Do Industrial Clusters Foster Technological Capability: A Comparative Study of Small and Large Scale Firms in Bangalore Machine Tool Cluster

Raghavendra N.V., and Prabhakara S.S.

Abstract – The paper examines whether clustering of firms influences acquisition of technological capability. It also draws a comparative picture between small scale and large scale firms viv-a-vis the learning mechanisms which enable firms to acquire higher technological capability. The study is based on empirical data collected from 6 large and 25 small firms in the city of Bangalore, India. While the results support central assertion made in the literature that clustering does influence technological capability, it also draws useful comparisons in learning experiences of small and large firms.
Index Terms: machine tool cluster; technological capability; technological learning; large scale firms; small scale firms

I. INTRODUCTION

Clustering of industrial enterprises is a phenomenon prevalent worldwide. It is an agglomeration of small and large firms in close geographical proximity. Research on clusters in developing countries is motivated by well-documented success stories of small firm industrial districts in Europe, especially Italy. The clothing, footwear, ceramics and light engineering districts of northern Italy became known, and came to be referred to as the "third Italy". These cases generated a lot of interest, especially in the small-scale industry literature, since they had many characteristics similar to the developing countries, such as: artisanal manufacturing traditions, informal and flexible work practices and structures of social cooperation [1]. There is a growing consensus among researchers and policy makers alike that an industrial cluster provides an environment which is conducive for improving technological capability resulting in higher productivity and competitiveness. Not surprisingly, the small industry policy in India in recent times has recognized the importance of cluster specific schemes to achieve higher benefit-cost ratio.

The *technological dynamism* of a firm is believed to be rooted in a specific set of change generating resources or *technological capability* located within the structure of technology using firms. Consequently, the *technological learning processes* which contribute to building and strengthening these capabilities are seen as playing important roles in the long-term dynamism and growth of firms. The forces of change brought about by external stimuli and cluster dynamics are believed to drive a firm through a process of technological learning.

The research agenda pertaining to industrial clusters has been well articulated by Schmitz and Nadvi more than two decades ago [2]. While tracing the trajectory of the debate on industrial clusters in developing countries, they have identified technological issues and knowledge accumulation in the fore front of the major concerns that need to be addressed. They have also underlined the importance of comparative studies between clustered firms and dispersed firms, as well as between small firms and large firms, which could throw more light on the major drivers for technological change. This debate has gained momentum in recent times. Shao et al, [3] and Zeng, et al, [4] have put forth the contention that for long term competitiveness, firms should be technologically dynamic. They argue that small firms cannot survive unless they continuously reinvent themselves and bring in modification in production methods and skills to meet the changes demanded by the market. Therefore, it is important for small firms to strengthen their technological base to survive in the competitive business environment.

While research study into the extent to which clustering has stimulated technological improvements in firms is important, there is a need to understand the system of knowledge accumulation and the role played by the various players such as the entrepreneur himself, cluster dynamics and government support institutions. Such investigations would provide the insight for policy makers to design and implement effective policies for stimulating technological dynamism in small firms. This was the motivation for the study which was carried out at the machine tool manufacturing cluster of Bangalore in the southern part of India. According to the estimates of the Indian machine tool manufactures' association (IMTMA), the Bangalore machine tool cluster has 6 large and about 30 small machine tool manufacturers. It accounts for 60% of the value of production of machine tools in the country and has been recognized as the "hub" for machine tool manufacture in India. Therefore, this cluster was selected for the study to probe and understand the dimensions of technological developments, major players, the growth trajectory and future prospects.

