DOES INTERNATIONAL RESEARCH AND DEVELOPMENT INCREASE PATENT OUTPUT? AN ANALYSIS OF JAPANESE PHARMACEUTICAL FIRMS

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ABSTRACT:

Internationalizing research and development is often advocated as a strategy for fostering the development of technological capabilities. Although firms conduct international R&D to tap into knowledge bases that reside in foreign countries, we argue that in order to benefit from international R&D investments firms must already possess research capabilities in underlying or complementary technologies. We examine the international R&D expansion activities and patent output of 65 Japanese pharmaceutical firms from 1980 to 1991 and find supportive evidence for our arguments. In addition to refining our understanding of when international R&D enhances firm innovation, our results foster an integration of asset seeking and asset based theories of foreign direct investment. Internationalizing R&D to tap into foreign knowledge bases is consistent with asset-seeking theories of foreign direct investment, while the contingent nature by which firms benefit from international R&D is consistent with asset-based theories of foreign direct investment and the notion of absorptive capacity.

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I. INTRODUCTION

The internationalization of research and development is increasingly recognized as an important firm strategy in many industries. In response to the perceived increase in technological sophistication throughout the world and to the existence of specific expertise in particular countries or regions, companies reach outside of their domestic boundaries to acquire technologies and technological skills (*e.g.*, Nelson, 1993). This search for new skills and technologies drives the internationalization of research and development.

Much of the current literature advocates internationalizing research and development in order to acquire new skills and technologies (*e.g.*, De Meyer, 1992; Komaran and Goodman, 1993). However, we know little about if, or when, firms that internationalize their R&D activities enhance their technological capabilities. Our contribution stems from the examination of this issue.

We argue that the mere establishment of international research and development activities is not sufficient for a firm to acquire desired skills and technologies. Just as entering a country that has a large consumer market is no guarantee for successful manufacturing foreign direct investment (FDI), entering a market that has a unique knowledge base is no guarantee for successful research and development FDI. Consistent with the notion of absorptive capacity (Cohen and Levinthal, 1990), we propose that the acquisition of skills and technologies is contingent on the investing firm possessing capabilities that foster the acquisition of skills and technology.

There are two forms of capabilities that we believe aid firms in successfully acquiring new skills and technologies through international research and development. First, firms with strong existing research activities in the underlying technologies will be better able to absorb and

put to use the skills and technologies they are exposed to in their international R&D activities. Second, firms that possess research skills in technologies complementary to the skills and technologies they are exposed to in their international R&D activities will be better able to adapt the new technologies to their use.

To test our arguments, we investigate the international research and development activities and patent output of a panel of firms in the Japanese pharmaceutical industry. We measure firms' research capabilities in the underlying technologies by previous drug patenting activity. Because most of the international research and development activities established by these firms were focused on biotechnology, we measure firms' technical capabilities in complementary technologies as the number of patents in fermentation technology prior to the study period. As we discuss shortly, fermentation technology is complementary to many biotechnology applications because it is the process by which many biotechnology products are produced.

The empirical results support our predictions. These findings have important implications for both practitioners and researchers. We shed light on what conditions must hold for international research and development to facilitate firm innovation. Moreover, we show that successful asset seeking FDI, such as internationalizing R&D, occurs when firms possess certain capabilities. This insight fosters an integration of asset seeking and asset based theories of FDI.

In the next section, we discuss previous research that addresses the internationalization of R&D and present our hypotheses of when internationalizing R&D increases firm innovation. The third section provides background information on the industry context of our study. In the fourth section, we describe our methodology and in the fifth section we discuss the findings of our study. We conclude with a discussion of the implications from our findings.

II. BACKGROUND AND HYPOTHESES

Internationalization of research and development has generated considerable interest in academic and business circles. The primary question addressed by existing literature has been "why do firms undertake international R&D?"

Previous research has pointed to the importance of accessing skills and capabilities that reside overseas as the underlying motivation for internationalizing R&D (*e.g.*, Buckley and Casson, 1976; De Meyer, 1989; Komaran and Goodman, 1993). Although technological capability is dispersing throughout the world, there exist pockets of expertise that develop due to peculiarities of a specific "national innovation system" (Nelson, 1993). Firms may find it necessary to establish research and development activities in these locations to tap into sources of technology that diffuse slowly across national boundaries (Kogut, 1991). Kuemmerle (1997) found that 45% of the foreign laboratories in his sample were established for "home-base-augmenting" purposes. That is, that the laboratories were established for the purpose of tapping knowledge from competitors and universities in other lands. Recent empirical evidence documents that foreign investors are able to tap into foreign knowledge bases and supports these arguments. For example, Almeida (1996) shows that foreign semiconductor firms tap into local knowledge in the United States. Cantwell (1995) shows that technological leaders are becoming increasingly geographically specialized with respect to their technological activity.

Similarly, firms might also conduct foreign research and development in order to be near the users of the technology. Foreign customers are often the most sophisticated users of a technology and therefore important contributors to future technology development. For example, Dow Chemical established a furniture research and development lab in Italy because Italian furniture makers are the most innovative in their demands for adhesives, finishes and other materials.

Researchers have also long recognized the difficulties associated with internationalizing R&D due to the costs associated with communicating across distance and culture (Fayerweather, 1969). Moreover, complications stemming from the tacitness and transferability of knowledge are often exacerbated in an international context (Teece, 1976).

Such complications are manifestations of the difficulties that foreign investors, in general, face when operating in a host country. Theories of foreign direct investment (*e.g.*, Hymer, 1960; Caves, 1971; Buckley and Casson, 1976; Dunning, 1977) argue that firms face disadvantages when doing business outside their home country due to the unfamiliarity of the business environment and the difficulty of coordinating business activities across distances of culture, language and geography. Several studies have empirically documented this issue. Morck and Yeung (1991, 1992) find that investors do not value international activities, *per se*, and that international acquisitions, in general, do not have positive stock-price reactions. Mitchell, Shaver & Yeung (1992) show that foreign expansion can often be harmful to the corporation. Moreover, Zaheer (1995) demonstrates that foreign entrants face a liability due to their foreignness.

Because there exist both benefits and difficulties in effectively conducting international R&D, we expect that the mere act of internationalizing research and development will not be sufficient to achieve increased innovative capability. We believe that there are necessary preconditions for successfully undertaking international research and development activities. Specifically, we expect that, in order to be successful, firms must possess (a) existing research skills that are akin to the skills they seek in foreign nations, or (b) research skills that are complementary to the skills they seek in foreign nations. The following paragraphs elaborate our arguments and present formal hypotheses.

Our arguments are consistent with previous research of international expansion success. First, Mitchell, Shaver and Yeung, (1992) and Morck and Yeung (1992) find that international

expansion activities in manufacturing contexts tend to be successful when the expanding firms possess existing skills or capabilities. These findings support asset-based theories of FDI that argue firms must bring with them some sort of skill or advantage that cannot be transacted at arms length, in order to overcome the disadvantages of operating in a foreign market (*e.g.*, Buckley & Casson, 1976; Dunning, 1977). Second, Shaver, Mitchell, and Yeung (1997) show that firms must possess a threshold level of knowledge in order to learn about activities in a foreign market.

In addition, several arguments in the research and development literature ground our expectation that the possession of research skills positively affects the effectiveness of international research and development. Cohen and Levinthal (1990) argue that firms undertake research and development not only as a part of the innovation process but also as a means of absorbing external knowledge. They show that this motivation plays an important role in the decision to invest in new knowledge. Cohen and Levinthal offer the following incentive for firms to invest in basic research:

> ... firms may conduct basic research less for particular results than to be able to identify and exploit potentially useful scientific and technological knowledge generated by universities or government laboratories, and thereby gaining a first-mover advantage in exploiting new technologies (p 593).

