MULTINATIONAL FIRMS AND KNOWLEDGE DIFFUSION: EVIDENCE USING PATENT CITATION DATA

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ABSTRACT

Analysis of patent citation data reveals significant bi-directional knowledge flows between MNCs and their host countries. On an average, MNCs gain more than they contribute to host country knowledge. However, this pattern is found to vary across specific countries and sectors, depending on the knowledge-intensity of MNC investments.

INTRODUCTION

Much of the recent debate on globalization has centered on whether MNCs contribute as much to as they gain from their host countries. To address one aspect of this broad issue, I study how the extent of knowledge flows from MNCs to their host countries compares with knowledge acquisition by MNCs from their host countries. While incoming foreign direct investment (FDI) by MNCs can be a source of knowledge for the host country's domestic players, it can also be a channel through which domestic technology falls into the hands of foreign competitors. Therefore, except for countries that have little unique technology of their own, it is important to consider *bi-directional* knowledge flows, and to study *net* knowledge gains from FDI. The potential "leakage" of domestic knowledge through FDI is a particularly real issue for technologically advanced countries, which are the focus of this paper.

I measure bi-directional knowledge flows between local subsidiaries of a foreign MNC and host country domestic players, and also between the MNC home base and the host country, using data on over one million patent citations originating from 4,400 MNCs and domestic organizations in the US, Japan, Germany, France, UK and Canada. In its use of patent data for studying the role of MNCs, the current paper extends related work by Almeida (1996), Branstetter (2000) and Frost (2001) through a closer look at *bi-directional* knowledge flows and at differences across specific countries and sectors. It also brings to the table a richer dataset that allows a more general analysis using an improved methodology.

HYPOTHESES

For international knowledge diffusion to be an interesting issue to study, the first result to establish is that knowledge does not automatically get transmitted across countries. While localization of knowledge spillovers has been previously studied (Jaffe, Trajtenberg and Henderson, 1993; Jaffe and Trajtenberg, 2002), I re-visit this question to address concerns about over-estimation of this effect by the existing methodology (Thompson and Fox-Kean, 2004):

H1. *The probability of knowledge flow within a country exceeds that between different countries, even after controlling for technological specialization of countries.*

A widely accepted "fact" is that cross-border flow of complex knowledge is easier within an MNC than between independent organizations (Hymer, 1976; Buckley and Casson, 1976; Teece, 1986; Hedlund, 1986; Bartlett and Ghoshal, 1989; Kogut and Zander, 1993; Nohria and Ghoshal, 1997). Before moving on to my main analysis, I formally verify if this is also true:

H2. *The probability of cross-border knowledge flow within an MNC exceeds that between different organizations, even after controlling for technological proximity of an MNC's divisions.*

After establishing strong intra-national and intra-MNC knowledge flows as above, I turn to detailed analysis of knowledge flows involving MNC subsidiaries. Simply looking at *uni-directional* knowledge flows from an MNC subsidiary to its host country misses the point that knowledge also flows from the host country to the MNC subsidiary (Almeida, 1996; Frost, 2001), and ultimately also from the subsidiary to the MNC home base (Hedlund, 1986; Bartlett and Ghoshal, 1989). My next task therefore is to empirically establish the presence of such *bi-directional* knowledge flows involving MNC subsidiaries:

H3. *There are significant bi-directional knowledge flows between an MNC subsidiary and its host country.*

H4. *There are significant bi-directional knowledge flows between an MNC subsidiary and its home base.*

Existing literature also suggests that knowledge flows are particularly strong between different foreign MNC subsidiaries located in the same country (Head, Ries and Swenson, 1995; Feinberg and Majumdar, 2001; Feinberg and Gupta, 2003), which I verify next:

H5. *There are significant knowledge flows between local subsidiaries of different foreign MNCs.*

Now I come to the crux of this paper, which is to study if MNCs contribute less knowledge to their host countries than they gain from them. If MNC subsidiaries are involved in advanced research or innovative product development, more knowledge spillover benefits might result to the host country. Existing evidence suggests, however, that even MNC subsidiaries actively doing R&D typically focus on adaptation of their parent firms' products for the local markets (Mansfield, Teece and Romeo, 1979), or on monitoring host country technological developments (Almeida, 1996; Florida, 1997; Frost; 2001).

Raising further doubts about net knowledge benefits from FDI to the host countries is the potential adverse selection in overseas operations of MNCs in terms of their "knowledge-intensity". Kogut and Chang (1991) find that a disproportionately large fraction of Japanese FDI in the US is restricted to industries where the Japanese MNCs lag behind. Similarly, Shaver and Flyer (2000) and Chung and Alcacer (2002) find that technologically advanced MNCs are less likely to locate sophisticated facilities overseas and, when they do, are likely to locate them far from domestic players. Cantwell and Janne (1999) find that foreign subsidiaries of even technologically advanced MNCs focus on the specific technologies where these MNCs lag behind. All of this raises a concern that host countries might lose more from "leakage" of

domestic knowledge to MNCs than they gain in the form of knowledge spillovers from MNCs. This motivates the next hypothesis:

