

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

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## **Abstract-**

*It is primarily understood that clusters are the sources of innovation and therefore, of late, the focus of researchers and practitioners has been increasingly to ascertain the factors driving innovation among the firms in a cluster, especially in a high-tech cluster. Researchers have identified that the dynamism of a firm in terms of degree of interactions of a firm with other firms and related institutions as one of the key drivers of innovations in a firm residing in a cluster. However, this has not been empirically validated considering the gamut of interactions of a firm with all the stakeholders within and outside a cluster. It is in the context of Bengaluru (erstwhile Bangalore) cluster which houses densely interconnected network of high-tech manufacturing firms this paper probes the influence of degree of cluster linkages on the firm-level innovation.*

**Key words:** Cluster Linkages, Innovation, High-tech Industries, Industrial Cluster, Bengaluru

## **1. Introduction**

Innovation is considered as one of the key drivers of productivity and firm performance (Schumpeter, 1934; Porter, 1990). In the context of a developing country, Mytelka (2000) defined innovation as the 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. Further, from the perspective of a manufacturing firm, the focus is laid on technological innovation which provides the firm a competitive edge over others (Becheikh et al., 2006). However, firms in general, and Small and Medium Enterprises (SMEs) in particular are constrained by internal resources that serve as impediments to undertake innovations by them. It is here the notion of industrial cluster which comes in handy to eliminate or lower these impediments and thereby propelling innovations in firms (Ketels, 2003).

Clusters offer various benefits to firms as well as regions housing these clusters (Muskell, 2001, Ketels, 2003; Sonderegger, 2010). Notably, they facilitate firms to achieve higher levels of innovation and productivity (Porter, 1990; Ketels, 2003). However, firms in a cluster can derive economic benefits from positive location specific externalities resulted out of network effects only if the firms in a cluster interact adequately. Hence, it is appropriate to understand the influence of interactions of firms in terms of cluster linkages on the innovation levels of firms.

Furthermore, among the clusters of the globe, Bengaluru cluster occupies a unique position as it includes not only IT sector but also multitude of high-tech manufacturing industries (e.g. electronics, pharmaceutical, machine tools,

electrical, etc.) forming a high-tech cluster (Nadvi, 1995; GoK, 2006). It is in the context of Bengaluru high-tech manufacturing cluster that this paper probes the influence of degree of cluster linkages on the firm-level innovation.

## **2. Literature Review**

### **2.1 Innovation and Industrial Clusters**

With the advancement of globalization era, and constantly changing tastes and preferences of customers, there is a pressing need for firms to innovate. More so in the context of high-tech firms which are challenged by swiftly changing frontiers of technology (Kakati, 2003). This has urged firms to build dynamic capabilities and collaborate with other to gain and sustain competitive edge over others (Rao and Klein, 2013).

Viewing firms from the perspective of -Resource-based Theory (RBT) (Wernerfelt, 1984; Barney, 1991), a firm is seen as “a bundle of resources”. However, firms in general and SMEs in particular are constrained by financial, technological, infrastructural (production capability, sales and distribution channel) and managerial bottlenecks (Kumar and Bala Subrahmanya, 2007). These are the impediments that are preventing firms to undertake technological innovations. Hence, there is a need for firms to build network ties with other firms, research institutions, suppliers and customers. These network ties enables firms to share knowledge on the one hand, and mobilize resources on the other (Mazzola and Bruni, 2000; Bullinger, et al., 2004).

Even though firms are not limited by internal resources, still they bank on network ties as no single firm can gain mastery at all levels of value chain and cannot efficiently produce everything due to incompatibility of scales (Steinle and Schiele, 2002). Hence, they have to produce what they are good at, and outsource rest of the components from other firms, especially SMEs, in the close vicinity in order to minimize transaction cost, and ultimately to sustain a competitive advantage (Berry, 1997). It is here that the concept of industrial cluster assumes vital role in facilitating firms to build network ties and thereby lower or eliminate the barriers holding back innovations in firms.

