Asian Journal of Innovation and Policy (2018) 7.1:103-130
DOI: http//dx.doi.org/10.7545/ajip.2018.7.1.103

Nature of a Firm, Degree of Cluster Linkages, and Innovation: A Study of Bengaluru High-tech Manufacturing Cluster

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Abstract It is generally understood that clusters are the promoters of innovation and therefore, the attention of researchers has been increasingly to discern the factors driving innovation among the firms in a cluster, especially in a high-tech cluster. In this study, we identify the variables capturing the nature of a firm that possibly impact the absorptive capacity of a firm and subsequently ascertain their impact on the degree of interactions between a firm, and other firms and associated institutions within and outside a cluster, respectively. Furthermore, we probe the influence of these interactions as a whole on firm-level innovation. The study was carried out in the context of Bengaluru, which houses the densely interconnected network of innovation-intensive high-tech manufacturing firms forming a high-tech manufacturing cluster. Data were drawn from 101 high-tech manufacturing firms belonging to electronics, machine tools, electrical and pharmaceutical industries. Based on the cluster analysis and subsequent graphical analysis on each of the three profiled clusters, it was found that size and origin of a firm have significant impact on the degree of firm's interactions. In turn, higher dynamism of firms in terms of degree of interactions led to higher innovation performance.

Keywords Absorptive-capacity, firm, innovation, high-tech cluster, manufacturing, linkages, Bengaluru, India

I. Introduction

The notion of industrial cluster has continued to gain interest of policy makers and researchers the world over as a prospect for economic development. Porter (1990) defined industrial cluster as "a geographically proximate group of firms and associated institutions in related industries, linked by economic and social interdependencies". In addition, industrial cluster is seen as a phenomenon offering myriads of economic benefits to

Submitted, August 15, 2017; 1st Revised, November 16, 2017; Accepted, January 23, 2018
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firms as well as regions housing a cluster. Notably, a cluster facilitates firms to achieve higher levels of innovation and productivity (Ketels, 2003).

Further, in an era of globalization, the rise of high-tech clusters that deal with a complex technology or innovation has placed a burgeoning need for firms to further their dynamic capabilities and enter into collaborations with each other to gain a competitive advantage (Rao and Klein, 2013). One of the best explanations of dynamic capability of a firm is its absorptive capacity. Absorptive capacity, which refers to the ability of a firm to learn and solve problems, facilitates a firm to reorganize its resource bases and swiftly adapt to changing market conditions to enhance its performance (Kim, 1995; Fosfuri and Tribo, 2008). In turn, absorptive capacity of a firm explains various complex and diverse organizational phenomena (Zahra and George, 2002). In addition, firms with higher absorptive capacities are more likely to connect to external sources of knowledge (Giuliani and Bell, 2005). Hence, absorptive capacity of a firm has a positive influence on degree of cluster linkages (DCL) comprising degree of intra-cluster linkages (DICL) and the degree of extra-cluster linkages (DECL) capturing interactions between a firm, and other firms and associated institutions within and outside a cluster, respectively.

Absorptive capacity is further a function of firm's knowledge base. The nature of a firm (in terms of industry-type, age, size and origin of a firm) alters the knowledge base of a firm and consequently induces a change in the firm's absorptive capacity. Since, it is challenging to quantify absorptive capacity of a firm as there is ambiguity among researchers about the factors determining absorptive capacity of a firm (Fosfuri and Tribo, 2008; Zahra and George, 2002), researchers have largely used different proxies to quantify it (Giuliani, 2005; Lau and Lo, 2015). However, none of the proxies could capture holistically, the variance in absorptive capacity that is credited to the nature of a firm. Hence, there is a need to identify such variables representing the nature of a firm and subsequently ascertain their impact directly on DCL of a firm. In addition, one key outcome of dynamism of a firm resulted out of intra-cluster and extra-cluster interactions is innovation performance of a firm. Therefore, devising a framework involving constructs such as nature of a firm, DICL and DECL, and innovation performance of a firm will provide fruitful insights about the dynamics of a cluster.

Among the clusters of the globe, Bengaluru (erstwhile Bangalore) cluster occupies a unique position as it includes not only IT sector, but also a multitude of high-tech manufacturing industries (e.g. electronics, pharmaceutical, machine tools, electrical, etc.,) forming a high-tech cluster (Nadvi, 1995). It is against this backdrop, within the context of Bengaluru high-tech manufacturing cluster that this paper, first, attempts to discern the influence of the nature of a firm (such as industry-type, age, size and origin of a firm) on

DCL of a firm. Subsequently, this paper examines the impact of DCL of a firm on firm-level innovation.

This paper has been organised in five sections. The next section deals with a review of literature related to the key constructs considered in our study. The subsequent section proposes the conceptual framework relating to all the important constructs considered in our study. This is followed by a section that provides the research objectives, scope, sampling and methodology adopted in our study to address the identified research gaps. Further, in the next section, the results of the study are discussed. The final section summarizes the findings of the study in form of conclusion.

II. Literature Review

To begin with, we review the literature that explores the importance of interactions of firms with other firms and associated institutions, and then we proceed to understand what constitutes knowledge system of a firm enabling these interactions.

1. Knowledge System and Its Key Components

Though clusters are considered as sources of innovation, only some clusters turn out to be successful and others fail. Firms perceive, understand and assess differently in the absence of interaction among them based on the environment surrounding them. However, such kind of a thought process may not result in a unique product or process addressing the needs of customers. They require an external source of cognition and competence to supplement their own in order to produce innovative outcomes while reducing the failure and transaction costs (Nooteboom, 1999). That is why basically knowledge system of a firm assumes a cardinal role catering to innovation. Giuliani (2005) proposes three basic components viz. (1) knowledge base, (2) intra-cluster linkages, and (3) extra cluster linkages that comprise knowledge system of a firm.

1.1 Knowledge Base

Knowledge base is the stock of knowledge embedded in firm's human capital to which the inventors refer to while searching for innovative solutions (Giuliani 2005; Giuliani and Bell, 2005). It is the result of a process of cumulative learning, which is inherently imperfect, complex and path dependent (Giuliani, 2005).

1.2 Intra-Cluster Linkages

Intra-cluster knowledge system is the flow of knowledge among linking firms and associated institutions in a cluster. Intra-cluster linkages are the connections between a firm and other firms, and associated institutions in a cluster. Proximity of firms enables them to not only access explicit (or codified) knowledge, but also access tacit (or implicit) knowledge, which is sticky and localized in nature, and could only be captured through face-to-face informal interactions among individual employees in a cluster (Baptista and Swann, 1998; Giuliani, 2005; Rosenfeld, 2005; Sonderegger and Taube, 2010).

1.3 Extra-Cluster Linkages

In the era of globalization, if firms are not connected globally, they soon become uncompetitive (Rosenfeld, 2005). Hence, to sustain in the international competition, local and global knowledge systems should be integrated. It is extra-cluster linkages, which assume key role in connecting firms to global knowledge system. Extra-cluster knowledge system is the flow of knowledge between linking firms in a cluster, and firms and associated institutions residing outside the cluster.

Further, the linkages can be classified into vertical and horizontal linkages (Maskell, 2001). On the one hand, the vertical linkages are the relationships between cluster participants along the value chain. On the other hand, the horizontal linkages are linkages between cluster participants at the same level of the value chain. No matter whether they are horizontal or vertical, they could be business and/or technical linkages.

With an understanding of the various components of knowledge system of a firm, we now focus on reviewing the literature related to innovation performance of a firm, which is one of the key outcomes of intra-cluster and extra-cluster interactions of a firm.