Cohen and Levinthal (1990) argue that firms with increased absorptive capacity will tend to be more proactive, exploiting opportunities present in the environment, independent of current performance. They argue that a firm's absorptive capacity is largely a function of the firm's level of prior knowledge. Absorptive capacity is the ability of a firm to recognize the value of new, external information and to assimilate it and apply it to commercial ends. They argue that by developing an absorptive capacity in a particular area "a firm may more readily accumulate what additional knowledge it needs ... to exploit any critical external knowledge that may become

available"(p. 136). Therefore, existing research capabilities are a manifestation of an investment in absorptive capacity.

Moreover, firms that have established a capability in a particular research skill are better able to absorb the information gained from external research activity in that area (Pisano, 1990). Presumably, these firms will be in a better position to evaluate the alternatives when establishing foreign research activities in related research areas.

As a result, we expect that firms that conduct international R&D and have greater research capabilities will exhibit greater innovative output. Given the industry context of our study we hypothesize the following.

> **Hypothesis 1**: Firms that conduct international R&D and have greater pharmaceutical research capabilities will generate greater patent output.

In multivariate analyses, this hypothesis suggests a positive interaction between international R&D and pharmaceutical research capabilities. We do not hypothesize relationships for the main effects of these variables for the following reasons. First, although our arguments suggest that there will be no or little effect of international R&D on firm innovation absent absorptive capacity, we do not state this as a formal hypothesis because it is a null hypothesis (*i.e.*, there is no effect of the independent variable). Second, we do not predict a main effect of pharmaceutical research capabilities because this is a measure of absorptive capacity and absorptive capacity is valuable only to the extent that there is knowledge available to absorb. Because Japan has a revealed technological *disadvantage* in pharmaceuticals (Cantwell, 1992), higher levels of absorptive capacity will not necessarily result in increased innovative performance because of the limited domestic technology base. Nevertheless, it is an empirical question whether firms with very high levels of absorptive capacity can absorb knowledge outside their nation without making investments outside of their nation. As a result, we do not

believe that we can justify a hypothesized main effect. While we do not hypothesize main effects of these independent variables, we want to reiterate that Hypothesis 1 predicts how these variables, in combination, affect firm patent output.

Following from the same line of reasoning that generated hypothesis 1, we expect firms that possess research capabilities in areas not directly related, but complementary, to the skills they seek overseas to benefit from international research and development. Complementary technical skills are forms of know-how or technologies that may be used in conjunction with the sought-after technologies to create new products. Preliminary discussions with executives in the pharmaceutical industry suggested that fermentation skills, which were associated to biotechnology research, were central to much of the research that they were conducting internationally. Grace (1997, p. 78) writes that, "To date, microorganisms are still the main tools bioengineers use to turn out pharmaceutical products." We corroborated the importance that these complementary skills played in the drug discovery process by interviewing chemistry experts in the United States.

Therefore, we expect that firms that conduct international R&D and have greater research capabilities that are complementary to the technologies they seek overseas will exhibit greater innovative output. In the context of our study, we hypothesize:

> **Hypothesis 2:** Firms that conduct international R&D and have greater fermentation research capabilities will generate greater patent output.

In a multivariate analysis, this hypothesis suggests a positive interaction between international R&D and pharmaceutical research capabilities. As we discussed previously, we do not hypothesize main effects for the independent variables because we expect no or little effect of international R&D, *per se*, on firm innovation. Moreover, because Japan is not a center of biotechnology research, we do not predict a main effect for how absorptive capacity (with respect

to these technologies) affects patent output.

III. INDUSTRY CONTEXT

The Japanese pharmaceutical industry, which we employ as the empirical setting, provides an excellent context for testing hypotheses related to the internationalization of research and development for four reasons. First, the pharmaceutical industry is a high-technology industry that depends heavily on the outcome of research and development activities. Japanese pharmaceutical firms, on average, spend 12 percent of sales on R&D (JPMA, 1992). In addition, the Japanese domestic pharmaceutical market is the second largest in the world after the United States.

Second, the Japanese pharmaceutical industry is sufficiently populated to provide a viable sample that offers the research design advantages of focusing on one industry and firms from one nation. The top four domestic firms accounted for 25% of sales in the Japanese market in 1991. The top 30 domestic firms (by sales) accounted for 70% of sales in 1980 and 85% of sales in 1991. Moreover, the introduction of biotechnology has resulted in a number of firms entering the industry. Because many of these new entrants have international R&D activities, an advantage of our sample is that there exists substantial variance in the research skills of firms that do and do not conduct international R&D.

Third, competition in the Japanese pharmaceutical market is increasing due to changes in the regulatory environment. Government restrictions on the entry of foreign firms were lifted in the mid-1970's. In addition, the government introduced price controls for pharmaceuticals starting in the 1980's in order to decrease national expenditures on health (Reich, 1990). The price controls were designed to encourage pharmaceutical innovation by allowing newer drugs to receive higher prices. These two factors started to place pressure on pharmaceutical firms'

profits. In turn, the need for innovative products in order to obtain higher prices increased the motivation for Japanese firms to undertake research and development.

Finally, there has been a recent change in the technology necessary for pharmaceutical discovery that requires a response from firms involved in the industry - the development of biotechnology. Scientists working in Great Britain provided the intellectual development of molecular biology (Nelson, 1993). Much of the subsequent work in biotechnology has been performed in the United States (National Research Council, 1992). Both countries continue to be leaders in the field of biotechnology. Thus the expertise in biotechnology has developed in the U.S. and Western Europe. Cantwell (1992) documents that Japan has a revealed technological disadvantage in pharmaceutical research when compared to the U.S., the UK, Germany and Switzerland, which he identifies as the powerhouses of pharmaceutical research. Therefore, the geographic concentration of advantages in pharmaceutical and biotechnology research outside of Japan provides an obstacle for Japanese wishing to obtain competence in new pharmaceutical creation. It is for this reason that many Japanese companies have looked outside of Japan for pharmaceutical R&D.

IV. METHOD

Sample

Our sample includes 65 participants in the Japanese ethical pharmaceutical industry over the period 1980 to 1991. The sample includes the 30 largest Japanese pharmaceutical firms by sales and 35 new entrants to the Japanese pharmaceutical industry. We excluded the Japanese subsidiaries of European and U.S. pharmaceutical firms from the sample.

The new entrants were selected on the basis of industry analyses by Yano Keizai

Research Institute, Toyo Keizai, the Pharmaceutical Industry Forum (PIF) which indicated that these firms had either initiated pharmaceutical research or had pharmaceutical products for sale. The new entrants include textile, food, beverage, chemical, and steel firms. Most of these firms started participation in the pharmaceutical industry during the 1970's, yet have only relatively recently introduced their first products.

The year 1980 is an appropriate starting point for considering the international activities of these firms because this is the beginning of a period of real change for the Japanese pharmaceutical industry. The development of biotechnology, the changes in the government's payment policy and increased foreign competition were all affecting Japanese pharmaceutical industry during this period. Moreover, we found no evidence of international R&D prior to this year.

Approach

To test the hypotheses, we examine how international R&D activity affects firm-level pharmaceutical patent output. Before we define the variables, we highlight the merits of our approach.

