FOREIGN DIRECT INVESTMENT AND THE SOURCING OF TECHNOLOGICAL ADVANTAGE: EVIDENCE FROM THE BIOTECHNOLOGY INDUSTRY

Weijian Shan*
J. P. Morgan

Jaeyong Song**
Columbia University

Abstract. This paper investigates the proposition that foreign direct investment in a high-technology industry is motivated in part by the sourcing of country-specific technological advantages embedded in foreign firms. The empirical findings show that foreign equity investment is drawn to American biotechnology firms with high levels of patent activity. We suggest that, in the biotechnology industry, foreign direct investment in the form of equity participation can be an efficient vehicle for tapping into country-specific, firm-embodied technological advantages.

It is frequently observed that technological advantages are heterogeneously distributed among countries and that this pattern tends to persist over time [Kogut 1990]. This heterogeneity in technological resources is strikingly evident in the biotechnology industry. The important research breakthroughs have been made in only a few countries, primarily the U.S., France, the United Kingdom, Japan, Germany, and Switzerland. This pattern of locational agglomeration is even more conspicuous in the commercialization of major discoveries. The U.S. has dominated the market for commercial applications of biotechnology research, and it has the largest number of start-up ventures in the biotechnology industry.

In this paper, we propose that the locational advantages of the U.S. in the biotechnology industry will attract foreign direct investments.[1] If this technology is firm-embodied though location-specific, foreign direct investment (FDI) in the form of equity participation will target U.S. firms with

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*Weijian Shan is Managing Director of J.P. Morgan, an investment bank. He was Assistant Professor of Management at the Wharton School, University of Pennsylvania between 1987 and 1993. He received his Ph.D. from University of California-Berkeley in 1987.

**Jaeyong Song is Assistant Professor of Strategy and International Management at the Columbia Business School, Columbia University. His current research interests focus on the management of global production and R&D networks.

We wish to thank Bruce Kogut, Ned Bowman, Steve Kobrin, George Day, and John Lafkas for their helpful suggestions. This research is supported by funding from the Huntsman Center for Global Competition and Innovation and the William H. Wurster Center for International Business Studies of the Wharton School. We would also like to thank Roger Longman and Windhover Information Inc. for graciously providing some of the data used in this analysis.

Received: February 1996; Revised: October 1996 & March 1997; Accepted: March 1997.

proven technological superiority. We empirically investigate whether foreign equity investments are drawn to existing biotechnology companies with proven technological capabilities in order to gain access to country-specific technological advantages. Treating the population of American biotechnology firms as being "at risk," we use a hazard model to test whether firms revealing a technological capability as measured in terms of patenting activities are more likely to be the target of FDI. Strong evidence is found for the proposition that FDI is attracted to sources of technological advantages.

THEORY AND HYPOTHESES

Emerging View of Foreign Direct Investment

Traditionally, theories of FDI have emphasized firm-specific advantages or ownership advantages derived from the ownership of intangible assets such as technologies, management skills, and organizational capabilities [Caves 1971]. For FDI to take place, these advantages must be sufficiently large to offset the fact that they are possessed by a foreign company [Hymer 1976]. Several empirical works find evidence of the positive effects of R&D intensity on the propensity to make foreign investments (e.g., Caves [1982]). In these studies, only peripheral and passing attention has been given to the possibility that firm-specific advantages may be sourced through FDI [Granstrand, Hakanson and Sjolander 1992].

Recently, multinational corporations (MNCs) have accelerated their efforts to acquire and develop new technologies overseas. In the analysis of U.S. patent data, European researchers (i.e., Cantwell, Pavitt and Dunning) found that more than 70% of patents registered by Belgian and Dutch MNCs originated from locations outside their home countries [Dunning 1994a]. In 1987, the twenty largest Swedish MNCs in the engineering and chemical industries made 22.8% of their R&D expenditures outside Sweden [Hakanson and Nobel 1993]. A recent survey revealed that executives in U.S. and Japanese MNCs, whose R&D activities have traditionally been much more centralized in their home countries [Patel and Pavitt 1991], ranked the "internationalization of R&D" as one of their top priorities [Pearce and Singh 1992].

The increase in foreign R&D activities of MNCs has led to the growing academic interest in a dynamic interaction between home-based and foreign-acquired technological advantages as sources of MNCs' competitive advantages. Dunning [1990:29] observes:

> In recent years, however, and especially in explaining high value activities of multinational companies, the main country specific locational determinants have shifted to reflect the innovatory and entrepreneurial dynamism of the recipient economy. Such dynamism is reflected inter alia in the availability and cost of assets which are complementary to those provided by investing companies; and which

enable these companies not only to exploit their competitive advantages, but to sustain or add to them.

