Proceedings of International Conference on Strategies in Volatile and Uncertain Environment for Emerging Markets
July 14-15, 2017
Indian Institute of Technology Delhi, New Delhi
pp.435-444

Geographical Clustering and Quality of Subsidiary Innovation in Developing Economies: A Comparative Study of Two Semiconductor Design Companies in India

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Abstract

Clustering has been found to have a positive impact on firm innovation and performance across the world. Clustering leads to local knowledge spillover which is vital to innovation. This paper attempts to study the impact of clustering on the quality of subsidiary innovation in a developing country context of India. Comparing the patent data of two semiconductor design subsidiaries located in India, this paper analyzes the moderating effect of clustering on the relationship between subsidiary age, local knowledge spillover, internal networks and the quality of subsidiary innovation. Being located in a cluster is found to have a positive impact on the quality of innovation. Clustering has also been found to positively moderate the impact of subsidiary age and internal network on the quality of innovation while it has been found to have no moderating impact of local knowledge spillover on the quality of subsidiary innovation.

Keywords: Geographical Clustering, Innovation, Knowledge Spillover, Local Internal Networks, Multinational, Subsidiary

1. Introduction

While researchers have come up with varying definitions for clusters, most of them agree that *"a cluster is a group of firms from the same or related industry located in the same or near geographic locations"* (Mudambi and Swift, 2012). Firms located in clusters have shown to innovate more and perform better (Baptista and Swann, 1998; Poon *et al.*, 2013) due to availability of specialized resources and local knowledge spillovers (Griliches, 1991).

One of the prime reasons for knowledge seeking MNEs to locate subsidiaries across the world is to access the unique knowledge available in those locations. Combining the external knowledge along with its internal knowledge and processes makes the MNE highly innovative and provides competitive advantage. Knowledge required for technological innovation is deemed to be highly tacit in nature (Mudambi and Swift, 2012) which is transferred through informal communication (Saxenian and Hsu, 2001) locally (Jaffe, 1986; Acs *et al.*, 1992; Jaffe *et al.*, 1993; Almeida

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and Kogut, 1999). Considering that specialized knowledge spill over occurs locally, we expect MNE subsidiaries located in clusters to be more innovative as compared to the ones located outside the cluster.

There are two complementary theories that attempt to explain innovation in MNEs located in clusters. The "physical attraction" thesis recognizes that MNEs have the best chance to be innovative by locating within the cluster due to valuable knowledge flows which occur through development of local relationships (Cantwell and Mudambi, 2011). On the contrary, the "oligopolistic deterrence" thesis proposes that innovative MNEs should stay away from technology clusters. Since these MNEs already are innovative, it is deemed that the losses from outward knowledge spill over to competitors is likely to be higher than the inward knowledge gain from them (Shaver and Flyer, 2000).

Prior studies on geographical clustering and innovation have focused on subsidiaries located in the developed countries where local institutions are advanced and mature. There is a need to look at the impact of geographical clustering on subsidiary innovation from the developing country context lens where institutions are under developed but foreign direct investments have been increasing in the past decade (UNCTAD, 2014). Moving away from using country as a proxy for locational choice, recent studies have started recognizing the importance of regions or clusters and their influence on innovation (Cantwell and Iammarino, 2000; Cantwell and Piscitello, 2005; Poon *et al*., 2013). However, more research needs to be done to explain the subnational influence on subsidiary innovation especially in the developing country context.

This study proposes to fill the above gaps. In the context of India which is a developing country, we attempt to answer the following research questions

- Does locating within cluster lead to higher quality of subsidiary innovation?
- Does geographical clustering positively moderate the relationship between subsidiary age and quality of subsidiary innovation?
- Does geographical clustering positively moderate the effect of local knowledge spillover on quality of subsidiary innovation?
- Does geographical clustering negatively moderate the effect of internal networks on the quality of subsidiary innovation?