We focus on firm pharmaceutical patent output because the impact of international R&D activities is not isolated within a particular foreign R&D lab. For example, many of the research managers we interviewed indicated that they planned to send domestic R&D personnel overseas and rotate them back into the domestic R&D labs. The goal was to diffuse the knowledge obtained abroad throughout a firm's research activities. Similarly, several managers mentioned establishing dual tracks of research - one at the foreign facility and one at a domestic facility. Some of the firms also held formal meetings of scientific staffs in order to share research findings. For example, one firm alternated scientific meeting sites between its Japanese lab and

its foreign lab in order to better acquaint the scientists with the activities occurring at each site.

In these cases, innovations and other benefits from international R&D are not necessary manifest or captured in the foreign facility but at other research facilities throughout the company. If we were only to focus on research output that was deemed to have occurred in a foreign facility, then our measure would miss important ways in which international R&D efforts were being managed to increase innovation. This is why we focus on firm-level pharmaceutical output rather than the output of the foreign R&D activities.[1]

In addition, by measuring firm pharmaceutical patent output, we are able to include in our comparisons firms that have and do not have international operations. We need this variance in the sample to properly test our hypotheses because they are interaction effects. Should we restrict the sample to firms with international R&D activities and find that previous pharmaceutical or fermentation research capabilities increase the patent output of firms, we cannot rule out that pharmaceutical or fermentation research capabilities *per se* affect patent output. In other words, the main effects of pharmaceutical or fermentation research capabilities, not their combination with international R&D affect patent output. Therefore, we must examine firms with and without international R&D activities to effectively test our hypotheses.

Variable Definitions

Dependent Variable

The dependent variable we employ to measure innovation is the count of U.S. drug patents granted to a firm in a given year, which we label DRUG PATENT COUNT. Examiners at the U.S. Patent and Trademark Office assign a primary patent class and subclass based on the information provided in the patent application. Patent classes reflect the technological and

functional principals of an application rather than products or industries. To restrict our examination to drug patents, we focus on patent classes 424 and 514. Patent class data have been previously used to assess firms' technical skills. For example, Jaffe (1986) used patent class data to characterize the technological positions of firms. Moreover, Griliches (1990) suggested that "it is possible to use a firm's distribution of patenting by field to infer its position in 'technological space'..." (p. 1702).

Patent counts have been used to measure innovative output in a number of previous studies (*e.g.*, Bound, et. al, 1984; Henderson and Cockburn, 1996). However, there are four issues with respect to our use of patent count that warrant comment. First, the propensity to patent is not necessarily constant across firms especially when looking across nations. However, as Cantwell (1989) notes, the variations between firm patenting levels seem to reflect systematic industry-specific and country-specific differences. Because we focus on Japanese pharmaceutical firms, our design holds constant industry and nationality.

Second, not all patented inventions result in innovations, as defined as new products. Once again, the design choice of the pharmaceutical industry mitigates this concern. In a study of pharmaceutical firms, Comanor and Scherer (1969) found a significant correlation between the number of patents and new products introduced. Henderson and Cockburn (1996) report preliminary results that indicate that Investigational New Drug Applications are highly correlated with "important" patents. Moreover, looking across many industries, Acs and Audretsch (1989) also found a high degree of similarity between patents and innovative activity.

Third, not all innovations are patented. Again, our choice of industry mitigates this concern. The pharmaceutical industry provides a setting where patents offer reasonable protection of proprietary knowledge. In his survey of companies about the effectiveness of

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[1] Focusing on firm-level pharmaceutical patent output raises the concern of controlling for many other firm

patents in protecting rights, Levin (1986) reported that only the pharmaceutical and chemical industries found patents to be an effective means of protecting competitive advantages of new technology. Moreover, the pharmaceutical industry is one in which patents play an extremely important role in protecting the intellectual capital of firms (Henderson and Cockburn, 1996). In this industry, more so than in many others, firms are likely to apply for patents when there is a development that may lead to a future drug. Pharmaceutical firm executives, with whom we conversed, noted that they tend to apply for patents within two to three months of discovery of a promising compound.

Fourth, we use U.S. patents to measure the technical skills of Japanese firms. Foreign firms, with and without operations in the U.S., patent in the U.S. system. Japanese firms had the largest percentage of U.S. patents granted, after U.S. firms, in 1986 (Wineberg, 1988). Because the U.S. represents the largest single market in the world for pharmaceutical products, foreign firms often seek to protect their intellectual property rights with U.S. patents. In addition, the Japanese system is very slow to grant patents, 5-7 years as opposed to 2-3 in the U.S., which might provide even more incentive for Japanese firms to patent their drug discoveries in the United States (Dunphy, 1988). One firm in our sample had over 450 U.S. patents granted during the period studied. Moreover, previous research has utilized United States patent counts to measure revealed technological advantage across countries (Cantwell, 1989).

We gathered patent data from the CASSIS Database of the Patent and Trademark Office of the U.S. Department of Commerce. These data are available on compact disk in selected depository libraries around the United States. We downloaded patent information for each company in the sample and used a FORTRAN program to extract patent class information.

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characteristics that would affect the dependent variable. We discuss our efforts to do so in the following section.

Independent variables

The variable INTERNATIONAL records whether or not a firm had international research and development activity within a given year. It takes the value of one for firms that engaged in international research and development activity, zero otherwise.[2]

The principal sources for information concerning entry and motivation were interviews with fifteen firms regarding their foreign research and development activities and a survey sent to the remaining firms in the sample. The interviews were conducted in Japan during May and June of 1993. In most cases, the company employees interviewed were members of the R&D strategy staff or the equivalent, who provided the study team with information regarding the companies' R&D strategies and general philosophy. Prior to the interviews the firms were sent summaries of their foreign research and development activity. The information for these summaries was obtained from public sources. The interviewers verified the accuracy of the activity reports and obtained information on any missing activities. Only in very isolated instances were any errors found. Moreover, such "errors" were often the companies updating us as to their current international R&D strategies. Given this confirmation of secondary sources' accuracy, we relied on the secondary sources to code the international activities for the remaining firms in the sample.

We included the following activities in our definition of international R&D: sponsored, collaborative, and controlled (Penner-Hahn, 1998). Sponsored research activities are those in which a firm funds research projects focused on the discovery of a specific product or phenomenon at a foreign university or R&D lab. Sponsored research involves the dissemination of knowledge back to the sponsoring firm and, in some cases, participation by a limited number

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[2] There might exist a time lag from the establishment international R&D activities until these activities affect firm innovative output. Our results do not materially change if we redefine INTERNATIONAL so that it takes the value 1 only after firms have international operations for at least 1 year, 2 years, or 3 years. Because we cannot

firm personnel in the foreign laboratories as researchers. Moreover, the sponsoring firm often receives rights to products produced as a result of the research. Collaborative research projects involve participation of a firm's employees in the foreign research activity, either through relocation and rotation of teams of employees to the foreign site or through undertaking dual tracks of research at home and abroad. Controlled research activities are those for which the firm establishes ownership either through the acquisition of a foreign facility or the establishment of a new facility. In these instances, the firm employs foreign researchers to work in these facilities and often transfers scientists from its domestic operation to the foreign site.

We excluded two types of activities from our definition of international R&D. We excluded patent licensing because the primary reason for such licensing is to sell a specific product in a foreign market, rather than to undertake research and development activities with the licensor. We also excluded clinical development facilities from our definition. Although a few firms established clinical development facilities during the study period, these activities were directed towards market adaptation and acceptance of existing research rather than the discovery and development of science. Therefore, we did not code either of these activities as international R&D for the purposes of this study.

Of the 65 firms in our sample, 36 undertook international R&D activities at some period during the sampling frame. Consistent with our priors and our discussions with the Japanese pharmaceutical executives, international R&D appeared to focus on sourcing knowledge that resided within countries with revealed technological advantage in pharmaceutical research. Of the 36 firms, 31 had investments in the U.S., the remaining 5 firms had investments in Germany

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justify the use of one of these lag structures over the other, we choose to present the results based on whether a firm has international R&D activities in a given year.