In this context, Dunning [1995] urges researchers to acknowledge more explicitly that firms engage in FDI in order to acquire or learn about to complementary technologies, as well as to exploit their existing competitive advantages. In other words, the emerging view of FDI emphasizes that FDI is not only "pushed" by the firm-specific advantages of the investor, but may also be "pulled" towards centers of innovations located in recipient countries as a means for the investor to acquire and develop new resources and capabilities.[2] Cantwell [1989], for example, performed a longitudinal analysis of the relationship between location of technology and FDI. He found that West German and American multinational firms are positively attracted to locations that are important sites of innovative activities in their own industries. In an historical analysis of patenting activities of leading multinational firms, Cantwell [1995] noted the greater recent significance of overseas technology development activities, especially in countries of technological leadership. Kogut and Chang [1991] analyzed Japanese direct investments into the U.S. They found that Japanese investments were attracted to R&D-intensive industries, often in the form of joint ventures. These studies, which used industry-level data, suggest that countries with technological advantages tend to attract FDI as well as generate outward FDI flows.[3]

This emerging view of FDI is based on the following observations. First, at the firm level, the technological capabilities necessary for competing in the high-technology industry might reside outside the firm's, or even the nation's boundaries. Second, at the country level, technological advantages are heterogeneously distributed and tend to persist over time.

Rapid Technological Changes and the Sourcing of Technological Advantages

As an intrinsic part of a firm's activities, developing new resources and capabilities is viewed as necessary for profitable growth of a firm [Penrose 1959; Nelson and Winter 1982; Dierickx and Cool 1989]. However, it might be a risky proposition for a firm competing in an industry of rapid technological change to premise its resource accumulation process solely upon internally existing capabilities. If a firm's competitive advantage is derived from its unique resources, the advantage is lost when its capabilities become obsolete through constant technological changes. For example, the entire U.S. steel industry made a strategic mistake in the late 1950s and early 1960s by renovating and expanding its capacity with the open-hearth technology, foregoing the new basic oxygen technology, because the former could be more easily absorbed into its existing capabilities [Crandall 1981]. It turned out that the new capabilities it developed became obsolete before they were put to use.

The question for a firm then becomes, not what capabilities it already possesses, but what it needs to acquire in order to remain competitive. Hence, under the condition of fundamental changes in the technological environment, the strategy formulation process should begin with the determination and identification of necessary capabilities that will provide a firm with competitive advantages in the foreseeable future. The firm must then decide whether it will acquire or develop these capabilities, or exit the market. This decision is often made as a function of its internal resources and investment requirements.

When Schumpeterian types of environmental changes occur, many incumbent firms simply exit the market because of their failure to break the technological path they locked themselves onto. The legacy of a firm's past including its organization, human resources and established routines constrain the development of new capabilities [Teece, Pisano and Shuen 1990]. When a firm's resources become antiquated by the major changes in technological trajectories and competitive environments, their "sticky" quality turns these assets into liabilities. However, some firms revitalize themselves by acquiring innovative capabilities specific to the new technology. Knowing the location of the advantages and the characteristics of the market, these firms choose the most efficient organizational form to develop such capabilities. If the origin of a technological revolution is outside the home country of a firm, FDI can be a way to obtain quick access to strategic resources and technological capabilities.[4]

Technology-Seeking Foreign Direct Investments into Countries of Technological Leadership

The need for technology-seeking FDIs into countries of technological leadership is bolstered by the persistence of country-specific technological advantages [Kogut 1990] and the path dependence in the process of technological development at the country level [Cantwell 1989]. Why do technological advantages tend to be country bound and persistent over time? Some recent research attributes country-specific advantages to national organizing principles [Kogut 1990] and national innovation systems [Nelson 1993]. For example, the Silicon Valley consists of a complex network of universities, venture capitalists and government agencies [Mowery and Rosenberg 1993] that interact with each other in a way defined by the distinct political, economic, legal, financial, and educational systems of the United States. It might be impossible to replicate such complex networks of institutional relationships. If the national innovation system gives rise to certain technological and competitive advantages, the innovating country is likely to be able to sustain, at least for some time, its advantage in the new technology.

Gaining access to technologies that reside in a foreign country often requires the presence of multinational firms in the country, due to the localized nature of knowledge spillovers [Jaffe, Trachtenberg and Henderson 1993] and complex, hard-to-replicate networks of institutional relationships [Dunning 1994b]. The semiconductor industry is a good example. In analyzing patent citations in the semiconductor industry in the U.S., Almeida and Kogut [1995] show that technological knowledge is localized for some, but not all regions. This localization is based on the mobility of engineers among firms situated in the same region.