Industrial Clusters are defined as a group of companies and institutions co-located in a specific geographic region and linked by interdependencies in providing a related group of products and/or services (Porter, 1990; Ketels, 2003). Further, high-tech clusters which are characterized by a complex technology or innovation are the groups firms and associated institutions related to high-tech industry (Wang and Yang, 2012).

Further, the process of clustering induces two kinds of effects: agglomeration effect and subsequently network effect. Agglomeration effect is due to agglomeration of firms belonging to one industry. This results in economic advantages stemming from close proximity of firms and associated institutions that benefit specific industries only (Morosini, 2004). It gives rise to passive location-specific externalities which renders basically three advantages to firms located in a cluster (Marshall, 1925). Firstly, geographic concentration of firms allows them to develop a specialized pool of skilled labour specific to an industry. Secondly, it supports the production of non-tradable specialized inputs. Thirdly, it generates maximum flow of information and ideas which provide cluster members a competitive edge over isolated firms. However, the benefits of mere agglomeration of firms are limited to availability of skilled human resources, reduction in transportation and transaction costs (Steinle and Schiele, 2002).

Network effect is when an addition of a cluster member adds value to incumbent firms and vice-versa (Krugman, 1991; Rao and Klein, 2013). The actors in the network can derive benefits from the network only if a cluster develops adequate scale to generate externalities (Ketels, 2003). Network effect gives rise to several active location-specific positive externalities such as access to specialized human resources and suppliers, knowledge spill-overs, pressure for higher performance in head-to-head competition, and learning from interaction with specialized customers and suppliers. Realization of these location-specific positive externalities facilitates firms to operate at higher levels of efficiency and achieve higher levels of innovation (Ketels, 2003; Muskell, 2001; Sonderegger, 2010).

Ultimately, firms are entitled to various economic benefits resulted out of network effects only if interactions among them exceeds conventional market exchange. Hence, it is appropriate to explore different types of cluster linkages and their importance.

### **2.2 Cluster Linkages**

Underscoring the importance of cluster interactions, Nooteboom (1999) contends that in the absence of interactions among firms, firms perceive, understand and evaluate differently based on the environment surrounding them. However, such kind of a thought process may not result in a novel product or process meeting the changing needs of end users. Hence, they need an external source of cognition and competence to complement their own in order to produce innovative outcomes while minimizing the transaction and failure costs.

Further, Giuliani (2005) identified two kinds of cluster linkages viz.- intra-cluster linkages and extra-cluster linkages. Intra-cluster linkages are the linkages between a firm, and other firms and related institutions in a cluster for the flow of knowledge between them. Extra-cluster linkages are the linkages between a firm, and other firms and related institutions outside a cluster for the flow of knowledge between them.

On the one hand, intra-cluster linkages facilitate firms in a cluster to access tacit/implicit knowledge which is locally diffused, and could only be captured through face-to-face informal interactions among personnel in a cluster (Baptista and Swann, 1998; Giuliani, 2005; Owen-Smith and Powell, 2004; Rosenfeld, 2005; Sonderegger and Taube, 2010). On the other hand, extra-cluster linkages facilitate firms to integrate both local and global knowledge systems (Giuliani, 2005; Rosenfeld, 2005).

No matter they are intra-cluster or extra-cluster linkages, the linkages could be vertical (linkages at different levels of value chain) or horizontal (linkages at the same level of value chain), business or technical, and ascribed (linkages based on socio-economic ties) or earned (linkages based on reputation) (Schmitz, 1999; Muskell, 2001; Giuliani and Bell, 2005).

Having dealt with various types of cluster linkages, we now move on to understand how these cluster linkages aid firms to produce innovative outcomes.

### **2.3 Cluster Linkages and Innovation**

Firms are facilitated by intra-cluster and extra-cluster linkages, identify the external sources of knowledge and acquire them based on their underlying knowledge levels (Giuliani 2005; Giuliani and Bell, 2005). Further, the degree of knowledge acquisition depends on the quantum of assistance received by a firm in a cluster from other firms within and/or outside the cluster via 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 keep the reciprocity going, firms in a cluster also diffuse the accumulated knowledge through the same intra-cluster and extra-cluster linkages. The degree of knowledge diffusion depends on the quantum of assistance provided by a firm in a cluster 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, personnel of firms also disseminate the acquired knowledge to academia by publishing papers, participating in workshops and conferences etc.