2. Innovation

Schumpeter (1934) regarded innovation as the driving force of economic development. He asserted that innovation takes several forms - introduction of new methods of production, new products, the opening of new markets, new sources of supply, and new forms of organization. Further, Porter (1990) contends that it is innovation and further productivity that determine the sustainable levels of prosperity and growth in a region in the long run.

Innovation being a multi-dimensional construct, researchers have defined it in several ways. Mytelka (2000) defined innovation in the context of a developing country as “a process by which firms master and implement the design and production of goods and services that are new to them regardless of

whether they are new to their competitors, their customers or the world". NKC (2007) regarded innovation as "a process by which varying degrees of measurable value enhancement is planned and achieved, in any commercial activity". This process may be radical or incremental, and it may occur continuously or sporadically in a company; it may be achieved by: (1) introducing new or improved goods and services and/or, (2) implementing new or improved operational processes and/or, (3) implementing new or improved organizational/managerial processes (NKC, 2007).

Following the Schumpeterian system of classification, innovations can be grouped into four types - product, process, organizational, and marketing innovations. However, in this paper we focus on technological innovation resulting in technologically-advanced product or process as a result of technological improvements. Technological innovation is inevitable for firms that want to create and sustain a competitive advantage and/or gain entry into new markets (Becheikh, Landry and Amara, 2006). In addition, it lends a competitive edge to firms. Further, it contributes greatly to productivity growth and higher living standards of a nation.

With this understanding of the definitions of innovation, we move on to explore the impact of intra-cluster and extra-cluster interactions of a firm on firm-level innovation. Preceding this, we shall also understand the role played by nature of a firm in determining the intra-cluster and extra-cluster linkages of a firm.

3. Nature of a Firm, Cluster Linkages, and Innovation

The extent of openness of a firm relies on its absorptive capacity (Giuliani 2005; Giuliani and Bell, 2005). Absorptive capacity of a firm is simply the ability of a firm to learn and solve problems (Kim, 1995). Not all firms in a cluster can reap economic benefits from external knowledge to the same degree although they are exposed to the same amount of external knowledge. This is because of varied absorptive capacity levels of these firms. Cohen and Levinthal (1990), who introduced the concept of absorptive capacity, defined firm's absorptive capacity as "the ability of a firm to value, assimilate and exploit the external knowledge the most and apply it to commercial ends".

Giuliani and Bell (2005) asserted that firms with higher absorptive capacities in a cluster are more likely to connect to external sources of knowledge. They based their explanation on the concept of cognitive distance between firms in a cluster and external sources of knowledge. The firms with higher absorptive capacities are cognitively close to external knowledge sources. Hence, firms with a higher level of absorptive capacities can leverage the external knowledge flows more efficiently, and consequently produce innovative

outcomes.

The nature of a firm in terms of its industry-type, age, size and origin alters firm's knowledge base, which is translated into absorptive capacity of a firm. Furthermore, intra-cluster and extra-cluster linkages depend on absorptive capacity of a firm. The stronger the knowledge base of a firm in terms of its absorptive capacity, the denser will be the intra-cluster and extra-cluster linkages (Giuliani, 2005). The degree of knowledge transfer between any two firms depends on the relative cognitive distance between them. Even though reciprocity/extent of co-operation between a firm and its stakeholders seems to be one of the rules of thumb that govern the information trading, it is likely to happen when there is a high degree of similarity between the cognitive levels of firms in terms of their absorptive capacities (Saxenian, 1994; Schmitz, 1999; Steinle and Schiele, 2002; Giuliani and Bell, 2005).

Based on the absorptive capacity levels of firms, firms are facilitated by cluster linkages, identify the external knowledge sources and, further acquire them. The degree of knowledge acquisition depends on the extent to which a cluster firm receives assistance from other firms within and/or outside the cluster through intra-cluster and extra-cluster linkages respectively (Bell and Albu, 1999; Giuliani and Bell, 2005). In addition, firms also acquire knowledge from associated institutions such as academic institutions, industry associations and government agencies located in a cluster.

Further, to continue the reciprocity, firms in a cluster also diffuse the knowledge amassed by them via the same intra-cluster and extra-cluster linkages. The degree of knowledge diffusion depends on the extent to which a cluster firm provides assistance to other firms within and/or outside the cluster through intra-cluster and extra-cluster linkages respectively (Bell and Albu, 1999; Giuliani and Bell, 2005). In addition, employees of the firms spread the acquired knowledge to academia through their paper publications and participation in workshops, seminars, symposiums and conferences etc.

On acquisition of external knowledge, firms comprehend and assimilate the information obtained from the acquired external knowledge (Zahra and George, 2002). Following this is the creation of new knowledge by combining existing knowledge with acquired knowledge

The nature and strength of cluster linkages determine the degree of knowledge integration and further knowledge creation within the firm. Basically, the two key dimensions of knowledge creation, viz.-horizontal and vertical dimensions deepen the knowledge base of firms in a cluster (Maskell, 2001). While the horizontal dimension of knowledge creation enables firms to benchmark with their competitors and provides a platform to assess their competitiveness, the vertical dimension of knowledge creation, which supports specialization of labour, gives rise to partnerships and collaborations as firms involve in complementary activities.

Further, in addition to the nature of linkages (horizontal/vertical), the degree of knowledge creation also mainstays on the channel for external sourcing (formal/informal), language proficiency, and intra-cluster and extra-cluster mobility of skilled labour (Bell and Albu, 1999; Muskell, 2001; Morosini, 2004). Finally, the operationalization of new/transformed knowledge results in innovative outcomes in the form of new/improvised products or processes.

As a whole, the varying levels of knowledge acquisition, diffusion and creation of drive differential innovation performances of firms in a cluster. In essence, these differences in the innovation levels of firms can be primarily rooted to varied absorptive capacity levels of firms. In addition, the nature of a firm in terms of the industry-type, age, size and origin of a firm play an important role in deepening the knowledge base of a firm which consequently is translated into absorptive capacity impacting both the degree cluster linkages of a firm.

Based on the review of literature, we propose the following hypotheses summarizing the influence of various variables capturing the nature of a firm, on its degree of cluster linkages:

> Hypothesis 1: The degree of cluster linkages is likely to be different for different industries.

Besides the relative cognitive distance between firms and external sources of knowledge, firms are likely to establish connections with other firms and associated institutions in an industry based on the secureness to build connections with other firms in an industry (Zahra and George, 2002) and effectiveness of regional innovation system (RIS) (constituting elements of ecosystem such as industry associations research centres and training institutes specific to an industry), respectively (Lau and Lo, 2015). The firm's knowledge about the secureness and effectiveness of linkages to other firms and elements of an eco-system constitutes the external factors of absorptive capacity of a firm.

The appropriability regime of an industry determines the secureness of firms to establish connections with each other in an industry (Zahra and George, 2002). Further, appropriability is defined as the industry dynamics that facilitate firms to protect benefits of innovative output. The strength of intellectual property rights (IPRs) and cost of replicability specific to industry are the key determinants of appropriability regimes of an industry (Rao and Klein, 2013). Hence, stronger and effective the appropriability regime of an industry and elements of RIS specific to an industry respectively, higher will be the degree of cluster linkages. Therefore, industry-type is likely to contribute to differential DCL among firms belonging to different industries.

Hypothesis 2: The higher the age of a firm in a cluster, the higher will be the degree of cluster linkages.