When strategic resources are embedded in country-specific institutional systems and are location-bound, a firm might find it imperative to plug itself into such locations. Multinational firms in such emerging high-technology industries as biotechnology and semiconductors can gain access to the technological advantages that reside in foreign countries by several different modes of FDI: greenfield R&D labs, joint ventures, foreign equity investments, and technology-licensing agreements. Setting up an overseas research lab in a country of technological leadership often requires a long incubation period and a large amount of investment for a new research lab to work effectively. Moreover, many country-specific advantages are likely to be embodied in "high-technology firms" [Shan and Hamilton 1991]. To a firm that does not have these advantages, the relevant strategic question is how to tap into such location-specific and firm-embodied technologies. Joint ventures with foreign high-technology firms may be an efficient vehicle for tapping into such advantages. Kogut and Chang [1991] found that joint ventures were frequently used for the sourcing of U.S. technological capabilities. In the face of rapid technological change, FDI in the form of acquisition or equity investment may also be a rapid and reliable way of gaining access to technological resources embedded in foreign firms. The empirical analysis of technology-seeking FDIs in this paper focuses on equity investments in high-technology firms.

Equity investments in foreign high-technology firms provide several advantages to the investing firm. First, a direct link facilitates learning of the intrinsic, complex and tacit processes by which technologies are generated in the recipient firm and in the country of technological leadership. Second, an equity stake might provide the investing firm with an option to acquire the recipient in the future [Kogut 1991]. By simultaneously investing in several high-technology concerns, the investing firm may also be able to minimize the risks and uncertainties that characterize emerging technologies. In addition, an equity stake may make it easier for the investing firm to become a licensee of a new technology that is developed by the recipient.

Recent data seem to suggest the growing use of equity investments as a way to tap into technological advantages. For example, Japanese equity investment in U.S. high-technology start-ups grew sevenfold over 1985–1989, soaring from an estimated $44 million to $320 million [*Corporate Venturing News* 1990]. A substantial share of this investment took place in the semiconductor and biotechnology industries.

Foreign equity investors in U.S. biotechnology and semiconductor start-up companies are predominantly established firms from the industrialized world. Many of these are firms with multinational manufacturing and marketing capabilities.[5] Through equity positions in these high-technology companies, they obtain technologies to feed their downstream, complementary capabilities [Shan 1990]. In cases like these, both the investing firm and the recipient firm have advantages to offer to each other.

The choice of the investment target therefore points to the advantages that the recipient firm has to offer to the investing firm. Needless to say, technological capabilities are frequently the only advantages that a company in an emerging high-technology industry possesses. The problem is that many firms in countries with technological advantages fail to develop the technological capabilities foreign investors are looking for. Moreover, foreign firms are often at an information disadvantage in the appraisal of the quality of high-technology firms abroad. Hence, verifiable signals of technological capabilities are especially important to foreign firms when they appraise equity investment targets.

Hypothesis

The preceding discussion proposes that FDI may be attracted to sources of technological advantages. This proposition leads to the central hypothesis. Given firm heterogeneity with respect to technological capabilities, FDI in the form of equity investment targets firms with identifiable advantages in new technology. A positive correlation is expected between the probability that a firm is selected for equity investment by a foreign firm and the strength of the recipient firm's technological advantage as measured in terms of patenting activities.

In contrast to industry-level analyses (e.g., Cantwell [1989]; Kogut and Chang [1991]; Anand and Kogut [1997]), the unit of analysis in this paper will be high-technology firms in which a nation's technological advantages are embedded. The cross-industry studies implicitly assume that all firms in the same industry and in the same country have equal technological capabilities and are thus equally likely to become the targets of foreign equity investments. However, even in the same country, firms differ in their possession of country-specific advantages due to either their own technological investments or their superior abilities to capture local spillovers. By conducting the firm-level analysis, we hope to pin down those attributes embodied in firms that attract foreign equity investments so that we can isolate the "pull" effect of country-specific advantages from the "push" effect of firm-specific advantages of the investing firm.

DATA AND METHOD

The sample in this study includes almost all of the population of biotechnology firms in the U.S. that are potential targets of foreign equity investments. There are several reasons for the choice of the biotechnology industry. First, the American advantage in biotechnology is unequivocally recognized. The American advantage in biotechnology has been manifested mostly in the innovative activities of biotechnology firms, which have been responsible for most of the new biotechnology products brought to market to date [Shan 1990]. Second, while large established firms engage in R&D in a diverse array of conventional and new technologies and extensive downstream capabilities, biotechnology firms specialize in the commercialization of biotechnology research. Therefore, the motive of a foreign investor in a biotechnology firm is rather straightforward.

