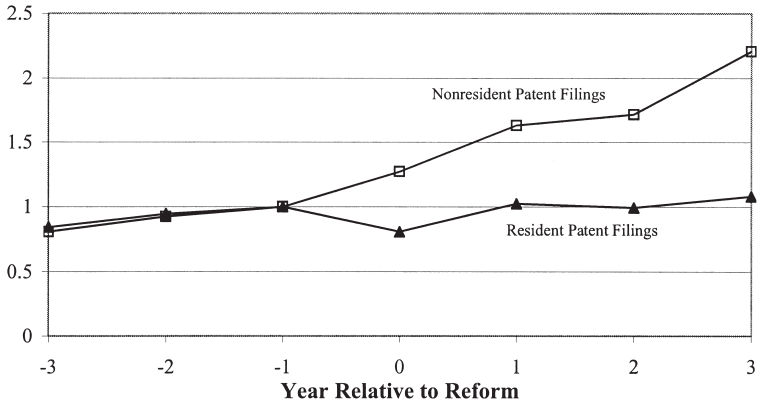

FIGURE II

Resident and Nonresident Patent Filings Around the Time of Reforms

The Nonresident Patent Filings line traces out an index of foreign patenting around the time of reforms. This index is calculated by first computing the ratio of the number of patent filings by foreigners in a particular year relative to reform to the number of patent filings by foreigners in the year prior to a reform and then selecting the median ratio across reforming countries. The Resident Patent Filings line displays the index for resident patent filings.

parallel those for the unscaled regressions: R&D intensity increases significantly among patent-intensive firms.

We test the robustness of these results on affiliate R&D spending in a number of alternative specifications. We incorporate region–year fixed effects into our specification. We drop observations for affiliates that report zero R&D spending. We expand the sample to include all available countries, not just those undergoing IPR reform over our sample period. We remove Japan from the sample, since it is the one country where affiliate R&D is not primarily focused on absorption and adaptation of the parent firms' technology. None of these alternative specifications qualitatively changed our results.

IV.C. Resident versus Nonresident Patenting

Figure II illustrates the patterns in patent filings by foreigners and domestic residents before and after IPR reform, comparing ratios of patent filings in the years around the time of reform to the level recorded in the year immediately preceding patent reform. This figure suggests that, relative to the prereform period, patenting grows for nonresidents after reform, while remaining flat for domestic residents. This pattern is broadly con-

sistent with the findings of Lerner [2002a, 2002b]. It also implies that at least one component of the observed increase in licensing payments is connected to an increase in the volume of technology transferred.

The analysis presented in Table V measures the impact of IPR reform on patent filings by both domestic and foreign innovators. We regress the log of the counts of patent filings (resident or nonresident) on a postreform dummy, an interaction term between the postreform dummy and a time trend that measures the number of years that have passed since the reform year, country and year fixed effects, country-specific time trends, and the same country level controls used in the previous tables. Columns (1) and (2) present specifications in which the dependent variable is the log of resident patent filings. In column (1) the coefficient on the postreform dummy is indistinguishable from zero, indicating that resident patent filings do not increase when reforms occur. Column (2) shows that the postreform dummy interacted with the time trend is also insignificant, indicating that the resident patent filings do not grow after reforms.

Columns (3) and (4) present similar specifications for nonresident patent filings. There is robust evidence that these filings increase and continue to grow after reforms. The coefficient on the postreform dummy in column (3) implies an increase in nonresident filings of about 52 percent. The positive and statistically significant coefficient on the postreform dummy interacted with the time trend in column (4) implies that the number of nonresident filings grows more rapidly after reforms. This evidence is consistent with the hypothesis that multinationals do not just patent technologies that had been used prior to reforms but also transfer new technologies to reforming countries.