On acquisition of external knowledge, firms analyze and understand the information obtained from the imported knowledge (Zahra and George, 2002). Later, they develop a new routine or refine an existing routine which facilitates collation of existing knowledge and acquired knowledge to create new/transformed knowledge.

The nature and strength of intra-cluster and extra-cluster linkages reflect the degree of knowledge integration and subsequently knowledge creation within the firm. Primarily, the two key dimensions of knowledge creation namely horizontal and vertical dimensions deepen the knowledge base of firms in a cluster (Muskell, 2001). On the one hand, vertical linkages aid firms to enter into partnerships and collaborations and thereby resulting in specialization of labour, while on the other, horizontal linkages aid firms to bench-mark with peers and competitors thereby helping them to assess their competence in the market (Muskell, 2001).

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

## **2.4 Gaps in the Literature**

Several researchers have made theoretical contributions to conceptualize cluster linkages of a firm largely capturing the interactions among firms within and outside a cluster respectively (Bell and Albu, 1999, Giuliani 2005; Giuliani and Bell, 2005). However, the influence of these cluster linkages of a firm covering entire gamut of interactions between a firm, and other firms and associated institutions within and outside a cluster respectively, on innovation performance of a firm has not been empirically validated.

## **3. Objective, Scope, Sampling and Methodology**

### **3.1 Objective**

To probe the influence of degree of cluster linkages (DCL) of a firm on the firm-level innovation.

### **3.2 Scope**

This study is confined to Bengaluru high-tech cluster. Further, 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 8 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 study is cross-sectional in nature, and it covers small (S), medium (M) and large (L) firms belonging to high-tech manufacturing industries such as electronics (EC), electrical (EE), machine tools (MT) and pharmaceutical (P) industries located in Bengaluru.

### **3.3 Sampling and Specifics of Data Collection**

We sourced the list of firms belonging to industries under consideration from multiple industry associations [Indian Machine Tools Manufacturers' Association (IMTMA), Karnataka Drugs and Pharmaceutical Manufacturers' Association (KDPMA), Indian Electronics and Semiconductor Association (IESA), Consortium of Electronics Industries in Karnataka (CLIK), Indian Electronics and Electrical Manufacturers Association (IEEMA) etc.,] and government agencies. By consolidating the lists of firms obtained from these sources, we identified 186 high-tech manufacturing firms whose manufacturing units are based in Bengaluru. For an identified population of 186 firms, with a confidence interval of 10 at 95% confidence level, the required minimum sample size is 64 firms. Further, we identified four strata corresponding to each of the industry sectors under consideration. We adopted Stratified Random Sampling technique to choose sample firms from our population. Based on the population size of each of the strata, total sample size and total population size, the minimum sample size required for each of the strata (20 for EC, 20 for MT, 13 for P and 12 for EE) was determined. Finally, we chose 101 (31, 30, 20 and 20 firms belonging to EC, MT, P and EE respectively) firms, from our population.

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 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.

### **3.4 Dimensions, Variables and Measures**

(1) *Degree of Intra-cluster and Extra-cluster Linkages:*

(a) Degree of Intra-cluster Linkages (DICL):

The factors determining the degree of intra-cluster linkages are presented in Table 1.

All the variables were measured on a 5-point interval scale. Further, the degree of knowledge acquisition and the degree of knowledge 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<sub>in</sub>( 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 inside Bengaluru to solve problem(s) related to j)*

Degree of Knowledge Acquisition<sup>1</sup> of a firm (*DKA<sub>in</sub>*) is calculated using the following equation

$$DKA_{in} = \sum_{\substack{1 \leq i \leq 2 \\ 1 \leq j \leq 2}} DKA(i, j) + \sum_{i=3}^5 DKA(i)$$

*Degree of Knowledge Diffusion [DKD<sub>in</sub> (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 to solve problem(s) related to j)*

Degree of Knowledge Diffusion<sup>2</sup> of a firm (*DKD<sub>in</sub>*) is calculated using the following equation

$$DKD_{in} = \sum_{\substack{2 \leq i \leq 3 \\ 1 \leq j \leq 2}} DKD(i, j) + \sum_{i=3}^5 DKD(i)$$

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 (*DKC<sub>in</sub>*) was calculated by adding all the variables determining the degree of knowledge creation.