Using patent data, we attempt to answer the above research questions by conducting a comparative study of two semiconductor design companies in India. By understanding the role of technological clusters on subsidiary innovation in a developing country context, this paper adds to the growing body of knowledge of MNEs and geographical clustering of innovation. This study also helps to extend and confirm (or contradict) findings from previous studies about the impact of geographical clustering on the quality of subsidiary innovation from a developing country context. The rest of the paper is organized as follows. In section 2, we discuss the theory of cluster and local knowledge spill overs. Hypotheses around the three research questions stated above are formulated. Section 3, discusses the data and methodology used in the study. Section 4 shows the results and section 5 presents concluding remarks and limitations of the study.

2. Literature Review: Geographic Clusters and Innovation

Research asserts that innovation is highly clustered (Jaffe *et al*., 1993; Audretsch and Feldman, 1996; Keller, 2002) due to three reasons. First, the presence of firms within the same industry in a geography leads to specialization externalities and intra-industry knowledge spill overs. Second, presence of firms in related industries in the same geography leads to diversity

externalities and inter-industry knowledge spill overs. Finally, presence of scientific labs or universities in the same geography contributes to science and technology spill overs (Cantwell and Piscitello, 2005).

Higher levels of tacit knowledge considered essential for valuable innovations (Mudambi and Swift, 2012) is highly contextual and extremely difficult to code and requires frequent and direct contact for transmission (Audretsch, 1998; Cantwell and Santangelo, 1999; Saxenian and Hsu, 2001; Sorenson *et al*., 2006) through social networks (Agrawal *et al*., 2008). Thus, firms located within the knowledge cluster have an advantage to tap into tacit knowledge and thus have been found to innovate faster and more than the firms located outside (Baptista and Swann, 1998; Poon *et al*., 2013).

Recent theory on multinational enterprises (MNE) has popularized the notion of MNE as a globally distributed innovation network (Frost, 2001; Almeida and Phene, 2004) that source, assimilate and integrate knowledge across the world to generate innovation (Ghoshal and Bartlett, 1988; Hedlund, 1994). Thus, MNEs looking to source knowledge through their subsidiaries would prefer to locate it in a cluster to take advantage of strong knowledge networks.

There are number of counter arguments put forth by researchers on the negative impact of clusters on innovation. It is hypothesized that knowledge spill overs occurs within a cluster due to labor poaching (Fosfuri and Rønde, 2004). Labor poaching leads to competition for R&D resources within a cluster and is found to suppress innovation (Alsleben, 2005). Also, high value knowledge is protected through legal means and only least valuable knowledge has been found to be available for free (Geroski, 1995). It is also argued that due to continuous knowledge spill overs, highly innovative firms within a cluster experience a net loss in knowledge due to higher outflows as compared to inflows (Mudambi and Swift, 2012).

3. Hypotheses

Geographical Clusters and Subsidiary Innovation

The physical attraction thesis (Cantwell and Mudambi, 2011) asserts the formation of closed innovation system which locks out firms located outside the cluster. R&D activities and innovative firms are found to be clustered due to the spatial dependency of knowledge spillovers (Feldman, 1994; Audretsch and Feldman, 1996). As a result, firms within a technological cluster have been found to have higher number of patents and patent citations (Jaffe *et al*., 1993; Zucker *et al*., 2002). Thus, knowledge seeking MNEs would like to establish their subsidiaries within those clusters.

Combining the existence of high value knowledge in host country clusters and the positive influence this knowledge can potentially have on subsidiary innovation, we hypothesize the following:

Hypothesis 1: Subsidiaries located within the host country cluster produce higher quality of innovation as compared to subsidiaries located outside.

Firm experience is associated with learning-by-doing. Learning by doing is expected to increase over time due to improvement in organizational competencies. Thus, firm experience is expected to have a positive impact on the quality of innovation. On the contrary, firm experience can lead to organizational inertia. Organizational inertia inhibits firms from making radical changes in structure and strategy which may be required to adapt to external environmental changes (Balasubramanian and Lee, 2008).