(2), the UK (1), Canada (1), and Israel (1).[3] As previously mentioned, Cantwell (1992) shows that the U.S., Germany, and the UK have a revealed technological advantage in pharmaceuticals.

We measure firms' pharmaceutical research capabilities by the count of drug patents in the three-year period prior to a focal year. We label this variable DRUG PATENT STOCK. Our aim in selecting the three-year period is to capture recent research skills. Moreover, by focusing on three years, we lessen the chance that a random, extreme event in one year disproportionately influences our measure of pharmaceutical research capabilities. Nevertheless, because the choice of a three-year period is arbitrary, we re-examined our tests by redefining this variable with periods as short as one year and as long as five years. Our results were not sensitive to the length of period over which we measured this variable.

An alternative way to measure such capabilities is to measure R&D spending or R&D intensity. We prefer DRUG PATENT STOCK because it is a focused measure of pharmaceutical capabilities. Due to data constraints, measures of R&D spending or R&D intensity are available only at the firm level, not the pharmaceutical business level. The difference in level of analysis is especially relevant for many entrant firms because they participate in many other lines of business.[4]

We measure firms' fermentation research capabilities by the count of patents in class 435 for the three-year period prior to a focal year. We label this variable FERMENTATION PATENT STOCK. Patent class 435, which is the Molecular Biology and Biochemistry class, is of particular interest because it includes all patents related to fermentation. Fermentation is identified as a complementary technical skill due to its importance to the production of many biotechnological products. Once again, because the length of time period over which we measure

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[3] The number of observations in the panel of firms with international R&D outside of the U.S. is too small to separately investigate these effects. Our results do not materially change if we remove the non-U.S. investments from our analyses.

this count is arbitrary, we also examined alternative period lengths. We examined periods from one to five years and found no material difference in the results that we present.

Controls

We expect that many other firm characteristics and strategies influence pharmaceutical patent output such as international experience, culture of innovativeness, size, or organization structure. To control for these effects we take advantage of the panel data design and include firm fixed-effects. The advantage of employing firm fixed-effects is that they will control for many firm characteristics and strategies that affect pharmaceutical patent output, which might or might not be observable and measurable to the researcher.

In some cases, where we do not estimate fixed effects models, we control for differences in patent output by firms that are entrants to the pharmaceutical industry. We create the dummy variable ENTRANT that takes the value one if a firm is an entrant to the Japanese pharmaceutical industry, zero otherwise.

Table 1 reports descriptive statistics for the variables. We have a balanced panel of 65 firms over 12 years (1980-1991). Because the patent stocks are calculated as the cumulative three-year lag of the drug and fermentation patent counts, the usable sample for the statistical analyses is a panel of 9 years (1983 to 1991).

V. ESTIMATION AND RESULTS

The empirical models that we estimate, in general, take the following form:

DRUG PATENT COUNT = f(INTERNATIONAL, DRUG PATENT STOCK, FERMENTATION PATENT

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[4] We were able to compare the correlation between DRUG PATENT STOCK and R&D for two years of our sample and found them correlated (r=0.61).

STOCK, CONTROLS).

Our first step in the estimation of these models is to employ OLS. The least squares estimator provides us with unbiased coefficient estimates and standard errors. Moreover, because of the panel data design we are able to include firm fixed-effects to better control for the existence of unobserved firm heterogeneity in the estimation.[5] However, because of the limited nature of the dependent variable (it is a count), the error term will not be normally distributed. The normality assumption derives the efficiency proof and the significance tests in OLS. Due to the central limit theorem, test statistics and confidence intervals will asymptotically hold. With respect to efficiency, OLS is the best linear unbiased estimator regardless of the distribution of the error term (Kmenta, 1986).

Because non-linear estimators might have increased efficiency over OLS, many studies of patent output rely on statistical techniques such as Poisson regression models (*e.g.*, Graves and Langowitz, 1993). However, non-linear models are often sensitive to the assumption of the distribution on which they are based and violations of this assumption lead to biased estimates. For example, Poisson regression models are based on the assumption that the dependent variable is drawn from a Poisson distribution. This distribution has equal mean and variance. Should this assumption not hold in the data, the likelihood function from which the estimates are derived is misspecified. We perform regression tests for over-dispersion (*i.e.*, inequality of the mean and variance) in our data and find significant evidence of such (Greene, 1997). Under these conditions, a common approach is to turn to negative-binomial regression analysis which allows the mean and variance of the Poisson process to vary by introducing an individual unobserved disturbance (*e.g.*, Hausman, Hall and Griliches, 1984; Henderson and Cockburn, 1996). Therefore, in addition to the least squares estimates, we also employ negative binomial

regression estimates when possible.

Column 1 of Table 2 first examines a specification that includes only the main effects of the variables of interest: INTERNATIONAL, DRUG PATENT STOCK, FERMENTATION PATENT STOCK.[6] These results provide a foundation from which to examine our hypotheses. The least-squares fixed-effects regression results show that DRUG PATENT STOCK and INTERNATIONAL have positive significant effects on DRUG PATENT COUNT. On average, international R&D operations increase drug patent output by 1.37 patents. While the sign of the coefficient estimate of FERMENTATION PATENT STOCK is positive, it does not significantly differ from zero. Finally, as a group, the firm fixed effects are significant which suggests that other firm-effects affect patent output. We attempted to estimate negative binomial regression models for this specification; however, the models would not converge.

Column 2 presents the test of our hypotheses by introducing the interaction terms of INTERNATIONAL with DRUG PATENT STOCK and FERMENTATION PATENT STOCK. Once again, we employ least squares with firm fixed-effects. Before examining the individual coefficient estimates, we test the incremental explanatory power of this model versus the model in column 1. As shown in the last row of column 2, the F-statistic of this test takes the value of 10.82 and is highly significant ($p<0.0001$). Adding the interaction terms significantly increases the explanatory power of the model. As we discuss shortly, it also significantly changes the interpretation of the marginal effect of INTERNATIONAL.

Turning to coefficient estimates, our hypotheses argue that the coefficients of the interaction terms will be positive and significant. The interaction term INTERNATIONAL*DRUG PATENT STOCK takes a significant positive sign as predicted by

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[5] The fixed-effect specification mitigates the possibility that the error terms among firms (across years) in the panel correlate.

Hypothesis 1. Although, the coefficient estimate of the interaction term INTERNATIONAL* FERMENTATION PATENT STOCK takes a positive sign as predicted by Hypothesis 2, the estimate is not significantly different than zero.[7]

Also interesting to note in column 2 is that the significance of the main effect of INTERNATIONAL disappears. When the values of DRUG PATENT STOCK and FERMENTATION PATENT STOCK are zero, the coefficient of INTERNATIONAL is interpreted as the marginal effect on the dependent variable. The non-significant value of this main effect suggests that international R&D activities of firms lacking pharmaceutical or fermentation research skills do not increase patent output. In other words, international R&D activities, *per se*, do not significantly affect DRUG PATENT COUNT. Moreover, the positive interaction terms indicate that international R&D activities have greater impact, the greater a firm's pharmaceutical or fermentation research skills.

While the results in Table 2 are consistent with our predictions, we want to investigate if they are statistical artifacts. For instance, the existence of outliers might be driving our results. To investigate this possibility, we examined the influence diagnostics from the reported models and removed observations with high leverage. We then re-ran the models in Table 2 finding consistent results with only marginal decreases in significance levels. For this reason, it appears that outliers do not drive the results.