IV.D. Endogeneity and Timing of Reforms

Our estimation strategy treats the timing of IPR reform in a given country as exogenous, at least with respect to the activities of U. S.-based multinational firms and their affiliates. It may be that other changes that are coincident with patent reform drive both the changes in the patent regime and the measured changes in affiliate behavior. For example, once a nation reaches a certain threshold level of development, internal and external pressure may build for a stronger patent system. Alternatively, pressure

TABLE V
HOST COUNTRY PATENTING ACTIVITY AND IPR REGIME CHANGES

Dependent variable:	Log of resident patent filings		Log of nonresident patent filings	
	(1)	(2)	(3)	(4)
Constant	−3.7953	12.7808	−20.0926	39.1461
	(46.6012)	(50.1311)	(78.3782)	(81.7430)
Postreform Dummy	0.0216	0.0563	0.5232	0.6425
	(0.1792)	(0.1832)	(0.1955)	(0.2172)
Postreform Dummy ∗ Number of Years Since Reform		0.0564		0.1968
		(0.0820)		(0.0846)
Host Country Corporate Tax Rate	1.1227	1.1212	−0.7735	−0.7643
	(0.6728)	(0.6755)	(0.7756)	(0.6524)
Host Country Withholding Tax Rate	−0.5192	−0.2306	−0.1672	0.8723
	(1.2679)	(1.3648)	(1.0045)	(1.1015)
Host Country Inward FDI Restrictions	0.7533	0.7749	−0.0646	0.0031
	(0.3344)	(0.3529)	(0.1641)	(0.1696)
Host Country Capital Controls	0.0032	−0.0374	−0.0150	−0.1528
	(0.1210)	(0.1322)	(0.1349)	(0.1533)
Host Country Trade Openness	0.0030	0.0061	0.0172	0.0263
	(0.0128)	(0.0129)	(0.0125)	(0.0136)
Log of Host Country GDP per Capita	−1.0645	−1.1958	0.1481	−0.2200
	(0.6728)	(0.6851)	(1.5014)	(1.4581)
Country and Year Fixed Effects?	Y	Y	Y	Y
Country-Specific Time Trends?	Y	Y	Y	Y
No. of obs.	223	223	226	226
R^2	0.9600	0.9600	0.9696	0.9723

The dependent variable in the first two specifications is the log of the number of patents filed in a particular country by residents of that country, and the dependent variable in the last two specifications is the log of the number of patents filed in a particular country by nonresidents. The Postreform Dummy is a dummy equal to one in the year of reform and the years following the reforms identified in Table II. Host Country Corporate Tax Rate and Host Country Withholding Tax Rate are annual median tax rates paid by affiliates in a host country. Host Country Inward FDI Restrictions and Host Country Capital Controls are dummies equal to one when inward FDI restrictions and capital controls exist, and they are drawn from Brune [2004] and Shatz [2000], respectively. Host Country Trade Openness is the index of constant price openness taken from Heston, Summers, and Aten [2002]. The Log of Host Country GDP per capita is derived from data provided in the World Bank, *World Development Indicators* [2003]. All specifications include country and year fixed effects as well as country-specific time trends. Heteroskedasticity-consistent standard errors that correct for clustering at the country level appear in parentheses.

by U. S. multinationals (exerted indirectly via the U. S. government) may cause countries to adopt reforms when companies have a need to increase technology transfer.

While we cannot completely rule out these alternative explanations, we can examine their plausibility more carefully. First, many explanations related to coincident changes and reverse causation predict that technology transfer begins to increase in the years prior to the date of reform. The specifications displayed