H6. *The probability of knowledge flow from the host country to an MNC subsidiary exceeds that from the MNC subsidiary to the host country.*

Extending the above logic, the relative extent of knowledge flow from the host country to MNCs should be most intense in settings where the domestic firms do more "knowledge intensive" work than the MNC subsidiaries. Knowledge intensity of operations can be measured using R&D intensity, or the ratio of R&D to total production, giving the following hypothesis:

H7. *The probability of knowledge flow from the host country to MNC subsidiaries is particularly high in countries and sectors where the R&D intensity for MNC subsidiaries is significantly lower than that of the host country players.*

Finally, if foreign subsidiaries of an MNC serve as listening posts for the home base, these subsidiaries should improve the absorptive capacity of the MNC *home base* for knowledge originating in the host countries. This gives the final hypothesis:

H8. *The probability of knowledge flow from a host country to a foreign MNC's home base is greater when the MNC's local subsidiaries are more active in knowledge-related activities.*

DATA

Following existing literature, I use patent citation data to track micro-level knowledge flows. Citations between patents leave behind a trail of how a new innovation potentially builds upon existing knowledge. This gives a way of measuring knowledge diffusion, motivating common use of these data for research. Though patent citations do not correspond exactly to knowledge flows, and hence are a noisy measure, their use is defensible at least in large samples. One challenge in using patent data is that only a subset of all innovations gets patented (Levin, Klevorick, Nelson and Winter, 1987). Since this makes counts of patents and patent citations misleading as raw measures, I estimate the probability of knowledge flow between innovations that do get patented, without making any assumption that patents capture all innovations.

My dataset combines raw data from the US Patent Office (USPTO) with an enhanced version from Jaffe and Trajtenberg (2002). I examine USPTO successful patent applications made during 1986-1995 by inventors from the six most innovative economies: US, Japan, Germany, France, UK and Canada. The number of such patents in my dataset is about 0.9 million, which is about 91% of all USPTO patents for this period. About 83% of these patents are owned by firms or organizations (and not just individuals), and are the focus of this study.

In order to ascertain whether a patent originates from a domestic organization or a local subsidiary of a foreign MNC, I had to identify whether an assignee firm had its home base in the country of innovation (e.g., IBM in the US), or if it was a local subsidiary of a foreign MNC (e.g., IBM in Germany). I performed this parent-subsidiary match for about 10,000 assignees using Compustat-based parent firm identifiers (Jaffe and Trajtenberg, 2002), Stopford's *Directory of Multinationals* (1992), *Who Owns Who* directories (1991), and company web sites. The resulting dataset had 556,000 patents, or about 73% of all assigned patents for 1986-1995.

CITATION-LEVEL REGRESSION METHODOLOGY

Imagine a population comprised of all potential patent citations. I estimate how the probability of citation between these potentially citing and cited patents varies with their characteristics, assuming that it takes a logistic functional form. The dependent variable *y* is 1 if a citation takes place, 0 otherwise. Since citations between random patents are extremely rare, I use a "choice-based sampling" procedure that deliberately oversamples observations with $y = 1$. Since this stratification is done on the dependent variable, using the usual logistic regression technique would lead to a selection bias. I avoid this by using the *weighted exogenous sampling maximum likelihood* (WESML) estimator suggested by Manski and Lerman (1977), which takes differences in sampling frequencies into account in constructing the likelihood function.

It is important to account for the fact that technologically similar patents have a greater probability of citation (Jaffe, Trajtenberg and Henderson, 1993). Existing literature typically controls for the 3-digit technological class of the citing and cited patents to achieve this. However, this is insufficient and can lead to biased inference (Thompson and Fox-Kean, 2004). To overcome this, I use information on the more detailed 9-digit primary subclass as well as secondary subclasses in the analysis. To account for other factors affecting citation probability, my regressions also use dummy variables for citing year, technological category, citing country and time lag between patents.

RESULTS

Intra-Country and Intra-MNC Knowledge Flows (Hypotheses 1 and 2)

Even with the above detailed controls, regression analysis found knowledge flows to be particularly strong within the same country or the same MNC. Patents from different organizations within the same country are about 52% more likely to have a citation than are otherwise similar patents from different organizations in different countries. Analogously, patents from different international divisions of the same MNC are around three times as likely to have a citation than are comparable ones from different organizations in different countries.

Details of Knowledge Flows Involving MNC Subsidiaries (Hypotheses 3, 4, 5 and 6)

Figure 1 uses examples to illustrate how I break up probability of intra-national knowledge flow into four categories: between domestic entities (D→D), from domestic entities to local subsidiaries of foreign MNCs (D→M), from MNC subsidiaries to domestic entities (M→D) and between MNC subsidiaries (M→M). The reference category is the cross-border inter-organizational knowledge flow, compared with which all four kinds of intra-national knowledge flow effects were found to be significantly larger.