As the firms spend more time in a cluster, they continually explore each elements of an ecosystem and subsequently build a perception about the effectiveness of each of them. At a later stage, based on their perception, firms actually establish and strengthen their linkages with other firms and associated institutions progressively. Further, the strength of these connections on a continual scale depends on how well the firms are able to upgrade their knowledge bases dynamically and hence improve their absorptive capacities (Giuliani and Bell, 2008).

Hypothesis 3: The degree of cluster linkages is likely to be higher for larger firms.

Unlike an IT firm, the learning curve in a manufacturing firm does not depend on the investment in human capital alone. The investment in physical capital as well assumes a key role as it enables specialization of labour (Patibandla and Petersen, 2002). The larger the size of a firm, the more likely the firm makes investment in physical capital. Hence, deeper will be the knowledge base of a firm and consequently higher will be the degree of cluster linkages of that firm.

Hypothesis 4: A firm in a cluster whose origin can be traced to a location outside the cluster is likely to have higher degree of cluster linkages than those firms based in the cluster.

An externally-based firm establishes a subsidiary in a cluster to take advantage of location-specific externalities rendered by the cluster (He and Fallah, 2011). In addition, they integrate the local knowledge system with the global knowledge system, with the help of its subsidiary located in a cluster to gain competitive advantage. Hence, a subsidiary of externally-based firm in a cluster is likely to have higher degree of cluster linkages than those firms based in the cluster.

Based on the review of literature, the following is the hypothesis summarizing the impact of degree of cluster linkages of a firm on its innovation performance:

Hypothesis 5: The higher the degree of cluster linkages, the higher will be the innovation performance of a firm.

As a firm acquires and diffuses knowledge to other firms and associated institutions within and outside a cluster via intra-cluster and extra-cluster linkages (Bell and Albu, 1999; Giuliani and Bell, 2005), it combines the acquired knowledge with existing knowledge to create new knowledge (Zahra and George, 2002). Finally, it puts the new knowledge into action to produce innovative outcomes in terms of innovated products/processes.

4. Gaps in Literature

Many empirical reseachers have put in efforts to conceptualise and empirically validate the impact of absorptive capacity of a firm on its degree of intra-cluster and extra-cluster linkages (Bell and Albu, 1999; Giuliani 2005; Giuliani and Bell, 2005). However, the possible influence that the nature of a firm (in terms of industry-type, age, size and origin of a firm) could have on the degree of cluster linkages of a firm by altering knowledge base and consequently absorptive capacity of a firm has not been explored. This is due to lack of consensus among researchers about the factors determining absorptive capacity of a firm which has made quantification of firm's absorptive capacity challenging. Hence, proxies that were used to measure absorptive capacity do not capture the role of nature of a firm in determining it.

Further, researchers have empirically validated the direct influence of absorptive capacity of a firm on firm-level innovation (Chandrashekar and Bala Subrahmanya, 2017b; 2017d). In addition, the influence of degrees of intra-cluster and extra-cluster linkages on innovation has been ascertained (Chandrashekar and Bala Subrahmanya, 2018). Furthermore, the factors of cluster linkages that determine the innovation performance of a firm at a micro-level have been explored (Chandrashekar and Bala Subrahmanya, 2017c). However, the impact of the nature of a firm translated through degree of cluster linkages as a whole on firm-level innovation has not been adequately explored (Fabrizio, 2009; Kostopoulos et al., 2011; Lau and Lo, 2015). It is with this understanding we devise a conceptual framework linking key constructs of a high-tech cluster based on the literature review, to ascertain the influence of degree of cluster linkages as a whole on firm-level innovation.

III. Conceptual Framework

A conceptual framework developed based on the literature review, linking the key constructs of a high-tech cluster is presented in Figure 1.

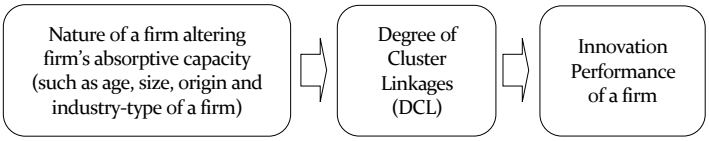

Figure 1 Nature of a firm, DCL and innovation

In a nutshell, the nature of a firm (in terms of industry-type, size, age and origin of a firm) alters knowledge base of a firm and consequently brings out changes in the absorptive capacity of a firm. This change in absorptive capacity is translated by the nature of a firm which impacts the degree of cluster linkages. Ultimately, the degree of cluster linkages determine the innovation performance of a firm. The research objectives which are set in the context of this conceptual framework is presented in the next section.

IV. Objectives and Methodology

1. Objectives

1. To probe the influence of the nature of a firm on the degree of cluster linkages of a firm.
2. To ascertain the impact of the degree of cluster linkages as a whole on firm-level innovation.

2. Scope

This study is limited to Bengaluru high-tech cluster. Bengaluru is the highest ranked hub in Asia among the 46 global hubs of technological innovations (UNDP, 2001). In addition, recently Bengaluru has been named among the top eight technology innovation clusters in the globe by MIT Technology Review (oneindia, 2013). It is also a haven for innovation-intensive firms belonging to high-tech industries (Nadvi, 1995; GoK, 2006; Okada and Siddharthan, 2007; Bala Subrahmanya, 2011; Bala Subrahmanya, 2013). Further, among the high-tech industries in Bengaluru, electronics, pharmaceutical, electrical and machine tools industries have gained the attention of global investors given the prospect these industries offer (GoK, 2006). The cross-sectional study includes firms of all sizes (measured by investment in plant and machinery above Rs. 25 lakhs) across high-tech manufacturing industries such as electronics (EC), electrical (EE), machine tools (MT) and pharmaceutical (P) industries.

3. Sampling and Specifics of Data Collection

At first, to develop the sampling frame for our study and subsequently, to derive insights on the distribution of firms across industry groups, we sourced data from multiple industry associations and government agencies. Later, we employed Stratified Random Sampling technique to choose 101 firms from our sampling frame corresponding to four industry sectors under consideration.

Primary data were collected from identified high-tech manufacturing firms across four industries under study through semi-structured questionnaires and in-depth interviews with the representatives (executives from the higher level management) of high-tech manufacturing firms. Further, PROWESS of Centre for Monitoring Indian Economy (CMIE) database was used to validate the firm-specific financial data (for the year 2015-16) which were collected through primary data collection method.

4. Dimensions, Variables and Measures

4.1 Nature of a Firm

Nature of a firm constitutes the following variables:

(a) Industry-type: It is a nominal variable with four levels, namely, electronics (EC), electrical (EE), pharmaceutical (P) and machine tools (MT) industries. Each level indicates the industry to which a firm belongs.
(b) Age of a firm: It is a continuous variable indicating how old a firm is in years since its establishment.
(c) Size of a firm: It is a nominal variable with three levels namely small [between Rs.2.5 million and Rs.50 million), medium (between Rs.50 million and Rs.100 million) and large (greater than Rs.100 million)]. Each level indicates the size of a firm in terms of investment in plant and equipment.
(d) Origin of a firm: It is a dichotomous variable indicating whether the cluster firm is Bengaluru based or a subsidiary of an externally based parent firm.

4.2 Degree of Intra-Cluster and Extra-Cluster Linkages

We adopt the definition and measurement of degrees of intra-cluster and extra-cluster linkages from Chandrashekar and Bala Subrahmanya (2018).