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N.V. Raghavendra is the Professor and Head of the Department of Mechanical Engineering, National Institute of Engineering, Mysore, India. Pin – 570 008, E-mail: raghu62.nie@gmail.com, Phone:91-98455 24956
*Corresponding author

S.S. Prabhakara is Associate Professor in the Department of Mechanical Engineering at Acharya Institute of Technology, Bangalore, India,
Pin – 560 090, E-mail: prabhakara@acharya.ac.in

This paper presents a cross sectional analysis of the field survey data by using suitable proxies for technological capability and various learning variables. First, we would like to provide statistical support for the contention that various learning variables identified in the study do indeed contribute to the acquisition of technological capability. We would also like to show the exact nature and strength of the relationship between the capability variable and the learning variables. Secondly, we would like to compare small and large firms' vis-à-vis the nature and strength of the relationship between the capability variable and the learning variables. This would provide useful insights about similarities as well as differences in the learning mechanism that influence technological capability in small firms vis-à-vis large firms.

II. TECHNOLOGICAL CAPABILITY AND TECHNOLOGICAL LEARNING

From 1990s onwards, a growing number of researchers in Mexico, Pakistan, India, Taiwan, and China began to explore the realities of technological change in industries and a large body of research started emerging. Incidentally, most of these studies were carried out in industrial clusters. Some of the major studies pertain to footwear industry of Leon in Mexico [5], the surgical instruments manufacturing cluster of Sialkot in Pakistan [6], the foundry clusters of south India [7], the machine tool industry of Taiwan [8] and Chengdu Furniture Industrial Cluster of China [3] to name a few. These studies outlined a picture entirely different from the stylized picture of earlier decades. Firstly, researchers started accepting the fact that technology is not just machinery-embodied knowhow. It is a more complex bundle of knowledge, comprising the knowhow pertaining to investment decisions, design, materials, operating procedure, maintenance, manpower training and the organizational arrangements needed to integrate these elements into a working production system. A firm, therefore, needs to respond dynamically to technological changes in the aforementioned areas and look continuously to add more value to its customers. Such a capability will qualify a firm to be called technologically dynamic firm.

Secondly, researchers began to appreciate the fact that marginal improvements in products and processes spread over long periods of time can also qualify a small firm to be recognized as technologically dynamic [9]. This view was also a major shift from the earlier perception that technological innovations could happen only in large firms, which discounted the importance of small firms to qualify as technologically dynamic. Consequently, the technological learning processes which contribute to building and strengthening technological capability are seen as playing an important role in the long-term dynamism and growth of firms [10]. Figure 1 illustrates the relationship between technological learning and technological capability, which in turn contributes to the required technological changes and improvements.

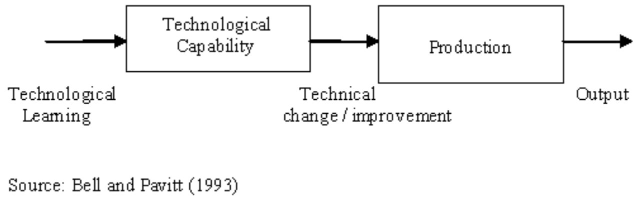

Fig.1: Bell and Pavitt's model

In a cluster setting, technological learning primarily takes place through combined effort; horizontal collaboration, in the form of co-operation among peer firms; vertical collaboration, across the supply chain; and, external linkages to the suppliers, technology providers and others outside the cluster [11] – [12]. In Horizontal collaboration, acquisition of technological information takes place through learning from each other among manufacturing firms either formally or informally. Studies by Chen D. [13], Chen L. [8] and Zeng [4] have thrown light on the nature and mechanisms of such collaboration. These studies have presented empirical evidence, which show that firms in a cluster, in contrast to dispersed firms, are proactive in collaborating with each other. Mobility of skilled workers, technicians and managers from one firm to the other also enables flow of information [14]-[15].

Vertical collaboration is characterized by information flow among suppliers, subcontractors, financial institutions and other service providers who have a stake in the well being of manufacturing firms [16]-[17]. Studies on the agricultural machinery industry in Brazil have revealed relatively stable cooperative relation and near absence of competitive pressures among firms in the vertical chain. The cooperation is smoother and of long term duration. The suppliers, sub-contractors and in many instances financial institutions bring in technological and marketing information from the outside world, which is highly beneficial to the manufacturing units. While the next section introduces the salient features of the machine tool manufacturing cluster of Bangalore, Section IV is a methodological section that discusses about the objectives, scope and research methodology. Results and discussions are presented in section V, followed by conclusions presented in section VI.