We argue that subsidiaries located within a geographical cluster can gain experience and learn faster due to the locational advantage. Given the competition for resources and technology, we

also believe that firms located within a cluster have to be more dynamic and will adapt to external changes faster than those located outside the cluster.

Based on the above arguments, we hypothesize the following:

Hypothesis 2: Geographical clustering positively moderates the relationship between subsidiary age and the quality of innovation.

Geographical Clustering, Local Knowledge Spillovers and Subsidiary Innovation

Firms involved in R&D activity rely heavily on skilled human resources. These skilled human resources are the primary medium of knowledge spillovers in industries which rely heavily on R&D. Higher the skill of the knowledge resources, more important is the knowledge spillover associated with them. Hence, geographical clusters which house such skilled workers are expected to have higher knowledge spillovers which in turn is expected to positively contribute to firms located in that cluster (Audretsch and Feldman, 1996).

Given the observations by past research that R&D knowledge spillover is high within a cluster and skilled labor contributes to the propagation of knowledge within a cluster, we hypothesize the following:

Hypothesis 3: Geographical clustering positively moderates the relationship between local knowledge spillovers and quality of subsidiary innovation.

Internal Networks and Subsidiary Innovation

The oligopolistic deterrence thesis (Shaver and Flyer, 2000) argues that firms with best technologies, human capital, training programs, suppliers, or distributors will minimally benefit from access to competitors' technologies, human capital, training programs, suppliers, or distributors due to higher knowledge outflows as compared to knowledge inflow. While agglomeration may facilitate hiring skilled R&D workers from competitors, there is also a threat of losing them to competition. Thus, there is very little motivation for large and dominant MNCs to locate their subsidiaries within a technology cluster. The absence of agglomeration externalities leads the subsidiary to lean heavily on its internal network. The capacity of the subsidiary to absorb incoming knowledge will lead to higher internal knowledge flows (Gupta and Govindarajan, 2000).

Based on the above discussion, we hypothesize the following:

Hypothesis 4: Geographic clustering negatively moderates the relationship of internal network to quality of subsidiary innovation

4. Data and Methods

Research Setting

The hypotheses are tested in the context of two semiconductor design subsidiaries located in India. The industry has an international character of knowledge development which requires sourcing of knowledge through the subsidiaries and proliferating it throughout the MNC (Almeida, 1996). In the Indian context, semiconductor design industry is found to be more advanced than China based on the number of design leads and the number and size of specialized design teams (Fuller, 2014).

Sample

Our sample consists of two companies, one located within the technology cluster of Bangalore and another located in the National Capital Region (NCR) of Delhi which is outside the technology

cluster. The company located within the cluster (will be called as Company A) is a subsidiary of a large US MNC and the company located outside the clustered (henceforth referred to as Company B) is the subsidiary of a large EU MNC. Every patent granted to the two companies by the US Patent Office (USPTO) in the time period 2001 – 2010 with at least one inventor located in India is analyzed. Subsidiary patent is the unit of analysis. The number of observations in the ten year period for Company A was 372 and for Company B was 175, bringing the total number of observations to 547.

Patents and Patent Citations

Patenting in the US system is done by every major semiconductor design company since US is a major design, manufacturing and market for semiconductor devices (Phene and Almeida, 2008). While patents as a measure of innovation look attractive, there are some limitations in doing so. First, patents represent only codified knowledge and not tacit knowledge. However, researchers have pointed out that codified and tacit knowledge are closely linked and complementary (Mowery *et al*., 1996). Second, not all technological innovations may be patented since patenting is a strategic choice of the MNC. However, the nature of the semiconductor design industry encourages firms to patent and every firm is found to have a very healthy patent portfolio (Almeida, 1996). Despite the above limitations, patents have been used by researchers to capture innovations and knowledge flows (Jaffe, 1986; Jaffe *et al*., 1993; Almeida, 1996; Almeida and Phene, 2004; Phene and Almeida, 2008).

Variable Operationalization

The variables included in the analysis and their operationalization are described below.