(a) Degree of intra-cluster linkages (DICL)

The factors that determine the degree of intra-cluster linkages are shown in Table 1. All the variables were measured on a 5-point likert scale. In addition, the degrees of knowledge acquisition and diffusion of a firm were separately calculated with respect to corresponding stakeholders with whom a firm is connected through intra-cluster linkages using the following equation:

> Degree of Knowledge Acquisition [DKA_{in}(i, j)] = (Extent of co-operation between a firm f and stakeholder i)*(Frequency of assistance received by a firm f from a stakeholder i residing inside Bengaluru cluster to solve problem(s) related to j)

Degree of knowledge acquisition of a firm (DKAin) is calculated using the following equation

$$DKA_{in} = \sum_{\substack{1\leq i\leq 2 \\ 1\leq j\leq 2}} DKA(i,j) + \sum_{i=4}^{6} DKA(i)$$

> Degree of Knowledge Diffusion [DKD_{in} (i, j)] = (Extent of co-operation between a firm f and stakeholder i)*(Frequency of assistance provided by a firm f to a stakeholder i residing inside Bengaluru cluster to solve problem(s) related to j)

Degree of knowledge diffusion of a firm (DKDin) is calculated using the following equation

$$DKD_{in} = \sum_{\substack{2\leq i\leq 3 \\ 1\leq j\leq 2}} DKD(i,j) + \sum_{i=4}^{6} DKD(i)$$

Where, f is a firm in a cluster whose degree of intra-cluster linkages is to be calculated i is a stakeholder with whom a firm is connected via intra-cluster linkage [i=1 (suppliers), 2 (peers and competitors), 3(corporate customers), 4 (academic institutions*), 5 (industry associations*) and 6 (government agencies*)] j is a nature of assistance sought [j=1 (technical), 2 (business)] *j is not applicable for associated institutions such as academic institutions, industry associations and government agencies.

The degree of knowledge creation of a firm (DKCin) was calculated by adding all the variables, which determine the degree of knowledge creation. Further, the degree of intra-cluster linkages of a firm was computed by adding degree of knowledge acquisition, degree of knowledge diffusion and degree of knowledge creation of a firm involved in intra-cluster cluster interactions.

DICL= DKAin+ DKDin+ DKCin

Table 1 Factors determining the degree of cluster linkages of a firm

Sl.	Factors	Dimensions	Variables
1	Degree of knowledge acquisition (Bell and Albu, 1999; Ketels, 2003; Morosini, 2004; Giuliani and Bell, 2005)	Extent of co-operation	Extent of co-operation between a firm and stakeholders such as competitors, suppliers, corporate customers, academic institutions, industry associations and government agencies.
		Frequency of assistance sought (Intra-cluster)	Frequency of assistance received by a firm from other firms in Bengaluru to solve technical/business problems. Frequency of active involvement in knowledge sharing sessions such as workshops, skill development programs, seminars, conferences, certification courses offered by academic institutions and industry associations in Bengaluru to gain knowledge.
		Frequency of assistance sought (Extra-cluster)	Frequency of assistance sought by a firm from other firms outside Bengaluru to solve technical/business problems.
2	Degree of knowledge diffusion (Bell and Albu, 1999; Ketels, 2003; Morosini, 2004; Giuliani and Bell, 2005)	Extent of co-operation	Extent of co-operation between a firm and stakeholders such as competitors, suppliers, corporate customers, academic institutions, industry associations and government agencies.
		Frequency of assistance provided (Intra-cluster)	Frequency of assistance provided by a firm to other firms in Bengaluru to solve technical/business problems. Frequency of carrying out knowledge sharing sessions such as workshops, skill development programs, seminars, conferences, certification courses to disseminate the updated or new knowledge to other stake holders (academic institutions, industry associations and government agencies) in Bengaluru.
		Frequency of assistance provided (Extra-cluster)	Frequency of assistance provided by a firm to other firms outside Bengaluru to solve technical/business problems.
3	Degree of knowledge creation (Bell and Albu, 1999; Muskell, 2001; Morosini, 2004)	(Intra-cluster)	Channel for external sourcing (formal/informal linkages), horizontal/vertical linkages, language proficiency and intra-cluster mobility of skilled labour.
		(Extra-cluster)	Horizontal / vertical linkages, language proficiency and extra cluster mobility of skilled labour.

Sources: Chandrashekar and Bala Subrahmanya (2017a, 2017c, 2018)

(b) Degree of extra-cluster linkages (DECL)

The factors which determine the degree of extra-cluster linkages are shown in Table 1. All the variables were measured on a 5-point likert scale. Further, the degrees of knowledge acquisition and diffusion of a firm were separately calculated with respect to each stakeholder with whom a firm is connected through extra-cluster linkages using the following equation:

Degree of Knowledge Acquisition [DKA_{ex}(i, j)]= (Extent of co-operation between a firm f and stakeholder i)*(Frequency of assistance sought by a firm f from a stakeholder i residing outside Bengaluru cluster to solve problem(s) related to j)

Degree of knowledge acquisition of a firm (DKAex) is calculated using the following equation

$$DKA_{ex} = \sum_{\substack{1 \le i \le 2 \\ 1 \le j \le 2}} DKA(i,j)$$

Degree of Knowledge Diffusion [DKD_{ex} (i, j)] = (Extent of co-operation between a firm f and stakeholder i)*(Frequency of assistance provided by a firm f to a stakeholder i residing outside Bengaluru cluster to solve problem(s) related to j)

Degree of knowledge diffusion of a firm (DKDex) is calculated using the following equation

$$DKD_{ex} = \sum_{\substack{2 \le i \le 3 \\ 1 \le j \le 2}} DKD(i,j)$$

Where, f is a firm in a cluster whose degree of extra-cluster linkages to be calculated i is a stakeholder with whom a firm is connected via intra-cluster linkage [i=1 (suppliers), 2 (peers and competitors), 3 (corporate customers)] j is a nature of assistance sought [j=1 (technical), 2 (business)]

The degree of knowledge creation of a firm (DKCex) was calculated by adding all the variables, which determine the degree of knowledge creation. Further, the degree of extra-cluster linkages of a firm was computed by adding degree of knowledge acquisition, degree of knowledge diffusion and degree of knowledge creation of a firm involved in extra-cluster interactions.

$$DECL = DKA_{ex} + DKD_{ex} + DKC_{ex}$$

Table 2 Descriptive statistics of DICL and DECL

	N	Minimum	Maximum	Mean	Std. Deviation
DICL	101	41	260	122.05	35.566
DECL	101	27	121	65.37	18.665

It can be noted from Table 2 that while DICL varies between 41 and 260, DECL ranges between 27 and 121. Further, the mean values of DICL and

DECL are 122.05 and 65.37, respectively. The standard deviation values of DICL and DECL are 35.566 and 18.665, respectively.

4.3 Innovation

The two dimensions capturing both the range of unique products produced and sales obtained from these unique products were used to build an Innovation Index (INI), which is presented in Table 3.

Table 3 Dimensions of firm-level innovation

Sl.	Dimension	Variable
1	Innovated products (D1) (Bala Subrahmanya, 2011; Li, Veliyath andTan, 2013; Sweet and Maggio, 2015)	Proportion of innovated products to total products (v1)
2	Innovation sales (D2) (Bala Subrahmanya, 2011)	Proportion of innovation sales to total sales (v2)

Sources: Chandrashekar and Bala Subrahmanya (2017a, 2017b 2017c, 2017d, 2018)

All the variables were measured on a ratio scale. Further, the weighted score for each dimension was calculated using standardized weights derived from the importance rating and the actual score of the innovation dimension. The weighted average for each dimension (Table 4) was calculated using following equation:

Weighted average for each dimension:

$$w_p = \sum_{k=1}^{m} \frac{W_k X_{kp}}{n}$$

Where, wp is the weighted average of pth dimension, Wk is the weight of kth importance rating, Xkp is the number of responses of kth importance rating for pth dimension, p is the number of dimensions, m is the total number of importance rating, n is the total number of respondents.