Measuring Technological Advantage

A frequently used measure of technological advantage is patenting activities.[6] Although patents do not capture all the innovative activities of a firm, as many types of intangible assets are either non-patentable or are better protected without patents, patenting activity has been found to be a good measure of the innovative capabilities of a firm [Pavitt 1985]. Previous research has found a strong positive relationship between R&D investments and patents [Acs and Audretsch 1988].

Patents are viewed as "the intellectual capital of the biotechnology industry and a cornerstone of a firm's ability to attract investment capital" [Ernst and Young 1993: 7]. Although the quality of patents is not easily captured, the number of patents taken out by a firm seems to best communicate the firm's technological strength and to explain the market valuation of biotechnology concerns [Lerner 1991]. In analyzing patent patterns in biotechnology, Spalding [1991] finds a strong correlation between number and quality of patents. Thus, the number of patents held by a firm appears to be the best verifiable information upon which a potential foreign investor can rely to evaluate a firm's technological capabilities in a high-technology industry.

By this measure, the U.S. enjoys a substantial advantage in the biotechnology industry. As shown in Table 1, biotechnology patents from U.S. sources outnumber those of all other countries combined by a factor of almost 3. In spite of the high propensity of Japanese firms to obtain patents in the U.S., the U.S. has six times as many biotechnology patents as Japan [Westney 1993].

Method

The empirical test is conducted using a discrete-time event history analysis [Allison 1984]. This method estimates the "hazard rate" of a biotechnology firm to become the target of equity investment by a foreign firm in a given year as a function of a number of fixed and time-varying variables including patenting activities of the firm. The risk set in any given year is the population of biotechnology firms in existence during that year. The population varies over time as new firms are founded and old ones exit by way of acquisition or

TABLE 1
Percentage Share of Biotechnology Patents Granted in the U.S. by Country (%)

		Foreign		
Year	U.S.	Japan	Germany	Other
Pre-77	44	17	3	36
77	43	10	10	37
78	76	3	7	14
79	58	8	6	28
80	57	20	3	20
81	66	14	4	16
82	75	14	5	6
83	82	9	2	7
84	77	9	3	11
85	71	13	2	14
86	77	8	3	12
87	76	18	1	5
88	78	14	2	6

Source: U.S. Patent and Trademark Office

bankruptcy. An "event" is defined as an equity investment by a foreign firm in one member of the risk set where relinquishment of some control or rights over the recipient's assets can be explicitly identified.

The dependent variable is the unobserved hazard rate – the probability that an event occurs in a particular time for firms at risk, i.e., those firms surviving to that time.[7] For each firm-year, the dependent variable is coded 1 if the firm receives an equity investment in that year and 0 otherwise. The nature of the dependent variable requires estimation with a logit model. The central explanatory variable, *Patents*, is the cumulative number of patents generated by a firm prior to the given year. In addition to the number of patents, independent variables also include a set of firm-attribute variables specified below.

Age is the difference between the year of incorporation for a firm and the event year. This variable is expected to capture a number of underlying firm-level attributes that vary with time. If *Age* captures some of the technological capabilities or other types of knowledge that a firm has accumulated over time but that are not captured by patents, it is expected to be positively correlated with the dependent variable.

Public is a dummy variable equal to 1 if a firm is a public company and 0 otherwise. It might be easier for a public firm to go to the capital market to raise capital than for a private firm. However, as Teece concluded in discussing FDI in Genentech, a U.S. biotechnology firm, "U.S. equity markets are not the place to finance long gestation industries" and foreign investment provides a significant internal cash flow stream crucial for the long-term viability of the recipient firm [1992:94]. To a firm looking for investment targets in a foreign country, one challenge is imperfect information about potential targets. The closely held nature of private firms might prevent foreign equity investment. Moreover, going public may be indicative of a firm's technological advantages in the highly competitive field of high technology, signaling its attractiveness as an investment target. Therefore, *Public* is expected to be positively correlated with the dependent variable.

Two types of variables are used to measure the impact of a firm's area of concentration on the dependent variable. The first is *Diversity*, which is a count variable measuring the number of areas in which the firm commercializes new technologies. As the value of *Diversity* increases, the probability that the firm will attract investment from foreign firms searching for capabilities in different areas will also increase. Therefore, this variable is expected to bear a positive sign.