Furthermore, 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.

$$DICL = DKA_{in} + DKD_{in} + DKC_{in}$$

<sup>1</sup> The linkage between a firm and suppliers/customers is bilateral in nature. Hence, we consider a linkage with suppliers but not customers while computing DKA since the linkage is initiated by a firm to address its technical/business needs by seeking assistance from suppliers.

<sup>2</sup> The linkage between a firm and suppliers/customers is bilateral in nature. Hence, we consider a linkage with customers but not suppliers while computing DKD since the linkage is initiated by a customer to address its technical/business needs by seeking assistance from a firm.

**Table.1: Factors Determining the Degree of Cluster Linkages of a Firm**

SI. No.	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 sought 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 (peer companies, competitors, academic institutions, industry associations etc.) 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.

(b) Degree of Extra-cluster Linkages (DECL):

The factors determining the degree of extra-cluster linkages are presented in Table 1.

All the variables were measured on a 5-point interval scale. Further, the degree of knowledge acquisition and the degree of knowledge 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<sub>ex</sub>( 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 to solve problem(s) related to j)*

Degree of Knowledge Acquisition<sup>3</sup> of a firm ( $DKA_{ex}$ ) is calculated using the following equation

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

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 to solve problem(s) related to  $j$ )

Degree of Knowledge Diffusion<sup>4</sup> of a firm ( $DKD_{ex}$ ) is calculated using the following equation

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

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 ( $DKC_{ex}$ ) was calculated by adding all the variables determining the degree of knowledge creation.

Furthermore, 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.

$$(2) \text{ DECL} = DKA_{ex} + DKD_{ex} + DKC_{ex}$$

(2) Innovation Performance of a Firm

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 2:

**Table 2: Dimensions of Firm-level Innovation**

SI. No.	Dimension	Variable
1	Innovated products ( $D_1$ ) (Bala Subrahmanya, 2011; Sweet and Maggio, 2015)	Proportion of innovated products to total products ( $v_1$ )
2	Innovation sales ( $D_2$ ) (Li et al., 2012; Bala Subrahmanya, 2013)	Proportion of innovation sales to total sales ( $v_2$ )

<sup>3</sup> The linkage between a firm and suppliers/customers is bilateral in nature. Hence, we consider a linkage with suppliers but not customers while computing DKA since the linkage is initiated by a firm to address its technical/business needs by seeking assistance from suppliers

<sup>4</sup> The linkage between a firm and suppliers/customers is bilateral in nature. Hence, we consider a linkage with customers but not suppliers while computing DKD since the linkage is initiated by a customer to address its technical/business needs by seeking assistance from a firm.

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 was calculated using following equations:

(1) Weighted average for each dimension:

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

Where,

$w_p$  is the weighted average of  $p^{\text{th}}$  dimension,

$W_k$  is the weight of  $k^{\text{th}}$  importance rating,

$X_{kp}$  is the number of responses of  $k^{\text{th}}$  importance rating for  $p^{\text{th}}$  dimension,

$p$  is the number of dimensions,

$m$  is the total number of importance rating,

$n$  is the total number of respondents.

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

$$INI = (w_1 * v_1) + (w_2 * v_2)$$

### 3.5 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, non-parametric ANOVA (Kruskal Wallis Test) was employed to examine whether the means of innovation performances of firms varied across the cluster groups. In addition, post-hoc test (Non-parametric LSD) was carried out to ascertain the extent of differences in the means of innovation performances of firms between the cluster groups.

