The International R&D Location Choices of US Multinationals

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INTRODUCTION

Researchers have observed that MNCs in the same industries tend to locate their international R&D activities in close geographic proximity (e.g., Silicon Valley and Route 128). There is considerable interest in understanding why this R&D clustering occurs. Although many governments have implemented policies designed to lure foreign R&D, the kinds of policies which would be most effective depend critically on the factors influencing MNCs' R&D location choices. Uncovering the patterns of firm behavior underlying observed R&D location choices is the goal of this research.

In particular, it is important to know whether *heterogeneity* or *state dependence* or both are important sources of the observed patterns of MNC R&D location decisions. In the theoretical economics literature, it is often assumed that firms in the same industries cluster their R&D activities because of agglomeration economies (Krugman, 1991). Because firms cannot fully appropriate the benefits of their own R&D, positive externalities in the form of human capital or infrastructure development and knowledge leakages provide incentives for other firms to locate R&D nearby. In this case, firms' R&D location decisions exhibit *state dependence* (Heckman, 1981). In other words, prior decisions by other firms in the same industry to locate R&D in the same state/country actually *cause* an otherwise identical firm to locate its own R&D in the same place. Theoretically, the most compelling explanation for this causal link is the existence of significant agglomeration economies in some industries.

The second pattern of firm behavior consistent with the observed clustering of R&D is one in which past R&D decisions by other firms have no causal connection with current R&D location choices. Rather, firms (MNCs) simply have different preferences over R&D locations for exogenous reasons. These reasons are unrelated to past R&D decisions of other firms and could include many plausible explanations such as national factor endowments (e.g., research universities or endowments of minerals, petroleum, or other critical production inputs which make local R&D more attractive) or government subsidies and tax breaks aimed at developing particular industries. In this case, we would still observe same-industry MNCs being more likely to locate R&D in the same country. However, this choice is due to differences in exogenous (and often unobserved) preferences, or firm or country characteristics, referred to as *heterogeneity*.

In the R&D location choice case, it is important to know, from a managerial and public policy standpoint, whether behavior is due to state dependence or heterogeneity. Consider, for example, the state-dependent case in which an MNC in a given industry is more likely to locate R&D in a particular country because of the presence of other same-industry firms already doing R&D there. In such a situation, governments interested in attracting domestic R&D should focus on luring initial entrants into a particular area, and R&D tax breaks and subsidies could be an effective motivating factor. Alternatively, if MNCs' R&D location choices are explained by heterogeneous country-specific characteristics like research universities and skilled labor (or firm characteristics, such as R&D-intensity), then R&D tax breaks and subsidies would be less effective than investment in infrastructure and education (in the country-characteristics case) or targeting specific firms (in the firm characteristics case).

This study examines state-dependence- (i.e., agglomeration) and heterogeneity-based explanations for MNCs' international R&D location decisions. Although there are many studies of MNC location choice which examine agglomeration (see Head, et al., 1995), data constraints have hampered previous attempts to test for state dependence. In particular, a test for state dependence requires that important sources of unobserved heterogeneity—which might be the real underlying behavioral explanation—be carefully controlled for. In examining MNC R&D location choices, it is clear that there are at least three potentially important sources of heterogeneity. At the most aggregate level, country characteristics like factor endowments may explain location choices. In addition, characteristics of the industries in which the MNCs operate may also be important sources of heterogeneity. The technology and research processes in some industries may simply make them more subject to having significant agglomeration economies. Finally, characteristics of the MNCs themselves may be important explanations for location choice decisions. All these sources of heterogeneity—country effects, industry effects, and firm effects need to be controlled for to avoid inflating estimates of state dependence.

In the next section, I describe the research design and econometric techniques used in the paper. Section III describes the data set used in the estimations. Section IV contains the empirical results, and Section V concludes.

RESEARCH DESIGN

The model to be estimated is based on the notion that discrete outcomes or choices are generated by continuous variables that cross thresholds. In the present study, the continuous variable that generates the choice of whether or not an MNC affiliate *i* in a given country, *c*, conducts R&D is the profitability stemming from the R&D location choice. The continuous variable that generates the discrete choice outcome (relative profits from one location versus another) is not observed. Only the outcome is observed and the aim of the empirical analysis is to shed light on the underlying behavior that produces the choice outcome.