TABLE VI
TIMING OF REFORMS

Dependent variable:	Log of intrafirm royalty payments	100 × log of intrafirm royalty payments/ affiliate sales	Log of R&D expenditures	Log of nonresident patent filings
	(1)	(2)	(3)	(4)
Constant	−2.0441	0.7016	−0.8979	0.8188
	(2.3708)	(1.6815)	(2.0430)	(4.7270)
Reform ($t - 4$)	−0.0780	−0.0305	−0.0147	−0.2616
	(0.1048)	(0.0569)	(0.0777)	(0.1801)
Reform ($t - 3$)	−0.1139	−0.0195	0.0842	−0.0541
	(0.1036)	(0.0552)	(0.0667)	(0.1041)
Reform ($t - 2$)	−0.0638	−0.0199	0.0802	−0.0105
	(0.0319)	(0.0254)	(0.0358)	(0.1015)
Reform (t)	0.0432	0.0267	0.1509	0.2272
	(0.0560)	(0.0280)	(0.0368)	(0.1024)
Reform ($t + 1$)	0.1265	0.0835	0.1145	0.7052
	(0.0403)	(0.0296)	(0.0577)	(0.2646)
Reform ($t + 2$)	0.2172	0.1196	0.1639	0.6654
	(0.0631)	(0.0362)	(0.0827)	(0.2948)
Reform ($t + 3$)	0.1990	0.1561	0.0475	0.6764
	(0.0745)	(0.0475)	(0.1050)	(0.2864)
Reform ($t + 4$)	0.2261	0.1480	0.2093	0.7309
	(0.1160)	(0.0827)	(0.1234)	(0.2681)
Controls?	Y	Y	Y	Y
Affiliate and year fixed effects?	Y	Y	Y	N
Country and year fixed effects?	N	N	N	Y
No. of obs.	52,067	49,970	31,739	226
R^2	0.7387	0.6746	0.7307	0.9410

The dependent variable in the first column is the log of one plus the value of royalty payments made by affiliates to their parents; the dependent variable in the second column is the log of one plus the ratio of intrafirm royalty payments to affiliate sales, multiplied by 100; the dependent variable in the third column is the log of one plus the value of affiliate R&D expenditures; and the dependent variable in the last specification is the log of the number of patents filed in a particular country by nonresidents. Reform ($t - 4$) is a dummy that is equal to one for observations from four or more years before a reform. Reform ($t + 4$) is equal to one for observations from four or more years after a reform. Other reform dummies are equal to one in particular years relative to reform. As controls, each specification includes the Host Country Corporate Tax Rate, Host Country Withholding Tax Rate, Host Country Inward FDI Restrictions, Host Country Capital Controls, Host Country Trade Openness, and the Log of Host Country GDP per Capita. Specifications (1)–(3) include affiliate and year fixed effects, and specification (4) includes country and year fixed effects. Heteroskedasticity-consistent standard errors that correct for clustering at the country level appear in parentheses.

in Table VI provide more detailed estimates of the timing of changes in affiliate royalty payments, affiliate R&D expenditures, and nonresident patent filings. These specifications are

similar to those described above, but they do not include country-specific time trends, and they yield coefficient estimates for a set of dummy variables that correspond to periods of fixed length before and after reform. The Reform $(t - 4)$ dummy is equal to one for all years that predate the reform by four or more years and is equal to zero in all other years, and the Reform $(t + 4)$ dummy is equal to one for all years at least four years after reform and zero during other years. The other reform dummies are equal to one in specific years relative to reform and zero during other years. There is no dummy for the year immediately preceding reform (i.e., year $t - 1$); the coefficients on the reform dummies provide estimates relative to that year.

Columns (1) and (2) present specifications using royalty payments and scaled royalty payments, respectively, as the dependent variable. The results indicate that while the coefficients on the dummies for years prior to reform are negative, they are all insignificant and fail to show any evidence of a clear upward trend prior to reform. The coefficients on the dummies for the year of reform are positive but insignificant, and the dummies for the years after reform are large, positive, and significant. Thus, the estimated timing of changes is consistent with a shift in activities that follows soon after the enactment of reform. A fairly rapid reaction is reasonable. Our sample of U. S. multinationals includes firms that possess a portfolio of technologies employed around the world and that are familiar with strong patent system environments. While indigenous firms might require some time to adjust to a strong IPR regime with which they have no previous experience, it is plausible that our U. S. multinationals could respond quickly, redeploying their existing technologies to take advantage of opportunities created by the new regime.