Second, because greater pharmaceutical research skills might be a strong predictor of which firms undertake international R&D, we are concerned that the interaction term is actually capturing a curvilinear effect of DRUG PATENT STOCK on patent output (*i.e.*, INTERNATIONAL*DRUG PATENT STOCK measures DRUG PATENT STOCK^2). There are

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[6] ENTRANT does not vary over time for a firm; therefore, its coefficient cannot be estimated in the fixed-effects specification.

[7] The t-value of 1.33 is significant with a one-tailed test at the 90 percent confidence level.

two reasons why we believe this is not the case. First, we examined probit specifications where the dependent variable was INTERNATIONAL. We found that DRUG PATENT STOCK had only a marginally significant effect on the probability of undertaking international R&D. Second, we added DRUG PATENT STOCK^2 as an independent variable to the specifications presented in Table 2. The coefficient estimates of this variable were non-significant.

We are also concerned that the interpretation of the individual coefficient estimates in column 2 might be misleading due to the correlation between the interaction terms and the main effects. Moreover, there might be benefits in using negative binomial regression, which would not converge for this specification, to estimate the effects. To address these concerns we split the sample into observations where DRUG PATENT STOCK is zero and where it is greater than zero.[8] Hypothesis 1 predicts that INTERNATIONAL will have a significant positive effect in the sub-sample where DRUG PATENT STOCK is greater than zero. Likewise, we do not expect much, if any, effect of INTERNATIONAL in the sub-sample where DRUG PATENT STOCK is zero.

We choose zero as the value of DRUG PATENT STOCK to split the sample because we believe that there are important differences in the research capabilities of firms that have pharmaceutical patents over a period of time versus those that have none. However, because the choice of zero versus some other cut-off point is somewhat arbitrary, we examined alternative cut-offs to assess if the results were sensitive to our choice. We examined cut-offs from zero to 4 patents (which is greater than the median) finding consistent results to those presented.

Table 3 presents these estimates. The first two columns present least squares estimates with firm fixed-effects. The remaining four columns present results from negative binomial

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[8] Note, the sample is split by observation, not firm. This means that a firm (but not the same firm-year observation) will appear in both sub-samples if the value of DRUG PATENT STOCK is zero in some years and non-zero in others.

regression models. The odd-numbered columns present results from the sub-sample where DRUG PATENT STOCK is zero. The even-numbered columns present results from the sub-sample where DRUG PATENT STOCK is greater than zero. In each specification we include the variables INTERNATIONAL and FERMENTATION PATENT STOCK. We include ENTRANT in columns 5 and 6.[9]

We turn first to the least squares regression results, which are consistent with Hypothesis 1. For the set of observations where DRUG PATENT STOCK is greater than zero, INTERNATIONAL is highly significant and takes a value of 2.41. This suggests that, on average, international R&D increases patent output by 2.41 patents for this sub-group. In contrast, the set of observations where DRUG PATENT STOCK is equal to zero, INTERNATIONAL takes a much smaller value. While the coefficient estimate is statistically greater than zero, the coefficient estimate of 0.22 it is much smaller than the estimate of INTERNATIONAL for firms with DRUG PATENT STOCK is greater than zero. Our estimates suggest that the marginal effect of doing international R&D is over 2 patents greater (*i.e.*, ten times greater) for firms with pharmaceutical patents in the last 3 years versus firms without any pharmaceutical patents in the last 3 years.

Turning to the negative binomial estimates, the results are consistent with the least-squares estimates. In fact, they show more vivid differences in the effect of INTERNATIONAL between the two sub-samples. Columns 3 and 4 present estimates from specifications most similar to those in columns 1 and 2. Once again, the coefficient estimate of INTERNATIONAL is positive and significant in the sub-sample where DRUG PATENT STOCK is greater than zero. The coefficient estimate is non-significant in the sub-sample where DRUG PATENT

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[9] In sensitivity analyses, we included DRUG PATENT STOCK as an additional independent variable for the sub-samples where DRUG PATENT STOCK was greater than zero. In all cases, the coefficient estimate of

STOCK equals zero. Because the negative binomial regression model is non-linear, the coefficient estimates cannot be interpreted as marginal effects as with OLS estimates. The size of the marginal effect varies by the value of the independent variables; therefore, comparing coefficient estimates and not marginal effects across sub-samples will often be misleading. We calculated the marginal effect of INTERNATIONAL at the mean level of the independent variables within each sub-sample. The marginal effect in the sub-sample where DRUG PATENT STOCK is greater than zero is 3.70 and in the sub-sample where DRUG PATENT STOCK equals zero, 0.06. In other words, the marginal effect is almost four patents greater (*i.e.*, sixty times greater) for the set of firms with previous drug patents compared to those without drug patents. Finally, the significant value of α in column 4 indicates the existence of over-dispersion and supports the use of negative binomial over Poisson regression models. The coefficient estimate of α in column 3 is non-significant providing no evidence of over-dispersion for this sub-sample. In all cases where α was non-significant, we examined the specification using Poisson regression and found results consistent with the negative binomial results that we present. We chose to present the negative binomial results for consistency.

Columns 5 and 6 add the variable ENTRANT to the specification. This variable was not included in the least-squares fixed-effect estimation because it does not vary over time for a firm. However, because this effect might be an important determinant of patent output, we include it as a control in this specification. With ENTRANT in the specification, the results are entirely consistent with those in columns 3 and 4. Once again, the coefficient of INTERNATIONAL is positive and significant in the sub-sample where DRUG PATENT STOCK is greater than zero and non-significant in the sub-sample where DRUG PATENT STOCK equals zero. Moreover, the marginal effect in the sub-sample where DRUG PATENT STOCK is approximately three

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INTERNATIONAL remained highly significant with similar marginal effects. Moreover, the coefficient estimate of

patents greater (*i.e.*, 27 times greater) than the marginal effect in the sub-sample where DRUG PATENT STOCK equals zero. As a control, ENTRANT takes a negative and significant effect, which is consistent with the interpretation that these firms have lower rates of patent output.

The pattern of results in Table 3 with respect to the variable INTERNATIONAL support Hypothesis 1. We find a significant positive effect of INTERNATIONAL on patent output for firms that have previous drug patents. However, we find little effect of INTERNATIONAL on patent output for firms without previous drug patents. In these cases the effect is either statistically non-significant or, when significant, the marginal effect is small.

Finally with respect to the results in Table 3, we would like to draw attention to the consistent pattern by which FERMENTATION PATENT STOCK affects DRUG PATENT COUNT across all specifications in Table 3. The effect is positive and significant in all specifications where DRUG PATENT STOCK is greater than zero. However, the effect is non-significant in all specifications where DRUG PATENT STOCK equals zero. Our results indicate that fermentation research skills increase drug patent output, only if a firm possesses pharmaceutical research skills. Therefore, fermentation skills appear to be complementary skills for pharmaceutical research, but in the sense that firms must possess skills in pharmaceutical research to see their fermentation research skills pay-off.

To further investigate the results from Table 2 with respect to Hypothesis 2, we further split the sample by the value of FERMENTATION PATENT STOCK. Given the support of hypothesis 1, we first split the sample by observations where DRUG PATENT STOCK equals zero and is greater than zero. Within these two subgroups we further split the sample by observations where FERMENTATION PATENT STOCK equals zero and is greater than zero. Once again, we choose zero as the value by which to split the sample because we believe that

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DRUG PATENT STOCK was positive and significant.

there are important differences in the research capabilities of firms that have fermentation patents over a period of time versus those that have none. We examined alternative cut-offs to assess if the results were sensitive to our choice. We examined cut-offs from zero to 3 patents (which is greater than the median and mean) finding consistent results to those presented.