Figure 1 about here

The probability of M→D knowledge flow was found to be 30% smaller than for D→M flow, and a statistical test of equality was easily rejected. D→M probability was found to be comparable to D→D probability. Thus, the intensity of knowledge flow from domestic organizations to MNC subsidiaries is statistically no different from that between host country organizations themselves, but that from MNC subsidiaries to domestic players is significantly

lower. I also found that MNC subsidiaries are particularly good at learning from each other, with the M→M probability being much greater than that for even D→D or D→M knowledge flow.

Figure 1 also breaks down the intra-MNC knowledge flow into two categories: from the MNC subsidiary to the home base (S→H), and from the home base to the MNC subsidiary (H→S). The estimates for the two were comparable. This is consistent with a view of MNCs as a "learning organization", where subsidiaries not only build upon the knowledge of the home base but also contribute to further learning (Kogut and Zander, 1993; Dunning, 1993).

Cross-Country Differences in Bi-directional Knowledge Flows (Hypothesis 7)

The aggregate finding that D→M knowledge flow probability is statistically greater than for the M→D case was found to hold true only for the US, Japan and Germany. The equality of flows in the two directions could not be rejected for France and Canada, while the trend actually reversed for the UK. One explanation for this pattern is that the domestic firms and organizations in the US, Japan and Germany are usually technologically more advanced than the typical foreign MNC subsidiaries based there, and therefore do not have much to learn from the latter. R&D data from OECD (1998) supports this explanation: the R&D intensity of domestic firms and foreign MNCs differs most in Germany and Japan, with the domestic R&D intensity being almost twice of that for MNC subsidiaries. Likewise, the fact that UK is the only country where the intensity of D→M knowledge flow is significantly *weaker* than that of M→D flow is consistent with UK being the only country where the R&D intensity of MNCs actually *exceeds* that of domestic players.

Cross-Sector Differences in Bi-directional Knowledge Flows (Hypothesis 7)

Next, I examined individual sectors within the US. For "Drugs & Medical" and "Chemical", knowledge flows from MNCs to domestic firms were found to be as intense as those in the other direction. This is consistent with analysis by Chung and Alcacer (2002), who find that both leaders and laggards from overseas locate technologically advanced operations in the US for these sectors. For example, foreign pharmaceutical firms invest heavily in R&D in the US in order to keep abreast with the latest developments: R&D intensity for Pharmaceuticals is 10.5% for MNC subsidiaries, which is even higher than the 6.5% figure for domestic firms (OECD, 1998).

Two sectors where M→D knowledge flows were found to be significantly weaker than D→M knowledge flows are "Computers & Communication" and "Electrical & Electronics", consistent with Chung and Alcacer's (2002) finding that FDI in these sectors is dominated by industry laggards. For example, R&D intensity for Computers is 4.5% for MNC subsidiaries and 13.5% for domestic firms in the US (OECD, 1998). This is also consistent with Florida's (1997) survey results that 37% of the MNC subsidiaries in the US for these sectors have a "listening post" role, as opposed to only 17% in "Chemicals" and 25% in "Drugs & Medical". For the "Mechanical" sector, localized knowledge flows involving MNC subsidiaries were all quite weak, possibly because it is not a particularly knowledge-intensive sector.

Cross-Border Citations between Different Firms (Hypothesis 8)

Next, I examined direct effect of an MNC's subsidiary activity on the probability of cross-border citation between the host country domestic players and the MNC home base. A 1% increase in inventive activity by a foreign MNC's local subsidiary was found to increase the

citation probability by the MNC's *home base* to the host country's domestic players by 3%. In contrast, there is only a 1.1% corresponding increase in citation probability by the host country's domestic players to the MNC's home base. Thus, though increased MNC activity is associated with increased cross-border patent citations in both directions, the asymmetry found in intra-national citations exists even for the cross-national case: the MNC *home base* gains more in terms of inter-organizational knowledge spillovers from its overseas investments than the domestic players in the host country do.

DISCUSSION AND CONCLUDING REMARKS

Knowledge spillovers from inward FDI, particularly in countries that possess valuable technology of their own, are not free – they come at the cost of significant "leakage" of domestic knowledge. For the policy maker, this implies that not just the magnitude of FDI but also its relative level of sophistication should be considered in pursuing knowledge spillovers. Policies should focus on attracting FDI that is technologically sophisticated, and in sectors where the host country is a lagging behind. The findings also suggest that *outward* FDI might be at least as effective as *inward* FDI for acquiring knowledge originating abroad. Thus, instead of only promoting inward FDI and discouraging outward FDI, a country might gain from encouraging its domestic firms to also seek out foreign sources of knowledge.

The focus of this paper has been on developed countries, partly because patent data is not as meaningful a source of information for developing countries. But the general point made in the paper should probably still apply: not just the magnitude but also the knowledge-content of investments by foreign MNCs affects the possibility of knowledge spillovers from FDI. Different kinds of MNC activity, like state-of-the-art R&D or production facilities versus simple assembly operations, might have different implications for knowledge flows. Future research on FDI could therefore gain from focusing less on just measurement of knowledge spillovers, and more on the conditions needed for and the mechanisms driving such spillovers.

COMPELTE PAPER AND REFERENCES AVAILABLE FROM AUTHOR'S WEBSITE

Figure 1: Six kinds of knowledge flows