III. THE MACHINE TOOL CLUSTER OF BANGALORE

The Bangalore Machine tool cluster is an important hub for the manufacture of conventional and CNC machine tools in India. It accounts for 60% of value of production of machine tools in the country. The Machine Tool Manufacturing (MTM) cluster of Bangalore comprises six large firms and around 30 small machine tool manufactures. The large firms such as Bharath Fritz Werner (BFW) and ACE Manufacturing Systems (AMS) have created a niche in the market for quality of their machine tools. They have expanded their marketing arm in south East Asia as well as central Europe. The customer base of small manufacturers is rooted predominantly among local automobile manufacturing companies, auto component manufacturing units, ancillary units of Indian railways and heavy engineering industries. The cluster is characterized by two classes of sub-contractors. At the higher level, there are suppliers who supply finished products that directly go into machine assembly. At the lower level, many small firms produce components to specifications, which hardly involve one or two operations. The other supporting institutions are financial institutions such as Small Industries Development Bank of India (SIDBI), National Small Industries Corporation (NSIC) and Nationalised banks. Major technical Institutions in the cluster are the Central Manufacturing Technology Institute (CMTI), Karnataka Council for Technological Upgradation (KCTU), the Indian Institute of Science (IISc), Nettur Technical Training Foundation (NTTF), the Government Tool & Training Centre (GT&TC) and the Foremen Training Institute(FTI.) The local industry associations of prominence are the Indian Machine Tool Manufacturers' Association (IMTMA), Peenya Industries Association (PIA), Karnataka Small Scale Industries Association (KASSIA) to name a few.

IV. OBJECTIVES, SCOPE AND METHODOLOGY

The main objective of the study was to assess the influence of various learning variables identified in the study on the acquisition of technological capability. More importantly, we were interested to compare small and large firms' vis-à-vis the nature and strength of the relationship between the capability variable and the learning variables. The study has been designed to extract the variables that discriminate between the two classes of firms. We have stratified the cluster into two major groups; the focal firms (large firms) with investment of more than Rs.50 million (approximately US$ 0.84 million), and small firms with investment in the range of Rs.2.5 million (approximately US$ 42,000) to Rs.50 million, as per the present administrative definition for small-scale and large scale firms in India. The data was collected during the year 2011 by canvassing the schedule. An innovative component of the study is the development of an indicator to measure the technological capability of a firm.

Based on the literature review followed by discussions with academicians, machine tool manufacturers and consultants, we have developed a technological capability index which serves as a measure of technological capability of a machine tool manufacture firm. The index, which we refer to as TECHLEV (for technology level), reflects the complexity of the manufacturing process and also includes the dimensions – product variability, inspection and testing – which were found to be good indicators of technological capability in Romijn's study [11].

The production of machine tool comprises four major processes: design, manufacturing, assembly, and inspection & testing. Each of these major processes comprises sub processes, machines and equipments which reflect differing levels of technological content. We have devised a methodology of scoring these elements on an interval scale based on their technological sophistication. Obviously, weights of parameters differ because the propensity to absorb technology differs across the different machine tool manufactures, sub-processes and other parameters. The weights were determined by consultation with machine tool experts. Table I illustrates the maximum score assigned to the machine tool manufacturing sub processes and other parameters at the first level of aggregation. A system of assigning weights for a firm's product was incorporated since product-manufacturing complexity is one of the most widely used capability indicators.

Table I: Technology Level Scores-Aggregate Breakup

Sl. No.	Departments	Max. Score
1	Design	08
2	Manufacturing	45
3	Assembly	23
4	Inspection and Testing	13
5	Product variability and Service	11
	Total	100

The construct validity of the capability index was evaluated by identifying group differences based on technology level score. Mean value of the technology level scores for the firms were computed. The firms were classified as low technology level firms and high technology level firms based on whether their technology level scores were higher or lower than the mean score, respectively. We found through t–test that the means of these two groups were significantly different. This exercise ensured that the measuring instrument was valid and provided a good discrimination between high technology level and low technology level firms.