Suppose that in a given country and industry, there are N MNC affiliates observed over T time periods. Holding industry constant, whether or not the MNC affiliate conducts R&D in country *c* is recorded for the dependent variable. If the affiliate conducts R&D, this is denoted as $y_{ict}=1$, and if it does not conduct R&D, then $y_{ict}=0$. Note that the affiliate will conduct R&D in country *c* only if the relative profits from this activity, denoted y^*_{ict} surpass a certain threshold.

We do not observe y^*_{ict}, but we can model it as a function of several components:

$$y^*_{ict} = X_{it} + Z_{it} + e_{it} \tag{1}$$

where Z_{it} consists of purely exogenous country characteristics, X_{it}, past outcomes of y_{ict}, and current and lagged characteristics of MNC *i* and e_{it} is a random disturbance which may or may not be independent of X_{it}.

The behavioral model in this study differs from previous research on heterogeneity and state dependence in the literature on consumer brand choice and labor economics in one key aspect. In those fields, state dependence is modeled as, for example, the previous purchase decisions by consumer *i* among a set of K brands, or the previous labor force experience of individual *i*. In the present study, state dependence is defined as the past R&D location choices of *other* firms, *J*, rather than firm *i*. In the agglomeration literature, it is not firm *i*'s past location choices which make firm *i* more likely to locate in the same place again. Rather, it is the past location choices of other firms, *J*, which make an otherwise identical firm *i* more likely to locate in the same place. This is simply a special case of state dependence.

The basic regression model used in my analysis is as follows:

$$Y^*_{ict} = B_o + BX_{it} + GY_{cj,t-1} + DZ_{it} + u_{it} \qquad i = 1, 2, \ldots N; \; t = 1, 2, \ldots T \tag{2}$$

Y^*_{ict} is the latent (unobserved) relative profits to MNC *i* of locating R&D in country *c* at time *t*. X_{it} contains both current and lagged MNC characteristics. Specifically, X_{it} includes the export intensity of the affiliate and the lagged total R&D conducted by all the foreign affiliates belonging to the same MNC parent as affiliate *i*. Variable selection and measurement is discussed in greater detail in the next section. $Y_{cj,t-1}$ is the lagged R&D conducted by other MNC affiliates, *J*, in country *c* at time *t-1*, and DZ_{it} is a vector of country dummy variables. Because Y^*_{ict} is not observed, we use the discrete R&D location choices, y_{ict}, as the dependent variable.

I estimate (2) using a random effects probit for five different industries. To test for heterogeneity and state dependence, I estimate (2) with and without country dummies (i.e., state dependence only and state dependence and heterogeneity). I test for the joint significance of the country dummies using a likelihood ratio test.

DATA

The data set used in this paper is from the Benchmark and Annual Surveys of US Direct Investment Abroad administered by the Bureau of Economic Analysis.[1] For this study, I use the BEA data disaggregated at the individual foreign affiliate level for each MNC from 1989-1996. Here, I use only affiliates that list their major industry in one of the five 3-digit BEA industry codes: 281: Industrial Chemicals and Synthetics; 283: Drugs; 367: Electronic Components and Accessories; 371: Motor Vehicles and Equipment; and 384: Medical Instruments and supplies. Industries were selected based upon being both manufacturing and R&D-intensive industries.

The dependent variable, y_{ict}, is a 0-1 indicator variable which is equal to 1 if an affiliate conducts R&D and equal to 0 if not. Because affiliates are nested within countries, the indicator variable can be interpreted as whether affiliate *i* in country *c* at time *t* conducts R&D.

For the agglomeration variable, I use the lagged sum of all R&D conducted in a given country minus affiliate *i*'s lagged R&D. This is the $Y_{cj,t-1}$ variable discussed in the previous section. I subtract out affiliate *i*'s own previous period R&D to reflect the idea that in the agglomeration literature, firms are thought to cluster their activities because of prior location decisions of *other* firms.

I also include two firm-specific variables which were thought to influence affiliate R&D location choices. First, affiliate export intensity, defined as an affiliate's total export sales divided by its total sales, was expected to increase the likelihood that an affiliate would conduct R&D. From the world product mandate literature (see, for example, Crookell, 1986), MNC affiliates with product mandates typically conduct local marketing and/or R&D functions and are likely to be export-intensive. As can be seen in Table 1, the average affiliate export intensity varies considerably between the 5 industries. It is highest in electronic components, in which more than 50% of affiliate sales, on average, are destined for export. It is lowest in pharmaceuticals, where only 15% of affiliate sales are exported.