Table 4 presents these analyses. We present estimates from negative binomial regression models. The column headings describe which of the four sub-samples is estimated in each column. To further examine hypothesis 2, we wish to examine the effect of INTERNATIONAL while varying the level of FERMENTATION PATENT STOCK. For this reason we are most interested in comparing the estimates INTERNATIONAL in column 1 to that in column 2 and the estimate in column 3 to that in column 4. As stated, hypothesis 2 would hold if the effect of INTERNATIONAL in column 2 is greater than column 1 and in column 4 is greater than column 3. The estimates of INTERNATIONAL for the sub-samples where firms have no DRUG PATENT STOCK are both non-significant (columns 1 and 2). Among these firms, FERMENTATION PATENT STOCK does not heighten the impact of international R&D on drug patent output.

The estimates of INTERNATIONAL for the sub-samples where firms have DRUG PATENT STOCK greater than zero are both significant (columns 3 and 4). Moreover, the marginal effect of sub-sample where FERMENTATION PATENT STOCK is greater than zero (column 4) is 3.32 compared to the sub-sample where FERMENTATION PATENT STOCK equals zero (column 3), which is 1.63. This is comparison is consistent with hypothesis 2. Among these firms, FERMENTATION PATENT STOCK heightens the impact of international R&D on drug patent output.[10]

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[10] The least squares fixed-effect estimates of these models provide results that are consistent with those reported in Table 4. The differences are that the marginal effect in column 4 is only slightly greater than the marginal effect in column 3. In addition, the coefficient estimate if INTERNATIONAL in column1 becomes

Table 4 provides results that are hypothesis 2 given one refinement. Fermentation research capabilities appear to be complementary to pharmaceutical research capabilities in the sense that firms must possess skills in pharmaceutical research to see their fermentation research skills pay-off. Therefore, fermentation research skills only heightened the effect of international R&D when firms possess pharmaceutical research skills.

Overall, the results are consistent with hypothesis 1 and the refined form of hypothesis 2, which we described in the previous paragraph. However, before concluding we wish to further examine the robustness of our findings. First, we examined whether the non-significant results of INTERNATIONAL in Tables 3 and 4 might be driven by a lack of observations where INTERNATIONAL takes the value of one. In all sub-samples, INTERNATIONAL takes the value of one in at least 19 percent of the observations.

Second, because the choice to conduct international R&D activities is endogenous, we are concerned that unobservable firm characteristics might be associated with both the choice to engage in international R&D activities and pharmaceutical patent output. Under these conditions, our estimates will not have desirable statistical properties (*e.g.*, Masten, 1993 and Shaver, 1998). It is for this reason that we include firm fixed-effects in the least-squares estimation. Moreover, the specifications that include firm fixed-effects show results that are consistent with our hypotheses.

Third, some of the firms in our sample undertook multiple international R&D activities during the sample period. Because we do not have any priors on the functional form by which multiple international R&D activities will affect patent count, we prefer defining the variable as zero-one. Nevertheless, we investigate the sensitivity of our results when we re-define INTERNATIONAL as the count of international R&D activities. Table 5 replicates the

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marginally significant. Nevertheless, the size of the coefficient estimate is much smaller than in columns 3 and 4

specifications from Table 4, which presents our most refined analyses. There is little change in the results after re-defining INTERNATIONAL. The greatest changes are in column 1. ENTRANT becomes significant with a negative coefficient estimate and INTERNATIONAL becomes marginally significant with a positive coefficient estimate. The marginal effect of INTERNATIONAL is small when compared to the columns where DRUG PATENT STOCK is greater than zero. The coefficient estimates of INTERNATIONAL in columns 3 and 4 remain highly significant. Moreover, the marginal effect in column 4 continues to be greater than in column 3.

In summary, the empirical results are largely consistent with our predictions. We find that firms without pharmaceutical research capabilities tend not to benefit from international R&D activities. It is the combination of international research and development activities with existing skills in pharmaceutical research that increases pharmaceutical patent output. Moreover, fermentation research skills did not affect patent output unless firms also possessed pharmaceutical research skills. Finally, firms that possessed fermentation research skills appeared to reap greater marginal benefits from international expansion, provided that they possessed pharmaceutical research capabilities.

VI. CONCLUSION

We find that international R&D activities, *per se*, do not increase the patent output of Japanese pharmaceutical firms. While there are many benefits these firms can obtain from international R&D activities, there also exist many complications that they incur when making and managing such investments. For this reason, only under certain conditions are net benefits from international R&D to be realized. This finding corroborates previous research showing that

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(approximately one-eighth the magnitude).

not all firms enjoy success with their international expansion efforts even when there exist advantages to having international operations (Mitchell, Shaver, and Yeung, 1992).

We find that in order for firms' patent output to benefit from international R&D, they must possess research capabilities in addition to overseas R&D activities. This is consistent with our argument that knowledge based skills and capabilities are not simply acquired and transferred back to the parent. Rather, firms must have existing research capabilities in order to fully benefit from engaging in international R&D. This finding is consistent with the notion of absorptive capacity as described by Cohen and Levinthal (1990).

While we find that international R&D activities, *per se*, do not increase patent output, we want to stress that international R&D was beneficial for many firms in the sample. This finding confirms the often-argued motivation of international R&D, which is the ability to tap into technological capabilities that reside overseas.

Our results have important implications for reconciling theories of asset seeking FDI (*e.g.*, Kogut and Chang, 1991) with theories of asset based FDI such as internalization (*e.g.*, Buckley and Casson, 1976; Dunning, 1977). Asset seeking theories argue that firms make direct foreign investments in order to obtain assets that they do not currently posses. Asset-based theories, on the other hand, argue that firms possess proprietary assets that they choose to internalize by making direct investment overseas.

Our research suggests that while the Japanese pharmaceutical firms expanded in order to gain access to skills and technology not resident in Japan, only those firms with pharmaceutical research capabilities were able to enhance their patent output. Therefore, it appears that both asset seeking and asset based factors are important in the success of international research and development. Just as entering a country that has a large consumer market is no guarantee for successful asset based FDI, entering a market that has a unique knowledge base is no guarantee

of successful asset seeking FDI.

Many previous studies have shown the importance of R&D when assessing which firms expand overseas (*e.g.*, Hennart and Park, 1994) and when international expansion is successful (*e.g.*, Morck and Yeung, 1991,1992; Mitchell, et al, forthcoming). In this paper we identify when international R&D activities enhance firms' innovation. Continuing research into what determines successful international expansion, especially expansion activities that focus on the acquisition of knowledge within geographical locations, is warranted.

REFERENCES

Acs, Zoltan J. and Audretsch, David, Patents as a Measure of Innovation. Kyklos, (1989), 42, 2, 171-180.

Almeida, Paul, Knowledge Sourcing By Foreign Multinationals: Patent Citation Analysis In The U.S. Semiconductor Industry Strategic Management Journal, 17 (1996) (Winter): 155-165.

Bound, J., J. Cummins, Z. Griliches, B. H. Hall, and A. Jaffe. "Who does R&D and who patents?" in Z. Griliches, ed., R&D patents and productivity. Chicago: University of Chicago Press, 1984.

Buckley, Peter J. and Mark C. Casson, The Economic Theory of the Multinational Enterprise. Macmillan, London, 1976.

Cantwell, John, Technological Innovation and Multinational Corporations Cambridge, Mass: Basil Blackwell Inc, 1989.