Table II: Learning Variables

Sl. No	Learning Variable	Definition (Type)
1	Age of the firm (AGE)	Number of years that have elapsed since its establishment (Dummy)
2	Education of Owner (EDU)	Whether or not the entrepreneur/manager has acquired formal technical education (Dummy)
3	Work Experience (EXP)	Previous work experience in a firm by the owner/manager (dummy)
4	Horizontal Collaboration (HORCOL)	Horizontal multilateral collaboration with other local foundries, R&D and testing centers, etc
5	Vertical Collaboration (VERCOL)	Vertical collaboration with local suppliers, external suppliers and customers.(Interval)
6	Mobility labour (MOB)	Degree of mobility of skilled labour in the cluster (Ordinal)
7	External technological assistances (EXTASST)	New technological information and knowledge obtained from number of external sources (Interval)
8	Marketing Network (MARNET)	New marketing information and knowledge obtained from number of external sources (Interval)
9	Finance network (FINSUP)	New marketing information and knowledge obtained from number of external sources (Interval)

Nine explanatory variables frequently referred to as learning variables in the literature, were selected for the study. Table II lists the variables. Although, the primary interest in our study was to understand the influence of horizontal, vertical and external collaboration on the acquisition of technological capability, we have included other variables to make the study more comprehensive and broad based. The other variables are age of the firm, education of the entrepreneur/manager, working experience of the entrepreneur and mobility of skilled labour. Suitable proxies have been developed to measure the learning variables. The survey data has been subjected to statistical analyses to identify the variables, which significantly influence the technological capability acquisition in firms.

Field survey was carried out by canvassing the schedules in twenty five small and six large scale firms in Bangalore. The questionnaires were filled up through personal discussions with entrepreneurs/managers. The next section discusses the tests carried out to validate the technological capability index. The results of statistical analysis are presented to understand the strength of relationship between technological capability and the various learning variables, which are believed to influence it.

V. RESULTS AND DISCUSSION

This section discusses the results of regression analysis that was employed to test the strength of relationship between various technological learning variables with technological capability, which is represented by the technology level index. This is followed by the results of discriminant analysis, in order to extract the variables that differentiate small firms from large firms.

Regression analysis:

Ordinary least squares (OLS) regression analyses were carried out to assess the nature and magnitude of the relationship between technological capability and the learning variables. On the whole, the OLS technique performed quite well. The normality and homoskedasticity assumptions were not violated. Multicollinearity between the explanatory variables was not a problem, suggesting that each of the independent variables is a unique dimension of the learning process. Table III summarises the results of the regression analyses.

Regression equation for small firms has a reasonably good explanatory power with adjusted R^2 being 0.91. Four variables, namely, vertical collaboration, marketing network, support of financial institution and external technological assistances turned out to be significant at 95% confidence interval level.

This is a surprising result since horizontal collaboration is not significant in the regression equation. External technological assistances has the highest regression co-efficient followed by, support of financial institution, marketing network and vertical collaboration. Machine tool is a customer oriented product and obviously, new technological information and knowledge obtained from external sources such as customer, market and other sources trade fairs, exhibitions etc have the greatest influence on the technological learning in the cluster.

Table III: Regression Equations.