Second, I also include the lagged total MNC R&D. This variable is the sum of all the global R&D conducted by the US MNC parent. In other words, it does not include the parent's

US R&D but does include all the R&D conducted by all the parent's foreign affiliates. A priori, it was expected that MNCs with higher levels of R&D would be more likely to conduct R&D in any given country.

All variables were normalized to real 1982 PPI dollars using industry-specific deflators from the Bureau of Labor Statistics. All foreign currency variables are expressed in current US dollars in the BEA data set.

**************TABLES 1 AND 2 ABOUT HERE**********************

EMPIRICAL RESULTS

Table 2 shows the random effects probit models for all five industries. The last seven rows of table 2 give values for the following: Sigma(u_i)—the firm-specific variance component, Rho, a number between 0 and 1 which indicates whether a pooled estimator would be different from the panel data (random effects) estimator. The fifth row from the bottom in Table 2 gives the Chi-Square values for the likelihood ratio test for the joint significance of the country dummies for each industry. Note that in the first column for each industry, the random effects probit model is run without country dummies. The second column for each industry gives regression results for estimates with country dummies. Beneath this row are the following: the estimated log-likelihood for each model, the number of affiliate-year observations in each industry, the number of affiliates in each industry sample, and the overall model test statistic, which is a Wald Chi-Square test for all the parameters in the regression equation (except the constant) being zero.

The expected signs on all the independent variables were positive, and all were expected to be significant both with and without country dummies. Instead, I find that the inclusion of country dummies changed the estimates considerably—particularly the estimates of the agglomeration variable (lagged R&D conducted by other MNCs in country *c* in each industry—called Lagged Cty-Ind R&D). Note that for all five industries, when country fixed effects are not controlled (i.e., when there is state dependence but no heterogeneity), the agglomeration variable is significant and positive. However, when country-specific heterogeneity *is* controlled for, the agglomeration variable becomes insignificant in two of the five industries (It flips signs in Pharmaceuticals but remains significant!). Specifically, the agglomeration variable becomes insignificant in motor vehicles and medical instruments. It remains significant and positive in electronic components and industrial chemicals. It is intuitively logical that industries should differ in the extent to which agglomeration economies in R&D exist at all and/or influence the R&D location choices of firms.

Several other interesting results appear in Table 2. First, affiliate export intensity is positive and significant in every industry. The results are quite similar for the lagged MNC R&D variable (R&D conducted in the previous period by all the foreign affiliates of affiliate *i*'s parent). This variable is significant and positive in all the estimates, indicating that the likelihood that an affiliate will conduct R&D in country *c* at time *t* is positively related to the level of international R&D conducted in the previous period by the MNC. It may be that special skills or learning are involved in the conduct of global R&D by multinationals. In such a scenario, an MNC with higher levels of global R&D would be more likely to conduct R&D in any given country.

Finally, the likelihood ratio test for the joint significance of the country dummies (i.e., heterogeneity) is significant in all industries, and the firm effects, Sigma(u_i) are significant at the 1% level in every estimate. This result implies that in addition to affiliate export intensity and the global R&D of affiliate *i*'s parent, unobserved characteristics of affiliates are important explanations of the variance in R&D location choices.

CONCLUSION

This study examined the relative importance of state dependence and heterogeneity as explanations for the international R&D location decisions of US MNCs. Using disaggregated panel data and carefully controlling for heterogeneity across countries and firms, I showed that the prior R&D location choices of other same-industry MNCs (state dependence) mattered to the current R&D location decisions of MNCs in only two of five industries. Indeed, when unobserved heterogeneity across countries was not controlled for, the effect of other MNCs' prior R&D location choices appeared to significantly increase the likelihood that an otherwise identical MNC in the same industry would locate R&D in the same country. However, accounting for country characteristics eliminated this result in all but the electronics and industrial chemicals industries. In general, firm heterogeneity and country heterogeneity appear to be more important predictors of MNC R&D location choice than agglomeration economies stemming from the prior R&D location choices of other firms.

These findings are important for several reasons. First, they indicate that industries differ in the extent to which there are likely to be agglomeration economies in R&D. This makes considerable intuitive sense, given the idiosyncratic nature of the R&D process, both within and across industries. Second, from a policy standpoint, governments interested in luring technology- based jobs confront a more complex optimal policy mix. If R&D location choices were systematically state dependent, then luring initial entrants with policies like tax breaks could be effective. However, because this research shows that international R&D location choices are *not* systematically state dependent, and indeed, may be influenced more by firm, industry and country characteristics, effective "off-the-shelf" policies to lure domestic R&D would be difficult to design and implement.