Table 4 Weighted averages and standardised weights for the variables of innovation

Variable	Weighted Average	Standardised Weights
Proportion of innovated products to total products (v1)	4.7525	0.5074
Proportion of innovation sales to total sales (v2)	4.6139	0.4926

Subsequently, the index number of innovation (INI) for each firm was calculated using the following equation:

$$INI = (w1 * v1) + (w2 * v2)$$

Table 5 Descriptive statistics of INI

	N	Minimum	Maximum	Mean	Std. Deviation
INI	101	.1000	1.0000	.5516	.2530

It can be observed from Table 5 that INI varies between .1000 and 1.0000. In addition, the mean and standard deviation values are .5516 and .2530, respectively.

5. Method of Analysis

Cluster Analysis was carried out to cluster the sample firms using a K-Means algorithm into three distinct groups - low DCL (low DICL, low DECL), moderate DCL (moderate DICL, moderate DECL) and high DCL (high DICL, high DECL) clusters based on the cluster variables DICL and DECL. Further, each of these clusters was profiled based on the underlying cluster profile variables [such as nature of a firm (industry-type, age, size, origin of a firm) and firm-level innovation] using statistical techniques such as Analysis of Variance (ANOVA) and Chi-square Tests of Independence.

V. Results and Discussion

1. Analysis of DCL Clusters and Nature of a Firm

The cluster analysis results along with the final clustering center for each cluster is presented in Table 6. Further, to ascertain whether the distinct clusters differ based on the underlying cluster profile variables (such as nature of a firm (industry-type, age, size, origin of a firm) and firm-level innovation), ANOVA (continuous profiling variables) and Chi-square Tests of Independence (nominal profiling variables) were employed. The ANOVA tests were preceded by normality and equality of variance tests for INI and age of a firm. The results of these tests are presented in Table 7 and Table 8.

The results of ANOVA and Chi-square Tests of Independence are shown in Table 9 and Table 10, respectively.

Table 6 Cluster analysis results

	Cluster 1 Low DCL	Cluster 2 Moderate DCL	Cluster 3 High DCL
Number of Observations	48	43	10
Percentage of Observations	47.5%	42.6%	9.9%
Cluster Variables	Final Cluster Centers		
DICL	99.52	139.21	184.30
DECL	55.17	69.70	95.70

Table 7 Tests of normality - INI and age of a firm across the cluster groups

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Standardized Residual for INI	.099	101	.017*	.948	101	.001*
Standardized Residual for Age of a firm	.075	101	.182	.978	101	.092

*p-value<0.05

Table 8 Test of homogeneity of variances-age of a firm

Levene Statistic	df1	df2	Sig.
.509	2	98	.603

*p-value<0.05

Table 9 ANOVA - cluster profile variables

Profile Variables	ANOVA	Test Statistic	Significance
Age of a firm	One-way ANOVA	.625 F	.538
INI	Non-parametric ANOVA Kruskal Wallis Test	6.048 Chi-square	.049*

*p-value<0.05

Table 10 Chi-square test of independence - cluster profile variables

Profile Variables	Chi-square Statistic	Significance
Industry-type	8.354	.213
Size of a firm	10.617	.031*
Origin of a firm	8.609	.014*

*p-value<0.05

The results of ANOVA and Chi-square Tests of Independence indicate that two out of four cluster profile variables (size and origin of a firm) representing the nature of a firm significantly differ between the three cluster groups. In

addition, there is a statistically significant difference in the means of innovation performance (INI) of sample firms between the three cluster groups.

2. Profiling of Clusters - Graphical Analysis

To derive deeper insights on the composition of identified clusters, each of them was profiled based on their vital attributes. The profiling results will further enable to understand the underlying characteristics of each of the clusters.

The clusters have been profiled with respect to the following attributes-

Nature of a firm: industry-type, age, size and origin of a firm.

Innovation performance of a firm

2.1 Nature of a Firm

(a) Industry-type

Figure 2 presents the profiles of three clusters with respect to industry-type of a firm. From the figure, it is evident that the proportion of electronics, electrical, machine tools and pharmaceutical firms is 31%, 20%, 30% and 20%, respectively, in the aggregate sample. However, the cluster constituting high DCL has 30% of EC and P firms, and 20% of EE and MT firms. In contrast, moderate DCL cluster largely consists of MT firms (44%) whereas low DCL cluster majorly constitute EC firms (38%).

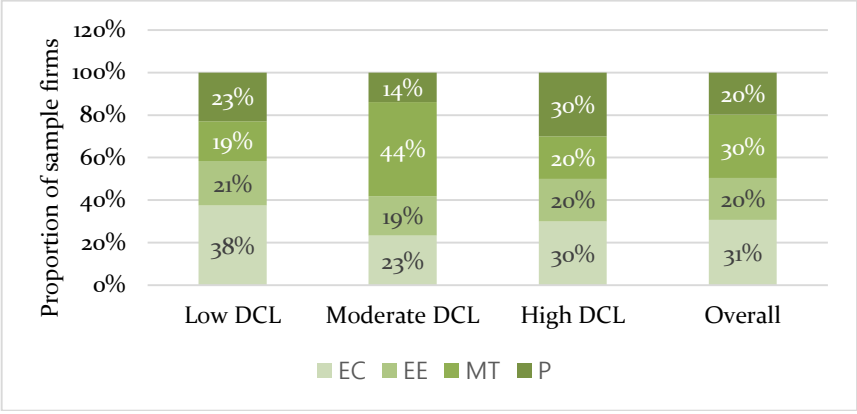

Figure 2 Cluster profile - industry-type

Although each of the clusters is marginally dominated by a specific industry, the extent of domination by an industry sector does not significantly explain the variance between the clusters.

(b) Age of a firm

Figure 3 presents the profiles of three clusters with respect to the age of a firm in terms of number of years of operation in Bengaluru. From the figure, it can be seen that the average age of sample firms constituting low DCL, moderate DCL and high DCL clusters are 21.21 years, 21.12 years and 25.4 years, respectively.

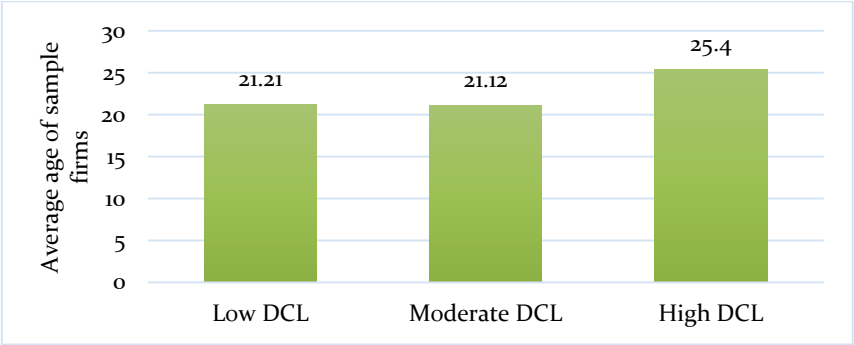

Figure 3 Cluster profile - age of a firm

Although there is no stark difference between the average ages of firms constituting low and moderate DCL clusters, the average age of firms belonging to high DCL cluster is slightly higher than that of low and moderate DCL clusters. This signifies that older firms are likely to have a higher DCL.