Six biotechnology areas are identified and each of them is coded as a dummy variable. These include *Agriculture*, *Food*, *Diagnostics*, *Therapeutics*, *Veterinary* products, and *Other*, which includes the remaining products. The effects of these non-mutually exclusive dummy variables are estimated in a separate model because inclusion of them with *Diversity* in the same model would create multicollinearity problems.

Relations is a count variable measuring the number of cooperative relationships that a biotechnology firm maintains with other institutions such as universities. The high number of cooperative relationships is a positive signal indicating the desirability of a firm as a cooperative partner. Many of the cooperative arrangements in the biotechnology area govern some carefully specified and narrow range of products, and confine the parties to well-defined activities. The problem, however, is that each partner in cooperative relationships has rights to claim the ownership of specific technologies [Shan 1990]. Therefore, a large number of cooperative relations may block the exclusive technological advantages that a foreign investor is looking for and make the firm an unattractive target. A negative sign is hypothesized for this variable.

Preinvest is a dummy variable indicating if a firm had received corporate equity investment from domestic or foreign sources in the past. While those firms that are acquired exit the risk set, those having received equity investment in the past remain a potential repeat target. This variable controls any inherent tendency for a firm to receive equity investment which is not captured by other variables in the model. However, a firm with many previous equity investments may not be an attractive investment target because foreign firms might prefer an exclusive window on the recipient firm's technology.

To allow for period effects, a set of dummy variables is specified, one for each

TABLE 2
Descriptive Statistics and Correlation Matrix

Variable	Mean	Std Dev.	1	2	3	4	5	6	7	8	9	10	11	12
1. *Y*	0.02	0.14	-	-	-	-	-	-	-	-	-	-	-	-
2. *Age*	5.28	3.66	0.02	-	-	-	-	-	-	-	-	-	-	-
3. *Public*	0.12	0.32	0.12	0.14	-	-	-	-	-	-	-	-	-	-
4. *Diversity*	2.07	1.07	0.08	0.07	0.25	-	-	-	-	-	-	-	-	-
5. *Agriculture*	0.18	0.38	0.04	0.01	−0.01	0.24	-	-	-	-	-	-	-	-
6. *Food*	0.10	0.30	0.07	0.02	0.08	0.50	0.24	-	-	-	-	-	-	-
7. *Diagnostics*	0.48	0.50	0.04	0.02	0.20	0.40	−0.28	-0.23	-	-	-	-	-	-
8. *Therapeutics*	0.44	0.50	0.06	−0.02	0.18	0.42	−0.17	0.02	0.05	-	-	-	-	-
9. *Veterinary*	0.19	0.39	0.02	0.11	0.19	0.59	0.09	0.23	0.10	0.13	-	-	-	-
10. *Other*	0.68	0.47	−0.02	0.06	−0.04	0.40	−0.16	0.12	−0.04	−0.13	0.04	-	-	-
11. *Patents*	0.43	3.20	0.15	0.15	0.28	0.23	0.06	0.18	0.10	0.12	0.16	−0.02	-	-
12. *Relations*	0.91	2.78	0.10	0.19	0.46	0.27	0.04	0.12	0.18	0.17	0.21	−0.03	0.53	-
13. *Preinvest*	0.11	0.32	0.10	0.16	0.44	0.21	0.07	0.10	0.14	0.15	0.11	−0.04	0.29	0.46

N=3737 (firm-year record)

of the event years except the initial year. These variables will capture the tendency, if any, for the hazard rate to change over time [Allison 1984].

Data

The data were collected from multiple sources over a period of six years. The patent data were obtained from the U.S. Patent and Trademark Office. The primary sources of both public company information and foreign investment data are two private information service companies that track the biotechnology industry. These data were checked against each other and other sources for accuracy. After missing values were deleted, data over thirteen years between 1978, when the first event of FDI in biotechnology firm was observed, and 1990, the last year of complete data, produced a sample of 3,737 firm-year records.[8] Foreign equity investors in our sample are mostly European and Japanese firms. Data description and summary statistics are provided in Table 2.

RESULTS

Table 3 contains the results of statistical analysis. Model 2 differs from Model 1 in that a set of concentration area dummy variables replaces the count variable of *Diversity*. The first two models (columns 1 and 2) estimated the effects of year dummies by the inclusion of a set of dummy variables. No pattern emerges from the results as none of the year dummies is significant, indicating that the hazard rate does not change with time. Therefore, the two models are reestimated in Models 3 and 4 (columns 3 and 4) with the year dummies removed. All four models produced largely consistent results.