## 4. Results and Discussion

The cluster variables DICL and DECL when subjected to cluster analysis using a K-Means algorithm resulted in three distinct groups – Low DCL (Low DICL, Low DECL), Moderate DCL (Moderate DICL, Moderate DECL) and High DCL (High DICL, High DECL) clusters. The final clustering center for each cluster is presented in Table 3.

**Table 3: Cluster Analysis Results: Degree of Cluster Linkages (DCL)**

	<b>Cluster 1 Low DCL</b>	<b>Cluster 2 Moderate DCL</b>	<b>Cluster 3 High DCL</b>
<b>Number of Observations</b>	47	43	11
<b>Percentage of Observations</b>	46.5%	42.6%	10.9%
<b>Cluster Variables</b>	<b>Final Cluster Centers</b>		
DICL	91.98	138.12	182.55
DECL	45	59	83

The one-way ANOVA results with respect to the variables considered in the clustering scheme is presented in Table 4. The results from the one-way ANOVA indicate that the mean values of all the cluster variables except  $DKC_{ex}$  varied across the three cluster groups. Hence, we excluded  $DKC_{ex}$  and executed the clustering algorithm yet again with just the significant variables. The results thus obtained have been presented in Table 4.

**Table 4: One-way ANOVA Results: Cluster Variables**

	<b>Cluster 1 Low DCL</b>	<b>Cluster 2 Moderate DCL</b>	<b>Cluster 3 High DCL</b>	<b>F-statistic</b>	<b>P-value</b>
	Average Values (for variables that are a part of the Clustering Scheme)				
DKA <sub>in</sub>	41.51	65.19	81.82	116.479	.000***
DKD <sub>in</sub>	40.28	61.74	89.18	75.443	<b>.000***</b>
DKC <sub>in</sub>	10.19	11.19	11.55	9.568	.000***
DKA <sub>ex</sub>	21.40	26.63	38.18	20.071	.000***
DKD <sub>ex</sub>	23.62	32.09	44.73	37.778	.000***
	Average Values (for variables that are not a part of the Clustering Scheme)				
DKC <sub>ex</sub>	10.15	10.47	11.09	1.699	.188

\*\*\*p<.01, \*\*p<0.05, \*p<0.1

Note: The test for equality of means was preceded by the test for Equality of Variances. In case the variances are equal, the regular F-Statistic values have been reported; otherwise Welch-F-Statistic values have been reported. P-values of significant results are marked in **bold**.

Further, to ascertain whether the innovation performances of firms (INI) vary across the distinct cluster groups, non-parametric ANOVA (Kruskal Wallis Test)<sup>5</sup> was employed. The results indicate that there is a statistically significant difference in the means of innovation performance (INI) of sample firms across the three cluster groups (Table 5).

**Table 5: Non-parametric ANOVA Results: Innovation Performance of a Firm (INI) across the Cluster Groups**

<b>Dependent Variable</b>	<b>Test</b>	<b>Test Statistic</b>	<b>P-value</b>
INI	Kruskal Wallis Test	Chi-square 5.958	.051*

\*\*\*p<.01, \*\*p<0.05, \*p<0.1

Furthermore, to understand the extent of differences in the means of innovation performances of firms between the three cluster groups, post-hoc test (Non-parametric LSD) was carried out. The results indicate that the means of innovation performances of firms for *Moderate and High DCL* clusters are significantly higher than those for *Low DCL* cluster (Table 6). However, there is no statistically significant difference in the means of innovation performances of firms between *Moderate and High DCL* clusters although the means of innovation performances of firms for *High DCL* cluster was higher than those for *Moderate DCL* cluster.