(c) Size of a firm

Figure 4 presents the profiles of three clusters with respect to size of a firm. From the figure, it is can be seen that the proportion of small, medium and large firms is 51%, 29% and 20%, respectively, in the aggregate sample. On one the hand, high DCL cluster consists 40% of small, 10% medium and 50% large firms. On the other hand, low DCL cluster constitutes 63% small, 25% medium and 13% large firms. However, moderate DCL cluster has a much more balanced composition consisting of small (42%), medium (37%) and large (21%) firms compared to that of low and high DCL clusters.

Thus, the large firms are more likely to have a higher DCL than small and medium firms. Although, small firms are more likely to have a lower DCL they are also likely to have moderate and high DCLs. However, medium firms are more likely to have low and moderate DCLs.

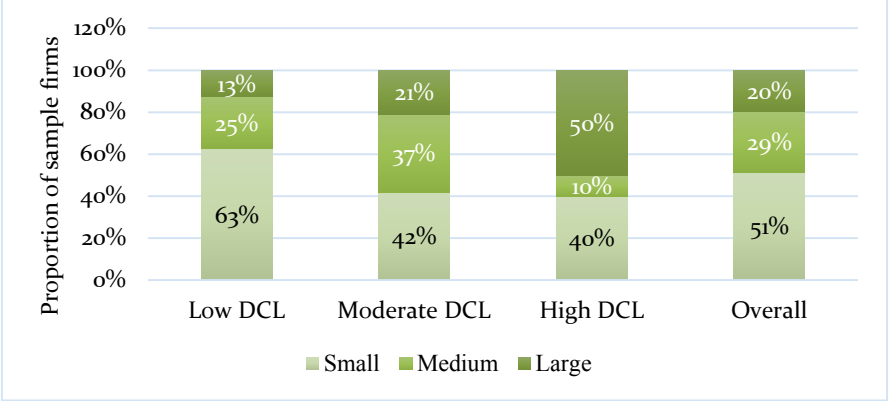

Figure 4 Cluster profile - size of a firm

(d) Origin of a firm

Figure 5 presents the profiles of three clusters with respect to the origin of a firm. From the figure, it can be seen that the proportion of Bengaluru and externally-based firms is 90% and 10%, respectively, in the aggregate sample. The high DCL cluster constitutes a high (30%) proportion of externally-based firms compared to low (2%) and moderate (14%) DCL clusters. Low DCL cluster consists of least proportion (2%) of externally based firms.

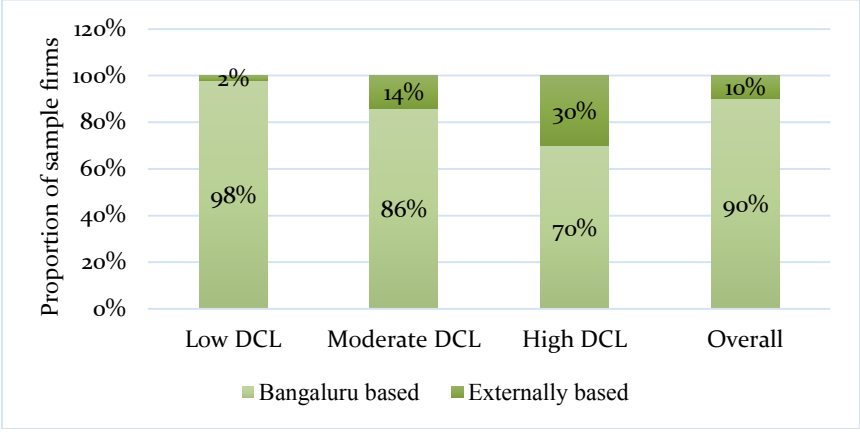

Figure 5 Cluster profile - origin of a firm

Thus, externally based firms are more likely to have high DCL and moderately likely to moderate DCL, compared to Bengaluru origin firms.

2.2 Innovation Performance of a Firm

Figure 6 presents the profiles of three clusters with respect to innovation performance of a firm in terms of innovation index (INI) computed for each sample firm. From the figure, it can be seen that the average INI of sample firms constituting low DCL, moderate DCL and high DCL clusters are 0.49, 0.59 and 0.68 respectively.

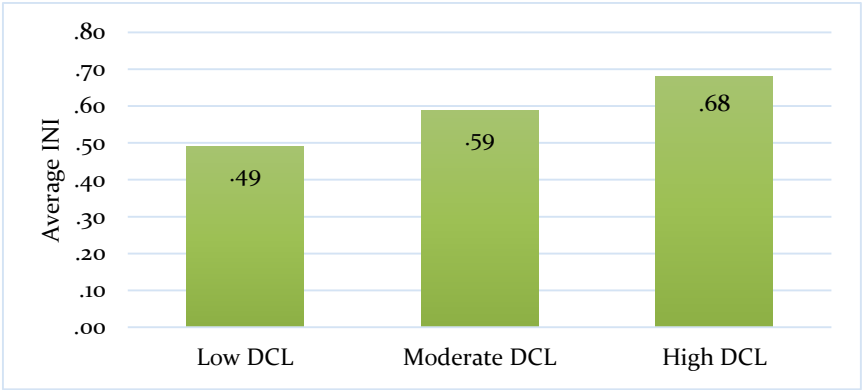

Figure 6 Cluster profile - innovation performance (INI) of a firm

The sample firms with higher DCL are more likely to exhibit higher innovation performance compared to firms with low and moderate DCLs. Although the magnitude of difference between average INIs of sample firms with moderate and high DCLs is small, still firms constituting high DCL cluster innovate much more than moderate DCL cluster firms.

In summary, the study provides evidence in favour of all the hypotheses proposed except H1 and H2. The degree of cluster linkages of a firm is found to be higher for large firms (H3) and also for firms that are the subsidiaries of externally-based firms residing outside a cluster (H4). Further, the degree of cluster linkages of a firm has a significant positive influence on innovation level of a firm (H5).

3. Profile Summary

Based on the results discussed in section 1 and 2, we present the summary profile of each of the three clusters in our sample.

3.1 Low DCL (low DICL and low DECL) Cluster

Low DCL cluster largely constitutes small firms (63%), and firms whose origin (98%) can be traced to Bengaluru. Though not so high, still a significant

proportion of medium firms (25%) co-exist with small firms in this cluster. In general, small and medium enterprises (SMEs) (88%) dominate this cluster. SMEs are known for adaptability, flexibility and simple organizational structure catering to technological innovation (Bala Subrahmanya, 2011; Revilla and Fernandez, 2013). However, these are the firms overweighed by infrastructural bottlenecks (Kumar and Bala Subrahmanya, 2007). Unlike the IT industry, which largely relies on human capital, the manufacturing industry requires investment in physical capital in addition to human capital to continually upgrade the knowledge base thereby improve the absorptive capacity of a firm (Patibandla and Petersen, 2002).

This is because the investment in physical capital enables specialization of labour and therefore contributes to the deepening of knowledge base of a firm. Further, failing to upgrade the knowledge base of a firm dynamically, other firms and associated institutions within and outside Bengaluru cluster find no value in building connections to the firm (Schmitz, 1999; Guilani and Bell, 2008). Soon the firm becomes espoused in a cluster. Ultimately, the lower absorptive capacity and consequently lower degree of cluster interactions of a firm results in lower innovation performance of a firm.