The central variable for estimation, *Patents*, is consistently significant in all four models. The sign is positive, indicating that the greater the number of

TABLE 3
Event History Logit Analysis

Variables	1	2	3	4
Intercept	−15.63	−15.62	−4.56***	4.67***
	(281.0)	(277.2)	(0.32)	(0.35)
Age	−0.05	−0.04	−0.04	−0.02
	(0.04)	(0.04)	(0.04)	(0.04)
Public	0.98**	0.99**	1.01**	1.04**
	(0.32)	(0.33)	(0.32)	(0.33)
Diversity	0.26*	-	0.21*	-
	(0.11)	-	(0.11)	-
Agriculture	-	−0.79*	-	0.72*
	-	(0.32)	-	(0.31)
Food	-	0.75*	-	0.69*
	-	(0.34)	-	(0.34)
Diagnostics	-	−0.53†	-	0.45
	-	(0.28)	-	(0.27)
Therapeutics	-	−0.64*	-	0.63*
	-	(0.27)	-	(0.26)
Veterinary	-	−0.42	-	−0.53
	-	(0.33)	-	(0.33)
Other	-	−0.25	-	−0.25
	-	(0.25)	-	(0.25)
Patents	0.06**	0.05*	0.05*	0.04*
	(0.02)	(0.02)	(0.02)	(0.02)
Relations	−0.07	−0.06	−0.04	−0.03
	(0.04)	(0.04)	(0.04)	(0.04)
Preinvest	0.65†	0.47	0.74*	0.53
	(0.33)	(0.34)	(0.33)	(0.34)
Y79	0.04	0.04	-	-
	(376.4)	(371.5)	-	-
Y80	0.04	0.02	-	-
	(362.6)	(357.7)	-	-
Y81	10.40	10.29	-	-
	(281.0)	(277.2)	-	-
Y82	10.85	10.73	-	-
	(281.0)	(277.2)	-	-
Y83	10.93	10.83	-	-
	(281.0)	(277.2)	-	-
Y84	10.83	10.72	-	-
	(281.0)	(277.2)	-	-
Y85	10.14	10.04	-	-
	(281.0)	(277.2)	-	-
Y86	11.11	11.02	-	-
	(281.0)	(277.2)	-	-
Y87	10.82	10.71	-	-
	(281.0)	(277.2)	-	-
Y88	11.68	11.58	-	-
	(281.0)	(277.2)	-	-
Y89	11.66	11.57	-	-
	(281.0)	(277.2)	-	-
Y90	10.94	10.84	-	-
	(281.0)	(277.2)	-	-
Chi-square ($p<0.001$)	75.72	88.79	56.28	69.62

† $p<0.10$, * $p<0.05$, ** $p<0.01$, *** $p<0.001$
Standard errors are in parentheses.

patents generated by a firm prior to the event year, the more likely it is for the firm to become a target of foreign equity investment.

The dummy variable, *Public*, is significant and positive in all four models. Similar results are obtained for *Diversity*, which is positive and significant, confirming the hypothesis that more diverse firms are more likely to become FDI targets. This variable is replaced with a set of dummy variables representing biotechnology areas of concentration of the firm in Models 2 and 4. The variables of *Agriculture*, *Food* and *Therapeutics* are consistently significant and positive. *Diagnostics* has a positive sign but is only marginally significant in Model 2. *Veterinary* and *Other* are not significant in any of the models. These results suggest that more diversified biotechnology firms and those that concentrate in areas of agriculture, food and therapeutics are more likely to be selected as targets of FDI.

The results from other variables are insignificant or mixed. No significant result is obtained for *Relations*. *Preinvest* is significant and positively signed in two of the models that do not have concentration area dummies. Controlling for concentration area dummies diminishes the significance as well as the coefficients of this variable. This indicates that *Preinvest* captures some of the concentration area effects when these dummies are not controlled. Therefore, the results do not provide sufficiently strong evidence that firms tend to be repeat targets.

DISCUSSION AND CONCLUSIONS

These findings support the central hypothesis that technological advantages of a firm, as measured by its patenting activities, increases the "risk" of a firm becoming a target of foreign equity investment. The positive effect of the number of patents supports the central hypothesis that foreign equity investments are motivated by the sourcing of country-specific advantages that are embedded in high-technology firms.

The stock market provides another source of information about the firm. A major objective for many entrepreneurs and venture capitalists is to bring their start-up company public [Teitelman 1989]. Still lacking downstream capabilities, these firms are evaluated by the stock market for their innovative potential. Only those firms that expect to be favorably received by the stock market because of their competitive potential are likely to go public. Moreover, information about public companies is generally much more available than for private ones because of the disclosure requirements of the Securities and Exchange Commission. It should not be surprising, therefore, that public companies are found to be the more likely targets of FDI.