Cantwell, John, The internationalisation of Technological Activity and its Implications for Competitiveness in Technology Management and International Business edited by Granstrand, Hakanson and Sjolander, New York; John Wiley and Sons, 1992.

Cantwell, John, The globalisation of technology: what remains of the product cycle model? Cambridge Journal of Economics, 19, (1995), 155-174.

Caves, Richard E., International corporations: the industrial economics of foreign investment. Economica , Vol. 38 (1971) February, pp. 1-27.

Cohen, Wesley M., & Levinthal, Daniel A., Absorptive Capacity: A New Perspective on Learning and Innovation. Administrative Science Quarterly, 35 (1990) 1, March, 128-152.

Comanor, W. S. & Scherer, F.M. Patent Statistics as a measure of technical change. The Journal of Political Economy, 77 (1969), 3, May-June, 392-398.

De Meyer, Arnoud., Management of International R&D Operations in Technology Management and International Business edited by Granstrand, Hakanson and Sjolander, New York; John Wiley and Sons, 1992.

DeMeyer, Arnoud and Mizushima, A., Global R&D Management. R&D Management, 19 (1989), 2, 135-145.

Dunning, John., Trade, location of economic activity and MNE: A search for an eclectic approach. In B. Ohlin, P. O. Hesselborn, and P. M. Wijkman, eds. The international allocation of economic activity. London: Macmillan. pp. 395-418, 1977.

Dunphy, J.F., Japan's Patent System Comes Under Fire. Chemical Week, July 27, 1988 Vol. 143, 4, pp. 26-28.

Fayerweather, John, International Business Management: A Conceptual Framework. McGraw-Hill Series in International Business. New York: McGraw-Hill, 1969.

Grace, E., Biotechnology Unzipped: Promises and realities. Joseph Henry Press, Washington, D. C. 1997

Graves, S. B. and N. S. Langowitz Innovative productivity and returns to scale in the pharmaceutical industry. Strategic Management Journal 14 (1993)., 593-605.

Greene, William, Econometric Analysis, 3rd edition. Upper Saddle River, NJ: Prentice Hall, 1997.

Griliches, Zvi, Patent Statistics as Economic Indicators: A Survey. Journal of Economic Literature, XXVIII (1990) (December), 1661-1707.

Hausman, J., B. H. Hall, and Z. Griliches. Econometric models for count data with an application to the patent-R&D relationship. Econometrica Vol. 52 (1984), No. 4, 909-938.

Henderson, Rebecca and Iain Cockburn. Scale, scope, and spillovers: the determinants of research productivity in drug discovery. RAND Journal of Economics 27 (1996), 32-59.

Hennart, Jean-Francois and Y.-R. Park. Location, governance, and strategic determinants of Japanese manufacturing investment in the United States. Strategic Management Journal, 15 (1994), 419-436.

Hymer, S., The International Operations Of National Firms: A Study Of Direct Foreign Investment A Ph.D. dissertation, (1960) published by MIT Press, 1976.

Jaffe, A. B., Technological Opportunity and Spillovers of R&D: Evidence from Firm's Patents, Profits, and Market Value. The American Economic Review, 76 (1986) (5), 984-1001.

Japanese Pharmaceutical Manufacturers Association (JPMA). Data Book 1992. Tokyo, Japan, 1992.

Kmenta. Jan, Elements of econometrics, 2nd edition. New York: Macmillan Publishing Company, 1986.

Kogut, Bruce, Country capabilities and the permeability of borders. Strategic Management Journal, 12 (1991) (Summer): 33-47.

Kogut, Bruce. & Chang, Sea Jing Technological Capabilities and Japanese Foreign Direct Investment in the United States. Review of Economics & Statistics. 73 (1991) 3: 401-413.

Komaran, R.V., and Goodman, R. A., Acquisition of Domestic and Foreign Technologies by American Multinational Corporations. In Academy of Management Proceedings, Atlanta, GA, 1993.

Kuemmerle, Walter, Building effective R&D capabilities abroad. Harvard Business Review March, April, (1997) p. 61.

Levin, R. C. "A new look at the patent system" American Economic Review 76, no. 2 (1 May), 1986, p.200.

Masten, Scott E., Transaction costs, mistakes, and performance: Assessing the importance of governance. Managerial and Decision Economics, 14 (1993)119-129.

Mitchell. Will, J. Myles Shaver, & Bernard Yeung, Getting there in a global industry: impacts on performance of changing international presence. Strategic Management Journal 13 (1992) (September): 419-432.

Mitchell, Will, J. Myles Shaver, & Bernard Yeung, Foreign Entrant survival and Foreign Market Share: Canadian Companies' Experience in United States Medical Sector Markets. Strategic Management Journal, 15 (1994), 7, 555-567.

Mitchell, Will, Randall Morck, J. Myles Shaver, & Bernard Yeung. Forthcoming. Causality between International Expansion and Investment in Intangibles, with Implications for Financial Performance and Firm Survival, in Global Competition and Market Entry Strategies, J-F Hennart (ed.) Elsevier, North-Holland.

Morck, Randall & Yeung, Bernard, Why Investors Value Multinationality, Journal of Business, Vol. 64 (1991), No. 2, 165-188.

Morck, Randall & Yeung, Bernard, Internalization: An Event Study Test Journal of International Economics, vol. 33 (1992), 41-56.

National Research Council, U.S.-Japan Technology Linkages in Biotechnology: Challenges for the 1990's National Academy of Sciences, 1992.

Nelson, Richard R. (Ed.), National Innovation Systems. New York: Oxford University Press, 1993.

Penner-Hahn, Joan D., Firm and Environmental Influences on the Mode and Sequence of Foreign Research and Development Activities. Strategic Management Journal, (1998), 149-168

Pisano, Gary P., The R&D Boundaries of the Firm: An Empirical Analysis. Administrative Science Quarterly, 35 (1990), (1, March), 153-176.

Reich, M. R., Why the Japanese Don't Export more Pharmaceuticals: Health Policy as Industrial Policy. California Management Review(Winter 1990), 124-150.

Shaver, J. Myles, Accounting for endogeneity when assessing strategy performance: Does entry mode choice affect FDI survival? Management Science, 44 (1998)(4): 571-585.

Shaver, J. Myles, Will Mitchell and Bernard Yeung, The effect of own-firm and other-firm experience on foreign direct investment survival in the United States, 1987-1992, Strategic Management Journal, Vol. 18 (1997) (10), 811-824.

Teece, David J., Technology transfer by multinational firms: The resource cost of transferring technological know-how. Economic Journal, 87 (1976), 242-261.

Wineberg, A. The Japanese Patent System: A Non-Tariff Barrier to Foreign Businesses? Journal of World Trade, Feb., Vol. 22 (1988), 1, pp. 11-22.

Zaheer, Srilata, "Overcoming the liability of foreignness" Academy of Management Journal, April, Vol.38 (1995), No. 2, pp. 341-363.

TABLE 1
DESCRIPTIVE STATISTICS

(n=585[a])

VARIABLE	Mean	St.Dev.	Min	Max	Correlation 1.	2.	3.	4.	5.	6.
1. DRUG PATENT COUNT$_t$	3.23	5.23	0	35	1					
2. INTERNATIONAL$_t$	0.33	0.47	0	1	0.37	1				
3. DRUG PATENT STOCK$_{(t-1,t-3)}$	8.34	13.55	0	89	0.89	0.35	1			
4. FERMENTATION PATENT STOCK$_{(t-1,t-3)}$	2.94	5.15	0	30	0.38	0.19	0.39	1		
5. INTERNATIONAL*DRUG PATENT STOCK$_{(t-1,t-3)}$	5.00	13.08	0	89	0.81	0.54	0.87	0.34	1	
6. INTERNATIONAL*FERMENTATION PATENT STOCK$_{(t-1,t-3)}$	1.45	4.25	0	30	0.45	0.48	0.44	0.72	0.55	1
7. ENTRANT	0.54	0.50	0	1	-0.41	-0.18	-0.42	-0.06	-0.33	-0.19

[a] The usable sample in the presented empirical tests is a nine-year balanced panel of 65 firms.