**Table 6: Non-parametric LSD Results: Innovation Performance of a Firm (INI) between the Cluster Groups**

<b>Dependent Variable: Innovation Performance of a firm (INI)</b>				
<b>Cluster No. (I)</b>	<b>Cluster No. (J)</b>	<b>Mean Difference (I-J)</b>	<b>Chi-square Statistic</b>	<b>P-value</b>
1 ( <i>Low DCL Cluster</i> )	2 ( <i>Moderate DCL Cluster</i> )	Negative	4.027	.045**
	3 ( <i>High DCL Cluster</i> )	Negative	3.745	.053*
2 ( <i>Moderate DCL Cluster</i> )	1 ( <i>Low DCL Cluster</i> )	Positive	4.027	.045**
	3 ( <i>High DCL Cluster</i> )	Negative	.365	.546
3	1 ( <i>Low DCL Cluster</i> )	Positive	3.745	.053*

<sup>5</sup> Failing to meet the normality assumptions of One-way ANOVA, Non-parametric ANOVA (Kruskal Wallis Test) was employed to test the difference in the means of INI (Table A3).

(High DCL Cluster)	2 (Moderate DCL Cluster)	Positive	.365	.546
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\*\*\*p<.01, \*\*p<0.05, \*p<0.1

## 5. Conclusion

This paper has ascertained the factors determining the cluster linkages in a high-tech manufacturing cluster of Bengaluru and subsequently examined the impact of degree of cluster linkages of a firm on the firm-level innovation.

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 the innovation performances of firms vary across the three cluster groups. It was found that there is a significant difference in the means of innovation performances of firms across the cluster groups. Further, from the post-hoc test (Non-parametric LSD) it was evident that means of innovation performances of firms for *Moderate and High DCL* clusters are significantly higher than those for *Low DCL* cluster. However, there is no statistically significant difference in the means of innovation performances of firms between *Moderate and High DCL* clusters although the means of innovation performances of firms for *High DCL* cluster was higher than those for *Moderate DCL* cluster. In essence, it can be inferred that cluster linkages play a significant role in enhancing innovation level of a firm in a cluster.

This paper has made a key contribution to the existing literature by empirically validating the influence of degree of cluster linkages of a firm on its innovation performance.

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## ANNEXURES

**Table.A1: Weighted Averages and Standardised Weights for the Variables of Innovation**

Variable	Weighted Average	Standardised Weights
Proportion of innovated products to total products ( $v_1$ )	4.7525	0.5074
Proportion of innovation sales to total sales ( $v_2$ )	4.6139	0.4926

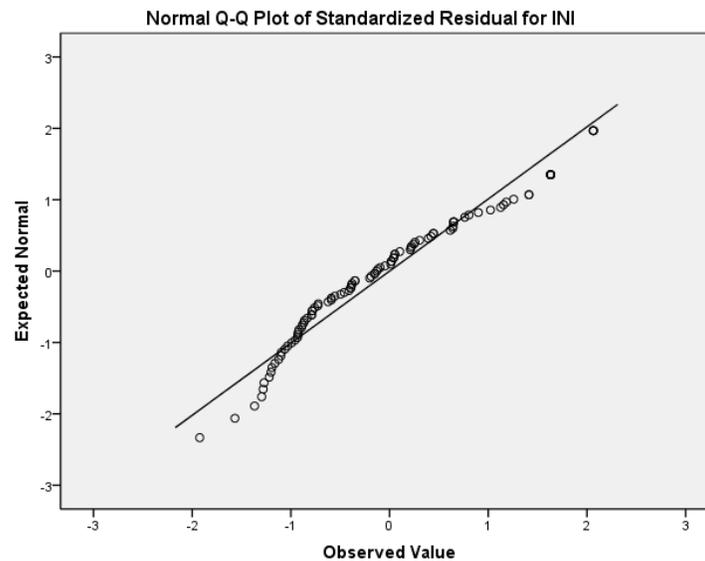
**Table.A2: Descriptive Statistics of INI**

	N	Minimum	Maximum	Mean	Std. Deviation
INI	100	.10000000	1.00000000	.5501635216	.25378442003
Valid N (listwise)	100				

**Table. A3: Tests of Normality- INI across the Cluster Groups**

	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Standardized Residual for INI	.094	101	.028**	.949	101	.001***

\*\*\*p<.01, \*\*p<0.05, \*p<0.1



**Figure. A1: Normal Q-Q Plot of Standardized Residual for INI across the Cluster Groups**

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