Diversity of research areas can also be seen as a measure of a firm's capabilities. Foreign equity investment is found to be more likely targeted at more diverse firms than at less diverse ones. It is interesting to note that our results show that those areas with large market potential in terms of valuation, such as agriculture, food and therapeutics [OTA 1984] are more attractive targets of FDI. Marginal areas such as veterinary products and others seem to be avoided by foreign firms.

Given the unequivocal leadership of the United States in biotechnology innovation, we expect that FDI in this industry is largely bound for America. To check the generality of our findings, we used the Toyo Keizai database [1994a,b] to investigate whether FDIs have been used for sourcing of technologies in different country settings. In the investigation of Japanese FDI into Germany, we did not find any case of equity investment into German biotechnology or pharmaceutical firms, although Japanese firms set up two pharmaceutical R&D labs in Germany. We also surveyed U.S. FDIs into Japan in the pharmaceutical industry, including biotechnology areas. Only one Japanese pharmaceutical company became a target of foreign equity investment of an American pharmaceutical company. A MITI survey [MITI 1994] provides interesting statistics on R&D activities of foreign affiliated firms. In the pharmaceutical industry, only two labs out of nineteen have focused primarily on the sourcing of technology in Japan by conducting basic research or by developing products for global markets. This evidence further corroborates the result of our analysis. As shown in Table 1, there is a large discrepancy in technological capabilities between the U.S. and other countries. This discrepancy has generated a significant flow of technology-seeking FDIs into the U.S. in the biotechnology industry.[9]

In order to determine whether technology-seeking FDIs are phenomena unique to the biotechnology industry, we analyzed FDI patterns between the U.S. and Japan in the semiconductor industry. In terms of the total number of semiconductor patents granted in the U.S., the Japanese share has grown from 8% prior to 1977 to 37% in 1991. In contrast, the U.S. share has shrunk from 75% prior to 1977 to 48% in 1991, mainly due to the rapid increase of patents of Japanese origin. The rapid development of Japanese technological capabilities in this industry suggests that technology-seeking FDIs, if any, may occur in both ways. In the surge of Japanese equity investments in U.S. high-tech startups in the 1980s, the semiconductor industry has been the primary target [*Corporate Venturing News* 1990]. A survey conducted by the Electronic Industries Association of Japan [1995] shows that 53 out of 105 overseas R&D labs in the Japanese electronics industry were set up in the U.S. According to the MITI survey, eighteen foreign firms established electronics R&D labs in Japan; fourteen of these labs were set up in the 1990s. In contrast to the foreign-owned pharmaceutical R&D labs in Japan, more than 30% of the electronics labs regarded sourcing of advanced technology (e.g., basic research; development of new products for the global market) as the main motive for setting up R&D labs in Japan. These survey results indicate that as Japan has emerged as a country of technological leadership in the electronics industry, Western multinationals have begun their efforts to seek technology in Japan.

Almeida [1996] also investigated the technology-seeking FDIs of foreign semiconductor firms in the U.S. Using patent citation data of the foreign semiconductor-related R&D labs in the U.S., he found that at the regional level, patents that belong to foreign R&D labs tend to cite local patents significantly more than those of the domestic R&D labs that are used as matched control cases. Almeida's findings at the regional level suggest that foreign firms set up R&D labs to gain access to the local knowledge that resides in the center of innovation.

Judging from these observations, technology-seeking FDIs do not seem to be unique to the biotechnology industry. Technology-seeking FDIs in the form of greenfield R&D labs or equity investment seem to be widely used in the semiconductor industry, too. The biotechnology industry shares some features with the semiconductor industry [OTA 1984]. Both industries are known for rapid technological changes. In these industries, R&D activities, especially new product development activities, can be separated from manufacturing activities. The possibility of creating new technologies through independent R&D activities encouraged multinational firms to set up greenfield R&D labs in the center of innovation. Moreover, the possibility of separating R&D and manufacturing activities led to the emergence of a large number of start-up firms that specialize in R&D activities. The presence of high-technology start-up firms in the U.S. biotechnology and semiconductor industries made it possible for foreign firms to tap into the technological advantages of the U.S. through equity investments. Many high-technology start-up firms view foreign equity investments as welcome help in their efforts to bring new technologies to the market, because they need a significant cash flow stream to finance R&D projects with long gestation periods.