3.2 Moderate DCL (moderate DICL and moderate DECL) Cluster

Moderate DCL cluster mainly consists of small firms (42%). However, medium firms (37%) find their place in this cluster much more than they do in low (25%) and high DCL (10%) clusters. Moderate DCL cluster also constitutes a higher proportion of externally based firms compared to low DCL cluster. Though not so high compared to low DCL cluster, still SMEs (79%) dominate this cluster. The small firms, which offset their infrastructural bottlenecks with their moderately high internal capabilities (in terms of human capital intensity) at the baseline, find a place in this cluster. In the case of medium firms, their improved accessibility to physical capital makes them a best fit to this cluster. SMEs in this cluster, despite their infrastructural constraints have been able to upgrade their knowledge base and consequently contribute to improve their absorptive capacity continually.

Further, externally-based firms in this cluster set up their subsidiaries in Bengaluru cluster to take benefit of the agglomeration effects, which resulted from the clustering process. Their interactions are limited as they intend to find a large mass of either suppliers or customers to achieve their business objectives. However, they may not derive any benefit from the location-specific externalities that exist in Bengaluru cluster. Hence, the reasonably higher absorptive capacity and consequently moderate degree of cluster interactions results in moderately high innovation performance of a firm.

3.3 High DCL (high DICL and high DECL) Cluster

High DCL cluster predominantly houses large firms (50%). The rest of the cluster is constituted of small firms (40%) followed by medium firms (10%). Further, large firms (50%) majorly find their place in this cluster compared to low (13%) and moderate (21%) DCL clusters. Besides human capital, they have been able to heavily invest in physical capital as well. Better infrastructural capabilities of large firms have enabled specialization of labour and ultimately contributed to the scaling up of absorptive capacities of these firms. Further, large firms source their components by subcontracting to capable and reputed SMEs in a cluster (Berry, 1997; Schmitz, 1999). In turn, SMEs, which have built exceptional capabilities (in terms of human capital intensity) overcoming their infrastructural bottlenecks, cater to the needs of large firms. In the process, they learn and dynamically upgrade their knowledge bases greatly.

Therefore, the typology of this cluster follows hub and spoke model (Bergman, 2008) consisting of a few dominant firms in each industry forming a hub, and SMEs spread around the hub forming spokes. Furthermore, this cluster (30%) largely houses subsidiaries of externally based firms compared to low (2%) and moderate (14%) DCL clusters. These subsidiaries are located in Bengaluru cluster to take advantage of location-specific externalities, which resulted out of the network effect. Their connections with Bengaluru-based firms (within the cluster), on the one hand, and with their parent firm back home (outside the cluster), on the other hand, put them into a better shape to integrate local and global knowledge systems. Hence, the higher absorptive capacity and consequently higher degree of cluster interactions yielded a higher innovation performance of a firm.

VI. Conclusion

This paper has ascertained both the degree of intra-cluster linkages (DICL) and degree of extra-cluster linkages (DECL) based on the degree of knowledge acquisition, diffusion and creation capturing interactions of each firm with other firms, and associated institutions within and outside Bengaluru cluster. Further, an index number of innovation was computed for each sample firm in the cluster. In addition, it probed the influence of the nature of a firm (in terms of industry-type, age, size and origin of a firm) on DICL and DECL. Furthermore, the impact of DICL and DECL of a firm on firm-level innovation was ascertained.

Using K-Mean clustering algorithm, the sample firms were clustered into three distinct clusters - low DCL, moderate DCL and high DCL clusters based

on the cluster variables, namely, DICL and DECL. Subsequently, we probed whether these clusters differ across each of the profile variables, and found that two out of four profile variables - size and origin of a firm representing the nature of a firm, and innovation performance of a firm - turned out to be significant.

Further, to understand the underlying characteristics of each of the three clusters, they were profiled based on the nature of a firm (such as industry-type, age, size and origin of a firm) and innovation performance of a firm. It was inferred from the results that low DCL cluster largely constitutes SMEs compared to moderate and high DCL clusters. However, SMEs play a significant role in all the identified clusters based on their ability to compensate their infrastructural bottlenecks due to lack of physical capital with their other internal capabilities. This dynamic ability of a firm to deepen its knowledge base on a continual scale, consequently shows up in terms of improved absorptive capacity of a firm. The large firms majorly constituting high DCL cluster have been able to make adequate investment in physical capital besides human capital, which has helped them to boost their absorptive capacity. In addition, their subcontracting ties with capable and reputed SMEs in an industry have mutually helped each other to produce innovative outcomes at different levels.

Furthermore, the high DCL cluster predominantly houses subsidiaries of externally-based firms compared to low and moderate DCL clusters. These subsidiaries of externally-based firms located in Bengaluru are less likely to take advantage of agglomeration effects resulted from the clustering process and more likely to further reap benefits of location-specific externalities resulted from network effects. Therefore, they are aggressively involved in interactions with the cluster participants in Bengaluru as well as their parent firms based outside Bengaluru. As a result, they greatly integrate both local and global knowledge systems resulting in innovative outcomes.

This paper has made two key contributions to the literature. Firstly, it has attempted to identify the variables that possibly alter the absorptive capacity of a firm, and subsequently empirically validated the influence of each of those variables on the degree of cluster linkages. Secondly, in the context of a developing economy, it has attempted to empirically validate the impact of degree cluster linkages as a whole on firm-level innovation. The study has implications for practitioners as well as policy makers. For practitioners, it provides inputs to understand the firm-specific factors that contribute to varied levels of cluster linkages and in turn innovation. For policy-makers, it advocates the need to extensively focus on the promotion of cluster linkages through creation of a vibrant ecosystem to enhance the innovation performance of firms.

The study is limited to the cluster in an emerging economy. Cross-country comparative study of clusters would provide more insights on the changing structures of clusters and their dynamism. This study did not consider the direct connections between a firm located in a cluster and the associated institutions outside a cluster. Hence, these provide scope for future research in the area.

Acknowledgement

An earlier version of this article was presented in the ICSSR, India-JSPS, Japan Joint Seminar on “Ecosystem For Technology Start-Ups In India And Japan: A Comparative Perspective", held during 1-5 May 2017 at the Department of Management Studies, Indian Institute of Science, Bangalore and jointly organized by the Department of Management Studies, Indian Institute of Science, Bangalore and Toyohashi University of Technology, Japan. The sponsorship provided by both Indian Council of Social Science Research (ICSSR), Government of India, New Delhi and Japan Society for Promotion of Science (JSPS), Government of Japan, Tokyo for the joint seminar is gratefully acknowledged. However, the author alone is responsible for any of the deficiencies if remain in the article and not the sponsors of the joint seminar.

Further, the author would like to acknowledge and thank the anonymous reviewer for the exhaustive review comments that helped improve the article.

Reference

Bala Subrahmanya, M.H. (2011) Technological innovation and growth of SMEs in Bangalore: does innovation facilitate growth of firm size?, Asian Journal of Technology Management, 4(1), 41-55.

Bala Subrahmanya, M.H. (2013) External support, innovation and economic performance: what firm level factors matter for high-tech SMEs? How?, International Journal of Innovation Management, 17(5), 1-26.

Baptista, R. and Swann, P. (1998) Do firms in clusters innovate more?, Research Policy, 27(5), 525-540.

Becheikh, N., Landry, R. and Amara, N. (2006) Lessons from innovation empirical studies in the manufacturing sector: a systematic review of the literature from 1993-2003, Technovation, 26(5-6), 644-664.

Bell, M. and Albu, M. (1999) Knowledge systems and technological dynamism in industrial clusters in developing countries, World Development, 27(9), 1715-1734.

Bergman, E.M. (2008) Cluster life-cycles: an emerging synthesis, In Karlsson, C., Handbook of Research on Cluster Theory, Northampton, MA: Edward Elgar, 114-132.

Berry, A. (1997) SME Competitiveness: The Power of Networking and Subcontracting, Washington D.C: Inter-American Development Bank.