Small Firms			Large Firms		
Adjusted R^2 = 0.91, n = 25			Adjusted R^2 = 0.92, n = 6		
VERCOL	Coefficient	1.99	VERCOL	Coefficient	2.66
	t value	3.2		t value	5.26
	Significance	0.004		Significance	0.006
MARNET	Coefficient	2.92	MARNET	Coefficient	4.69
	t value	2.93		t value	4.25
	Significance	0.007		Significance	0.013
FINSUP	Coefficient	3.05	FINSUP	Coefficient	1.89
	t value	3.00		t value	5.3
	Significance	0.006		Significance	0.006
EXTASST	Coefficient	4.26	EXTASST	Coefficient	5.19
	t value	4.56		t value	13.12
	Significance	0.00		Significance	0.00

Support of financial institution is found to have significant influence on technological capability. It is clear that to upgrade the technological base, firms require investment on new machine, technological efforts and access to external sources. It is evident in recent times that financial institutions have been proactive in ensuring that small firms strengthen their technological base so that the risk involved in lending to this sector is minimized.

Marketing linkage has significant influence on technological capability and is on expected lines. Many of the small firms in the cluster are exporting machine tools. Such firms have developed knowledge about Indian and foreign markets, which has evidently translated into improvements in technology in order to compete with global players. This finding gives credence to the arguments of Nadvi that markets could significantly drive technological upgradation efforts in small firms [6]. Vertical collaboration is significant since the Bangalore machine tool cluster is a sub-set of a larger heterogeneous cluster of aerospace, machine tool, information technology, heavy electrical and electronic industry. This enormous industrial growth has nurtured and sustained a chain of vendors, sub-contractors and service providers. These people carry information about market opportunities and technology, which is of benefit to small firms.

The regression equation for large firms (table III) has good explanatory power with adjusted R^2 being 0.92. Four variables, namely, vertical collaboration, marketing network, support of financial institutions and external technological assistances turned out to be significant at 95% confidence level. Once again, in this case also, horizontal collaboration is not found significant in the regression equation. This finding supports the argument that firms linked vertically in a cluster are likely to collaborate while firms located on the horizontal dimension are likely to be rivals [18]. It also appears that larger firms are well disposed to make investment in research and development and have well qualified technical manpower. This might result in near absence of horizontal collaboration.

Quite similar to small firms, 'external technological assistance' has the highest regression co-efficient in case of large firms also. It is evident that for large scale firms the new technological information and knowledge obtained from external sources such as customer, market and other sources trade fairs, exhibitions etc have the greatest influence on their technological learning. This is closely followed by marketing linkages as the significant variable in regression. The large scale firms have the customers from both Indian and foreign markets, to meet this diversified and quality demand firms have to improve their technological-base. This study supports the argument of Tiwari about the success of Taiwan's machine tool industry in which strong marketing network had significant influence on technological learning [19].

Support of financial institutions is found to have significant influence on technological capability. In order to upgrade the technological base, firms require investment on new machine, technological efforts and access to external sources. It also gives credence to the argument that investment capability, which is a dimension of technological capability, is achieved through systematic technological learning process. Vertical collaboration is significant since the main customers are auto and auto component industry, aviation industry, heavy electrical and electronic industry, defence and computer hardware manufacturing. This substantial industrial growth has increased the strength of chain of vendors, sub-contractors and service providers. The people involved in the value chain will carry and diffuse the information about market opportunities and technology, which is important source for them to build up their technological-base.

Discriminant analysis has been employed to answer two questions:

i. What is the order of importance of the learning variables in discriminating between the high technology level and low technology level firms among small scale firms in the cluster, and
ii. To extract variables that discriminate between high technology level firms among small scale firms with large scale firms

It became evident during the field survey that among the small scale firms, we could identify firms which proactively seek improvements in technology. At the other end of the spectrum are those small firms, which appeared to be passive and preferred to take things as they came. Discriminant analysis has been attempted to understand the inherent differences between the two types of firms in their pursuit for acquiring higher technological capability. Secondly, in order to draw meaningful conclusions, it was decided to compare only the high technology level firms among small scale firms with large scale firms.

Discriminant analysis results in reduction of the multiple measurements to one or more weighted combinations having maximum potential for distinguishing among members of the different groups. A good discriminant function is one that has more 'between group variability' when compared to 'within group variability'. Tests of significance are available to make estimations. The SPSS package has been used to carry out discriminant analysis. Table IV gives the details of the discriminant function that has been obtained in the two cases.