Dependent Variable

The dependent variable – quality of subsidiary innovation was constructed by examining the patent portfolio of the two companies and the citations received by the portfolio between the years 2001 to 2010.

Quality of Subsidiary Innovation (QSI): Trajtenberg (1990) has demonstrated that the importance of an innovation can be studied through patent citations. This measure was constructed by considering the total citations received by each of the patents granted between the years 2001 – 2010.

Independent Variables

Local Knowledge Spillover (LKS): One of the important ways of local knowledge spill over within a cluster in a high technology sector like semiconductors is through mobility of technology workers (Almeida and Kogut, 1999; Fosfuri and Rønde, 2004). LKS is calculated by dividing the local inventors by the total inventors for each patent.

Internal Network (INW): The strength of internal network for each patent is measured as the ratio of the number of international inventors to the total number of inventors. Higher the number of international inventors, stronger is the internal network.

Geographical Clustering (GC): Geographical clustering is defined as a categorical variable. For all the patents filed by Company A, GC is sent to IN and for all the patents filed by Company B, GC is set to OUT.

Control Variables

R&D Intensity (RDI): RDI is calculated by dividing the MNC R&D spending by Net Sales. R&D spending and net sales data is directly from the annual reports for the year *t*-3 as a proxy for subsidiary R&D intensity.

Subsidiary Age (SA): Subsidiary age for each of the patent is computed by subtracting the subsidiary establishment year from the patent filing year and taking a natural log of it.

Methods

Poisson model is typically suggested for analyzing patents which has count data. However, overdispersion in such data due to presence of a large number of zero counts (patent citations) leads to underestimation of standard errors and inflation of significance levels (Phene and Almeida, 2008). A chi-square goodness of fit value of 5747.46 with a p-value of 0.00 was obtained for the quality of innovation. High and significant value of chi-square indicates presence of overdispersion and suggests that the Poisson model is not suitable for our analysis. To correct the presence of overdispersion, negative binomial regression model is used (Almeida and Phene, 2004; Phene and Almeida, 2008) for analysis.

5. Results

Descriptive statistics for the number of citations are tabulated in Table 1 below. Median number of citations is 6 for the company located in the cluster while it is 5 for the company located outside the cluster. This suggests that foreign subsidiaries of semiconductor MNCs located in India have a limited capability to generate quality innovations.

Table 1: Descriptive Statistics of Citation Count

	Within Cluster	Outside Cluster
No. of patents	372	175
Min no. of citations	0	0
Max. no. of citations	202	87
Mean (No. of citations)	10.95	7.93
Median (No. of citations)	6	5
Variance	278.42	123.56

The variable inflation factor (VIF) for all the factors in a negative binomial regression model was checked and found to be less than 5. The highest value of VIF was 1.46 for INW which indicates very low levels of collinearity amongst the explanatory variables.

Our findings are presented in Table 2. Model 1 is the baseline model. Model 2, 3, 4 and 5 incorporates the effect of geographical clustering, moderating effect of geographical clustering on subsidiary age, local knowledge spillover and internal network respectively. Model 6 is the comprehensive model which incorporates the effect of all the explanatory and control variables. Wald statistic values indicate that adding more independent variables contribute to increased explanatory power.

Table 2: Quality of Subsidiary Innovation: Negative Binomial Regression

	Hypothesis	Model 1	Model 2	Model 3	Model 4	Model 5	Full Model
Direct Effects							
GC (OUT)	H1	-0.226 * (0.114)	-0.353 ** (0.108)	2.947 (2.004)	-0.297 (0.194)	-0.217 § (0.119)	4.316 * (2.041)
LKS		0.297 * (0.14)			0.153 (0.156)		0.569 ** (0.185)
INW		0.588 * (0.243)				0.462 * (0.228)	0.953 *** (0.272)
Indirect Effects							
SA X GC (OUT)	H2			-1.249 § (0.756)			-1.521 * (0.761)
LKS X GC (OUT)	H3				-0.092 (0.261)		-0.64 * (0.281)
INW X GC (OUT)	H4					-1.649 * (0.699)	-2.296 ** (0.734)
Control Variables							
SA		-1.964 *** (0.298)	-2.093 *** (0.298)	-1.844 *** (0.343)	-2.108 *** (0.299)	-2.02 *** (0.299)	-1.725 *** (0.34)
RDI		-0.005 (0.01)	-0.003 (0.01)	0.002 (0.011)	-0.002 (0.011)	-0.008 (0.011)	-0.001 (0.011)
Wald Statistic		52.5 ***	66.4 ***	71.1 ***	67.2 ***	70.5 ***	84.4 ***