ENDNOTES

[1]The statistical analysis of firm-level data on US multinational corporations reported in this study was conducted at the International Investment Division, Bureau of Economic Analysis, US Department of Commerce, under arrangements that maintained legal confidentiality requirements. Views expressed are those of the author and do not necessarily reflect those of the Department of Commerce.

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Table 1: Descriptive Statistics

	Pharmaceuticals		Electronic Components		Motor Vehicles And Equipment		Industrial Chemicals		Medical Instruments	
	Mean	St Dev	Mean	St Dev	Mean	St Dev	Mean	St Dev	Mean	St Dev
Affiliate R&D	5687	21904	1236	4579	11126	72087	855	3185	1263	5090
MNC R&D	132034	132977	47935	175104	153141	385251	27440	51236	55590	101219
Cty-Ind R&D	101596	145559	29176	34658	208325	395563	24892	25981	22094	29752.96
Aff. Export Int.	0.152146	0.263605	0.53492	0.939104	0.282152	0.294274	0.224611	0.312376	0.302746	0.35326
Affiliate Sales	116328	207703	88134	199490.7	843812	2910474	137512	293779	68163	130358

Table 2: Random Effects Probit Results for Affiliate R&D

	Pharmaceuticals		Electronic Components		Motor Vehicles And Equipment		Industrial Chemicals		Medical Instruments	
Aff. Export Intensity	1.102205[c] (0.249734)	2.164098[c] (0.410402)	0.103500 (0.071370)	0.256534[b] (0.103358)	0.946315[c] (0.319807)	1.535408[c] (0.339597)	1.007361[c] (0.213008)	1.149894[c] (0.223103)	0.341349 (0.225215)	0.485982[a] (0.283611)
Lagged MNC R&D	0.000005[c] (0.000001)	0.000006[c] (0.000001)	0.000001[a] (0.000000)	0.000001[c] (0.000000)	-0.0000003 (0.0000004)	0.000001[b] (0.0000002)	0.000006[c] (0.000001)	0.000003[c] (0.000001)	0.000008[c] (0.000001)	0.000006[c] (0.000001)
Lagged Cty-Ind R&D	0.000006[c] (0.000001)	-0.000004[b] (0.000002)	0.000009[c] (0.000003)	0.000014[b] (0.000006)	0.000001[c] (0.0000003)	-0.0000001 (0.000001)	0.000014[c] (0.000003)	0.000009[b] (0.000004)	0.000005 (0.000003)	-0.000003 (0.000005)
Constant	-0.162271 (0.125967)	-0.484851[b] (0.233895)	-1.293125[c] (0.211763)	-3.910016[c] (0.519030)	-0.934730[c] (0.212704)	-2.125382[c] (0.468612)	-1.745552[c] (0.134456)	-11.02855[c] (0.854047)	-0.804767 (0.141999)	-2.091038[c] (0.504715)
Sigma(u_i)	3.090358[c] (0.167991)	3.589730[c] (0.221473)	2.995415[c] (0.211695)	3.120323[c] (0.174895)	2.764248[c] (0.256867)	3.479522[c] (0.281453)	2.685777[c] (0.141477)	3.120020[c] (0.177909)	2.754105 (0.191720)	2.823540[c] (0.203741)
Rho	0.905216[c] (0.009328)	0.927986[c] (0.008246)	0.899724[c] (0.012752)	0.906859[c] (0.009469)	0.884274[c] (0.019019)	0.923705[c] (0.011401)	0.878248[c] (0.011265)	0.906843[c] (0.009634)	0.883519 (0.014328)	0.888547[c] (0.014292)
Country effects LR test (Chi^2)	-	112.144[c]	-	100.844[c]	-	92.678[c]	-	92.308[c]	-	24.694[a]
Log-Likelihood	-685.713	-629.641	-934.169	-883.747	-581.678	-535.339	-1124.973	-1078.819	-499.006	-486.659
Observations	2223	2223	2422	2422	1477	1477	3013	3013	1224	1224
Affiliates	568	568	627	627	379	379	730	730	316	316
Chi^2 model	107.21[c]	202.42[c]	14.57[c]	195.20[c]	21.48[c]	146.60[c]	53.74[c]	309.71[c]	39.03[c]	85.78[c]

Notes: [a]Significant at the 10% level, [b]Significant at the 5% level, [c]Significant at the 1% level