Brenner, T. and Gildner, A. (2006) The Long-term implications of local industrial clusters, European Planning Studies, 14(9), 1315-1328.

Cohen, W. and Levinthal, D. (1990) Absorptive capacity: a new perspective on learning and innovation, Administrative Science Quarterly, 35(1), 128-152.

Chandrashekar, D. and Bala Subrahmanya, M.H. (2017a) Degree of cluster linkages and innovation performance of a firm: a study Bengaluru high-tech manufacturing cluster, Bristol, UK: International Symposium on Industrial Engineering and Operations Management, 834-847.

Chandrashekar, D. and Bala Subrahmanya, M.H. (2017b) Absorptive capacity as a determinant of innovation of SMEs: a study of Bengaluru high-tech manufacturing cluster, Small Enterprise Research, 24(3), 290-315.

Chandrashekar, D. and Bala Subrahmanya, M.H. (2017c) Exploring the Factors of Cluster Linkages that Influence Innovation Performance of Firms in a Cluster, Economics of Innovation and New Technology.

Chandrashekar, D. and Bala Subrahmanya, M.H. (2017d) Exploring the influence of absorptive capacity on innovation in Bengaluru high-tech manufacturing cluster, Santa Clara, CA: IEEE Technology and Engineering Management Society Conference, 166-172.

Chandrashekar, D. and Bala Subrahmanya, M.H. (2018) Absorptive capacity, cluster linkages and innovation: an evidence from Bengaluru high-tech manufacturing cluster, Journal of Manufacturing Technology Management, 29(1), 121-148.

Fabrizio, K.R. (2009) Absorptive capacity and the search for innovation, Research Policy, 38(2), 255-267.

Fosfuri, A. and Tribo, J.A. (2008) Exploring the anticidents of potential absorptive capacity and its impact on innovation performance, International Journal of Management, 36(2), 173-187.
Gildner, T.B. (2006) The long-term implications of local industrial clusters, European Planning Studies, 14(9), 1315-1328.
Giuliani, E. (2005) Cluster absoptive capacity: why do some clusters forge ahead and others lag behind, European Urban and Regional Studies, 12(3), 269-288.
Giuliani, E. and Bell, M. (2008) The industrial clusters and the evolution of their knowledge networks: Revisiting a Chilean Case, Brighton, UK: SPRU working paper series.
Giuliani, E. and Bell, M. (2005) The micro-determinants of meso-level learning and innovation: evidence from a Chilean wine cluster, Research Policy, 34(1), 47-68.
Go, K. (2006) New Industrial Policy 2006-2011, Bangalore: Department of Industries and Commerce.
He, J. and Fallah, M.H. (2011) The typology of technology cluster and its evolution-evidence from hi-tech industries, Technology Forecasting and Social Change, 48(6), 945-952.
Ketels, C.H. (2003) The development of the cluster concept-present experiences and further developments, Duisburg, Germany: NRW Conference on Clusters.
Kostopoulos, K., Papalexandris, A., Papachroni, M., and Loannou, G. (2011) Absorptive capacity, innovation, and financial performance, Journal of Business Research, 64(12), 1335-1343.
Kim, L. (1995) Absorptice Capacity and Industrial Growth: A Conceptual Framework and Korea's Experience, St. Martin's Press, 256-287.
Kumar, S.R. and Bala Subrahmanya, M.H. (2003) Subcontracting relationship of Indian, SMEs with a global TNC: do SMEs gain? How?, Singapore: Singapore Economic Review Conference.
Lau, A.K. and Lo, W. (2015) Regional innovation system, absorptive capacity and innovation performance; an empirical study, Technological Forecasting and Social Change, 92, 99-114.
Li, W., Veliyath, R. and Tan, J. (2013) Network characteristics and firm performance: an examination of the relationships in the context of a cluster, Journal of Small Business Management, 51(1), 1-22.
Markusen, A. (1996) Sticky places in slippery space: a typology of industrial districts, Economic Geography, 72(3), 293-313.
Miguelez, E. and Moreno, R. (2015) Knowledge flows and the absorptive capacity of regions, Research Policy, 44(4), 833-848.
Morosini, P. (2004) Industrial clusters, knowledge integration and performance, World Development, 32(3), 305-326.
Mowery, D.C. and Oxley, J.E. (1995) Inward technology transfer and competitiveness: the role of innovation systems. Cambridge Journal of Economics, 19(1), 67-93.
Maskell, P. (2001) Towards knowledge-based theory of the geographical cluster, Industrial and Corporate Change, 10(4), 921-941.
Mytelka, L.K. (2000) Local systems of innovation in a globalized world economy, Industry and Innovation, 7(1), 33-54.

Nadvi, K. (1995) Industrial Clusters and Networks: Case Studies of SME Growth and Innovation, UNIDO, Small Medium Enterprises Programme.

NKC (2007) Innovation in India, Government of India.

Nooteboom, B. (1999) Innovation and inter-firm linkages: new implications for policy. Research Policy, 28(8): 793–805.

Okada, A. and Siddharthan, N. (2007) Industrial Clusters in India: Evidence from Automobile Clusters in Chennai and the National Capital Region, Institute for Studies in Industrial Development, Chiba, Japan: JETRO.

Oneindia (2013) Retrieved from http://www.oneindia.com/2013/08/02/bangalore-listed-among-top-8-tech-clusters-in-mit-review-1274110.html

Patibandla, M. and Petersen, B. (2002) Role of transnational corporations in the evolution of a high-tech industry: the case of India's software industry, World Development, 30(9), 1561-1577.

Porter, M.E. (1990) The Competitive of Nations, Harvard Business Review.

Rao, P. and Klein, J.A. (2013) Inter-firm technology tranfers and collaboration, In Rao, P. and Klein, J.A., Strategies for High-tech Firms, New York: M.E. Sharpe, 107-120.

Rao, P. and Klein, J.A. (2013) Sustaining competitive advantage in a high-tech environment, In Rao, P. and Klein, J.A., Strategies for High-Tech Firms, New York: M.E. Sharpe, 3-28.

Revilla, A. and Fernandez, Z. (2005) Environmental dynamism firm size and the economic productivity of R&D, Industry and Innovation, 20(6), 503-522.

Rosenfeld, S. (2005) Industry cluster: business choice, policy outcome, or branding strategy, New Business Ideas and Trends, 3(2), 4-13.

Saxenian, A.L. (1994) Regional Advantage: Culture and Competition in Silicon Valley and Route 128, Cambridge: MA: Harvard University Press.

Schmitz, H. (1999) From ascribed to earned trust in exporting clusters, Journal of International Economics, 48(1), 139-150.

Schumpeter, J.A. (1934) The Theory of Economic Development: An Inquiry Into Profits, Capital, Credit, Interest, and the Business Cycle, Transaction Publishers.

Sonderegger, P. and Taube, F. (2010) Cluster life cycle and diaspora effects: evidence from the Indian IT cluster in Bangalore, Journal of International Management, 16(4), 283-397.

Steinle, C. and Schiele, H. (2002) When do industries cluster? a proposal on how to assess an industry's propensity to concentrate at a single region or nation, Research Policy, 31(6), 849-858.

Sweet, C.M. and Maggio, D.S. (2015) Do stronger intellectual property rights increase innovation?, World Development, 66, 665-677.

UNDP (2001) Human Development Report, New York: Oxford University Press.

Zahra, S.A. and George, G. (2002) Absorptive capacity: a review, reconceptualization, and extension, Academy of Management Review, 27(2), 185-203.