However, other high-technology industries such as the aircraft industry often lack the aforementioned features shared by the biotechnology and semiconductor industries. In many industries, in which capabilities are generated mainly through learning in the manufacturing process and in which process innovation thus is critical to the competitive advantages of a firm, the need for the close linkage between R&D labs and plants may reduce a firm's motivation to set up independent R&D labs overseas. In addition, the lack of R&D specialist start-up firms makes it difficult for foreign firms to find suitable targets for equity investment. Therefore, the findings of this research should be generalized to other industrial settings only with caution.

In conclusion, the findings of this research contribute to the literature on FDI and strategic management by establishing a link between the sources of technological advantages in a new technology and firm strategies to obtain access to these advantages. The empirical evidence suggests that FDIs are not only "pushed" by firm-specific capabilities; they are also "pulled" by resources beyond the country boundaries of the firm if environmental conditions favor the ownership of these resources.

Complex, hard-to-imitate networks of institutional relationships often result in the persistence of country-specific technological advantages or path dependence in the process of technological development at the country level. An example is the leadership of the U.S. in the biotechnology industry. When many country-specific technological advantages are embedded in certain high-technology firms in a country of technological leadership, foreign equity investments into those firms can be an efficient vehicle for tapping into these advantages.

NOTES

1. The U.S. Department of Commerce defines a foreign investment as direct when a single investor has acquired a stake of 10% or more in a U.S. firm [Graham and Krugman 1989:8]. The 10% test is supposed to be a rule of thumb to determine if the investor has acquired some control over the operation. It is well known, however, that the 10% rule is arbitrary as more or less than 10% of equity holdings may or may not provide the investor with any degree of control.

2. Dunning [1958] recognized the possibility of using FDI as a vehicle to tap into location-specific technological advantages in his earliest book, *American Investment in British Manufacturing Industry*. We appreciate an anonymous reviewer who reminded us of Dunning's insightful early work.

3. Anand and Kogut [1997] also investigated the "push" effects of industry rivalry and the "pull" effects of geography to explain foreign direct investments in the U.S. They found that industry rivalry plays an important role in foreign direct investment decisions. However, they failed to find evidence that foreign direct investment is motivated to acquire U.S. technology. They suggested that a more disaggregated, firm-level analysis would provide evidence of the "pull" effects in specific industries.

4. The above strategic implication of this paper is somewhat at odds with the typical description of the strategy formulation process in the resource-based view of the firm, which begins with identifying a firm's unique resources or firm-specific advantages [Teece, Pisano and Shuen 1990]. Neither, however, is it consistent with the "environmental models" of competitive advantage [Porter 1980, 1985], which focus on industry differences and assume distribution of homogenous resources across firms in an industry or a strategic group [Barney 1991:100]. While firm resources such as competencies and capabilities are rightfully recognized as a source of competitive advantage, these resources are meaningful only in terms of technological requirements of the market and competition. For example, the capabilities of a carbon paper company could be rendered almost irrelevant by the advent of xerography.

5. In discussing the case of the purchase of 60% of the equity of Genentech, a leading U.S. biotechnology firm, by Roche Holdings of Basel, a Switzerland-based pharmaceutical concern, Teece [1992:94] observes: "In part, it is also a recognition that Genentech and other U.S. companies have the lead in this industry; by far the cheapest way for the European and Japanese to catch up is for them to acquire U.S. biotech firms."

6. Whereas the R&D ratio may be the best measure of technological capabilities of a firm, the firm-level data on R&D investment are not available in the biotechnology industry.

7. As a dependent variable, we used the "hazard rate" of a biotechnology firm to become the target of equity investment by a foreign firm rather than the probability of a multinational firm to make foreign equity investment. The primary reason for this choice was to isolate the "pull" effect of country-specific advantages embedded in these firms from the "push" effect of

the firm-specific advantages of the investing firm. In our empirical model, we included the characteristics of recipient firms only, without an explanatory variable regarding characteristics of investing firms, to extract pure "pull" effects of the recipient firm's technological capabilities on an investing firm's choice of the investment target.

8. About 10% of the sample firms were eliminated due to missing values. The elimination of missing values does not appear to cause significant biases because there is no significant difference between deleted and remaining samples.

9. Our findings must be interpreted with some caution. The propensity to use equity investments to obtain access to technology is apparently different across countries even in the same industry. The lack of equity investments into Japan, for instance, may be partly because of the rarity of high-technology start-ups [Teece 1992] as investment targets and partly because of the difficulty of foreign firms to acquire equities in Japanese corporations in the high-technology industry [Lawrence 1992].

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