N = 547; Standard errors in parentheses; §p<0.1, *p<0.05, **p<0.01, ***p<0.001; Dependent variable: Quality of Subsidiary Innovation

Based on Model 2, we conclude that Hypothesis 1 is supported indicating that geographical clustering has a positive impact on the quality of innovation. Hypothesis 2 is weakly supported in Model 3 and strongly supported in full model which indicates that subsidiaries located within the cluster tend to produce higher quality of innovation faster than the ones located outside the cluster. Hypothesis 3 is not supported which indicates that subsidiaries located within clusters don't appear to benefit from local knowledge spillovers occurring due to expert resource movement. Model 5 and full model support Hypothesis 5 but in opposite direction. This means that stronger internal networks are built with subsidiaries located within cluster.

Of the control variables, subsidiary age has a negative impact on the quality of innovation. This is in line with the findings of earlier studies (Sørensen and Stuart, 2000; Balasubramanian and Lee, 2008) indicating existence of inertia. R&D intensity does not seem to have any impact on the quality of innovation.

6. Discussion and Conclusions

The primary contribution of our study is providing a clearer picture about the impact of geographical clustering on the quality of subsidiary innovation. The results of our study suggests that subsidiaries located within a cluster produce higher quality of innovation in a shorter duration of time as compared to subsidiaries located outside the cluster.

There are two non-intuitive results obtained from this study. First, geographical clustering does not positively moderate the impact of local resources (which are a proxy for local knowledge spill over) on the quality of subsidiary innovation. There are a couple of possible explanations for this result. Since the subsidiary was one of the first one to be established within the cluster, it may not have benefitted much from the inward labor movement. It could also be that the free knowledge available within the cluster could be of limited use to generate quality innovation (Geroski, 1995; Zucker *et al*., 1998).

The second non-intuitive result is the negative moderating effect of geographical clustering on the relationship between internal network and quality of subsidiary innovation. This relationship suggests that internal networks are strong in a subsidiary located within the cluster. Given the fact that the subsidiary located within the network produces high quality of innovation, we posit that it has higher absorptive capability. Higher absorptive capability is one of the perquisite for higher internal knowledge flows (Gupta and Govindarajan, 2000).

7. Limitations and Future Work

Though our study highlights a number of interesting findings regarding the influence of geographical clustering on the quality of subsidiary innovation, it has several limitations. Caution is suggested in interpreting the results while providing opportunity for future research. First, the sample for study is limited to two semiconductor design subsidiaries located in India. It is recommended to extend this study to other high technology industries like pharmaceuticals, automobile etc. with focus on other emerging markets like China, Brazil etc. The sample used in this study is a convenience sample and may not truly represent the population. Thus, the findings of this study may not be directly translated to the population of the semiconductor design firms in an emerging market.

Second, only citation of patents is used as indicator for quality of innovation. It is understood that there are other forms and indicators of innovation like new products, process and centers of excellence. As a future study, it is recommended to comprehend broader innovation capabilities through a research survey instrument.

Finally, we have used the availability of local resources as a proxy for local knowledge spillovers. While it is a good indicator, we acknowledge that it is a partial one. Knowledge acquired through interactions with suppliers, customer, R&D labs and Universities is not captured by this study. Future research can focus on these sources of local knowledge spillover and examine its impact on the quality of subsidiary innovation.

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