Column (3) presents results of a specification using the log of affiliate R&D expenditures as the dependent variable. Again, there is no clear upward trend prior to reforms, and the postreform coefficients are, with one exception, larger than the prereform coefficients. The postreform coefficients are jointly significant and suggest a substantial postreform increase in R&D spending, though the relationship between patent reform and the timing of measured changes in affiliate activity does not appear to be as clear as it is for technology transfer.[30] The dependent

30. This may be a consequence of the nature of the affiliate R&D data since these data were not collected from 1983–1988. Given that a number of reforms

variable in the specification in column (4) is the log of nonresident patent filings. As suggested by the pattern in Figure II, there is an increase patent filings precisely timed to our reform dates, and these filings continue to grow once reforms take place.

Several other considerations also help to ease concerns about the endogeneity of IPR reform. First, it is clear from a casual look at the wide divergence in per-capita income among the IPR reforming countries in our sample that these countries were at very different levels of economic development at the time of reform. It is therefore very unlikely that these countries were reaching a common development threshold at the time of their IPR reform.

The argument that reforms were driven by the desire of U. S. multinationals to obtain advantages in reforming markets is premised on the assumption that these firms developed a list of lucrative potential markets, and pushed the U. S. government to apply diplomatic pressure on selected countries at precisely the time that they wished to increase technology transfer. Econometric evidence, derived from a unique feature of U. S. trade law, casts doubt on the possibility that U. S. multinationals were able to effectively control the timing of reform to their advantage. Since the passage of the Omnibus Trade and Competitiveness Act of 1988, the U. S. government has been required by law to identify nations that violate the intellectual property rights of U. S. firms. In accordance with this requirement, every year the United States announces a "Special 301 Watch List" and a "Special 301 Priority Watch List" of nations in which violations are deemed to be especially injurious and where changes in the national IPR environment are a U. S. diplomatic priority. For reforms after 1988 we estimated hazard models of the timing of IPR reform using the presence of a country on one of these lists as an explanatory variable. This variable had no statistically significant explanatory power in our regressions.[31] Hence, the timing of reforms is not correlated with this measure of U. S. diplomatic pressure.

This econometric result is consistent with the historical accounts of Ryan [1996] and Uphoff [1990], and with our own interviews with multinational managers and resident legal experts in the reforming countries. All of these sources indicate that

occur during this period, obtaining precise estimates of effects in years relative to reform years is difficult.

31. These regression results are available from the authors upon request.

U. S. pressure interacted in complicated ways with domestic counterpressure, and this interaction introduced an element of randomness into the timing of reforms that is exogenous to the wishes of U. S. multinationals.[32]

V. Conclusion

Over the past twenty years, the international economic policy agenda has increasingly taken the enactment of strong, globally enforced intellectual property rights as a priority. This represents a significant departure for international economic policy, and it remains deeply controversial. Advocates of stronger IPR have asserted, with little evidence, that stronger IPR will yield benefits by inducing multinational firms to engage in more technology transfer. This paper empirically tests that hypothesis by analyzing the effects of reform on the royalty payments and R&D expenditures of U. S. multinational affiliates, as well as the level and growth rate of patent filings by nonresidents, and finds that all of these increase following reforms. Increases in affiliate royalties and R&D are concentrated among affiliates of firms that make extensive use of the U. S. patent system prior to reforms and are therefore likely to value reforms the most. For these patent-intensive firms, we estimate that increases in affiliate royalties exceed 30 percent. Our results collectively imply that U. S. multinationals respond to changes in IPR regimes abroad by significantly increasing technology transfer to reforming countries.

These results are not, of course, sufficient to demonstrate that IPR reform is welfare enhancing for reforming countries. The analysis does not consider the impact of reforms on locally owned firms that may be displaced after reforms, nor does it examine the effects of the reforms on the pace of innovation in nonreforming countries. However, given the limited evidence that IPR reform spurs domestic innovation, increases in technology transfer are likely to be a necessary condition for IPR reform to increase welfare in reforming countries. Our results suggest that

32. Further evidence of America's lack of diplomatic omnipotence is provided by the timing of other reforms that multinationals would obviously have an interest in promoting—such as a lifting of FDI restrictions and an expansion of openness to trade. In most cases, these other reforms were not coincident with patent reform.

for at least one type of transfer, international technology transfer within multinational firms, this condition is met.

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