Table IV: Summary of Discriminant Function

Serial No.	1	2
Comparison	Small Scale firms: High technology level V/s Low technology level	Small scale High Technology level firms V/s Large firms
Eigen Value	1.460	2.20
Canonical Correlation Coeff	0.770	0.830
Wilk's Lambda	0.407	0.311
Chi-square	24.750	19.878
Significance	0.0	0.00
Variables (Standard Canonical Discriminant Function Coeff.)	EXTASST (1.00)	HORCOL (0.959) MOB (-0.789)
Group centroid	Hightech.(1.092) Lowtech (-1.248)	Small (0.707) Large (-2.827)

1. When the discriminant analysis is carried out among small scale firms of the cluster, Eigenvalue value is 1.460, canonical correlation coefficient 0.770 and Wilk's lambda 0.407, which indicate a good discrimination between the high technology and low technology groups. External technological assistance has a high discriminant function coefficient indicating its stronger influence in high technology level small firms. Obviously, high technology firms are more outward looking and actively access external channels to access technological information and knowhow.

2. When the discriminant function is fitted between high technology level firms among small firms and large scale firms, we obtain high Eigen value 2.20 and canonical correlation coefficient 0.830. Wilk's lambda is 0.311 indicating high discriminatory power. In this case, while horizontal collaboration appears to be stronger among small firms, mobility of skilled labour is comparatively higher among large firms. We again put forth the argument that small firms are more receptive to joint efforts across horizontal channels. This fact is reinforced by the interaction with office bearers of local machine tool industry association. It is already pointed out that the major chunk of skilled manpower moves towards large firms, which offer better pay packet. Therefore, we see high mobility of skilled manpower into large firms.

VI. CONCLUSIONS

An important conclusion that has emerged out of the study is that it supports the central assertion made in the literature that customers, markets and supporting institutions are important sources for knowledge accumulation. The variables such as vertical collaboration, marketing network,

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support of financial institution and external technological assistance are significant in regression. The fact that the variables 'external technological assistance' and 'marketing network' are significant clearly brings out the fact that the small firms in the Bangalore machine tool cluster are outward looking and have forged strong links with external sources of technological information. Surprisingly, horizontal collaboration is not found to be significant in the regression analysis. While larger firms cater to bulk orders of higher end machines, small firms have found opportunities to cater to smaller sized orders and machines meeting basic configurations and limited budgets. Since both these sectors operate in their own domains, we see limited interactions/collaborations across horizontal channels. Among larger firms, low key horizontal collaboration may be attributed to stiff competition.

Vertical collaborations plays a significant role in both small and large firms. This is presumably due to the availability of large number of suppliers and service providers. Bangalore is also home to aerospace cluster and automotive cluster, which are complimentary to machine tool cluster. This provides the critical mass for the vendors of components and services to be profitable and competitive. The fact that external sources are significant in the regression model indicates that the companies have been proactive in sourcing technological information from external sources. The cluster appears to be outward looking, rather than being inward oriented, which is the hall mark of a progressive cluster.

Discriminant analyses reveals that the relatively high technology firms among the small firms in the cluster are more outward looking and actively access external channels to access technological information and knowhow. Whereas vertical collaboration is the preferred channel for joint action, horizontal collaboration is more pronounced in smaller firms rather than larger firms. Smaller firms appear to resort to co-operation with peer firms to gather technological and market information. Additionally, these firms show more enthusiasm towards joint efforts initiated either by local industry associations or government agencies. Also, mobility of skilled labour is higher towards large firms rather than smaller firms.

The foregoing findings have important implications for policy makers. The policy makers should focus on creating consultancy organizations, which can provide access to information about emerging markets and technologies. These organizations should be joint ventures among government, financial institutions and entrepreneurs/companies. These organizations could facilitate the need for free exchange of technological information, especially for smaller firms and forge strong collaborative relationship, All the parties should have financial stake in such an organization, which ensures transparency and equal opportunity for all.

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