TABLE 2

ANALYSES OF FIRM INNOVATION RATE

Least-Squares Estimates with Firm Fixed-Effects[a]

Dependent Variable: DRUG PATENT COUNT$_t$
(t-values in parentheses)
n = 585

	1.	2.
INTERNATIONAL$_t$	1.37***	0.33
	(4.10)	(0.86)
DRUG PATENT STOCK$_{(t-1,t-3)}$	0.11***	0.01
	(4.51)	(0.32)
FERMENTATION PATENT STOCK$_{(t-1,t-3)}$	0.05	0.05
	(0.89)	(0.72)
INTERNATIONAL* DRUG PATENT STOCK$_{(t-1,t-3)}$		0.10***
		(3.37)
INTERNATIONAL* FERMENTATION PATENT STOCK$_{(t-1,t-3)}$		0.08
		(1.33)
R^2	0.83	0.84
F	38.25^{+++}	39.10^{+++}
(d.f.)	(67, 517)	(69, 515)
F-test of incremental explanatory power of the additional independent variables, (d.f.)		10.82^{+++} (2, 515)

[a] Note, the specification does not estimate an intercept due to the inclusion of firm fixed-effects. ENTRANT does not vary over time for a firm; therefore, its coefficient cannot be estimated in the fixed-effects specification.

*p < 0.1, ** p< 0.05, *** p < 0.01 : two-tailed tests
$^{+++}$ p <0.001 : one-tailed test

TABLE 3

ANALYSES OF FIRM INNOVATION RATE:
SAMPLE SPLIT BY VALUE OF DRUG PATENT STOCK

Dependent Variable: DRUG PATENT COUNT$_t$
(t-values in parentheses)
[Marginal effects for the Negative Binomial estimates in square brackets, estimated at the mean of the independent variables]

Method:	Least Squares with firm fixed-effects[a]		Negative Binomial		Negative Binomial	
	1. Equal to zero	2. Greater than zero	3. Equal to zero	4. Greater than zero	5. Equal to zero	6. Greater than zero
Intercept			-1.71***	0.89***	-0.69*	1.15***
			(6.53)	(11.13)	(1.39)	(11.88)
			[-0.32]	[4.09]	[-0.13]	[5.26]
INTERNATIONAL$_t$	0.22*	2.41***	0.30	0.80***	0.57	0.65***
	(1.72)	(4.27)	(0.62)	(7.31)	(1.18)	(5.86)
			[0.06]	[3.70]	[0.11]	[2.97]
FERMENTATION PATENT STOCK$_{(t-1,t-3)}$	0.04	0.13*	-0.03	0.05***	0.01	0.05***
	(0.96)	(1.67)	(0.22)	(4.32)	(0.04)	(4.29)
			[0.01]	[0.21]	[0.00]	[0.22]
ENTRANT					-1.32**	-0.68***
					(2.27)	(6.33)
					[-0.24]	[-3.09]
α			1.95	0.84***	1.37	0.73***
			(1.33)	(9.64)	(1.11)	(9.11)
R^2	0.29	0.78				
F or $\chi 2$ (d.f.)	1.93^{+++} (31, 146)	20.61^{+++} (41, 235)	6.94^{+} (3)	12.46^{++} (3)	1331.94^{+++} (4)	1366.72^{+++} (4)
N	178	407	178	407	178	407

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$: two-tailed tests
$^{+}$ $p < 0.1$, $^{++}$ $p < 0.01$, $^{+++}$ $p < 0.001$: one-tailed test
[a] The fixed-effects models preclude the estimation of an intercept. ENTRANT does not vary over time for a firm; therefore, its coefficient cannot be estimated in the fixed-effects specification.

TABLE 4

ANALYSES OF FIRM INNOVATION RATE: SAMPLE SPLIT BY VALUE OF DRUG PATENT STOCK AND FERMENTATION PATENT STOCK

Dependent Variable: DRUG PATENT COUNT$_t$
(t-values in parentheses)
[Marginal effects in square brackets, estimated at the mean of the independent variables]

Method:	**Negative Binomial**			
	1. DRUG PATENT STOCK = 0 FERMENTATION PATENT STOCK = 0	**2.** DRUG PATENT STOCK = 0 FERMENTATION PATENT STOCK > 0	**3.** DRUG PATENT STOCK > 0 FERMENTATION PATENT STOCK = 0	**4.** DRUG PATENT STOCK > 0 FERMENTATION PATENT STOCK > 0
Intercept	-0.47 (0.36) [-0.07]	-0.98 (1.11) [-0.22]	0.82*** (10.69) [2.07]	1.64*** (13.74) [8.98]
INTERNATIONAL$_t$	1.05 (1.33) [0.17]	0.03 (0.04) [0.01]	0.65*** (3.15) [1.63]	0.61*** (4.50) [3.32]
ENTRANT	-1.96 (1.48) [-0.31]	-0.59 (0.97) [-0.13]	-0.63*** (2.98) [-1.59]	-0.85*** (6.35) [-4.65]
α	3.90 (0.96)	0.06 (0.05)	0.60*** (3.93)	0.74*** (7.57)
χ^2 (d.f.)	18.26*** (3)	0.61 (3)	115.22*** (3)	1062.31*** (3)
N	108	70	132	275

*p < 0.1, ** p< 0.05, *** p < 0.01 : two-tailed tests
*** p <0.001 : one-tailed test

TABLE 5

ANALYSES OF FIRM INNOVATION RATE: SAMPLE SPLIT BY VALUE OF DRUG PATENT STOCK AND FERMENTATION PATENT STOCK INTERNATIONAL RE-DEFINED AS A COUNT

Dependent Variable: DRUG PATENT COUNT$_t$
(t-values in parentheses)
[Marginal effects in square brackets, estimated at the mean of the independent variables]

Method:	**Negative Binomial**			
	1. DRUG PATENT STOCK = 0 FERMENTATION PATENT STOCK = 0	**2.** DRUG PATENT STOCK = 0 FERMENTATION PATENT STOCK > 0	**3.** DRUG PATENT STOCK > 0 FERMENTATION PATENT STOCK = 0	**4.** DRUG PATENT STOCK > 0 FERMENTATION PATENT STOCK > 0
Intercept	-0.47 (0.52) [-0.07]	-0.98 (1.14) [-0.22]	0.80*** (7.59) [2.00]	1.65*** (14.60) [9.07]
INTERNATIONAL$_t$	1.44* (1.74) [0.22]	0.64 (0.64) [0.15]	0.68*** (3.57) [1.72]	0.60*** (4.16) [3.30]
ENTRANT	-2.13** (2.17) [-0.32]	-0.72 (0.77) [-0.16]	-0.64*** (3.02) [-1.61]	-0.86*** (6.53) [-4.72]
α	2.36 (0.74)	0.00 (0.01)	0.53*** (3.67)	0.73*** (7.63)
χ^2 (d.f.)	21.26^{+++} (3)	1.33 (3)	121.05^{+++} (3)	1066.35^{+++} (3)
N	108	70	132	275

*p < 0.1, ** p< 0.05, *** p < 0.01 : two-tailed tests
$^{+++}$ p <0.001 : one-tailed test