T-Shape Competence Model for Firms to Leverage Innovation Capabilities and Create Impact in a Cluster

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Abstract--**Automobile clusters, driven by innovation capabilities, have emerged as competence centers and engines of new economic growth in India. Identified as a high potential sector, the automobile industry has been targeted under the 'Make in India' initiative to foster inclusive growth in the country. The dynamism within a cluster emerges from the interaction between innovation systems and global value chain systems, which contribute to developing a framework for evaluating the innovation performance and maintain competitiveness of firms. While evaluating innovation performance, this research examined the innovation capabilities of auto component firms and analyzed how firms in the Pune automobile cluster integrate technology management and innovation strategies with their business strategy. A mixed research methodology was adopted for this study. Structured equation modeling (SEM) was used to test the hypotheses, and the results show how firms utilize innovation capabilities and leverage their innovations through emerging practice domains. A T-shape competence model is proposed to achieve global competitiveness and create sustainable impact through social innovations.**

I. INTRODUCTION

Regional cluster development has been identified as a strategic tool for industrialization and wealth creation in emerging economies. In India, the automobile industry has witnessed remarkable changes over the last two decades. Liberalization and globalization have enabled the entry of international automobile majors in India. As a result, the auto component industry has transformed itself from a traditional job fulfiller to vital an integrated organization role [33]. Prominent auto clusters in India include NCR-Uttaranchal in the north, Jamshedpur-Kolkata in the east, Chennai-Hosur-Bangalore in the south, and Mumbai-Pune-Aurangabad in the west. These clusters have experienced all the phases of life cycle: pre-foundation (1945-1965), emergence (1966-1984), growth phase I (1985-1995), growth phase II (1996-2007), and sustenance (2008 onwards).

The life cycle of Indian automobile clusters, influenced by governmental policy framework, has considerable impact on the growth of industry-fostering innovations and global competitiveness. Intense competition and changing customer demand in India have led to more significant advances in the product development process than in product architecture. Product cycles continue to grow shorter as more companies adopt the simultaneous engineering approach pioneered by Japanese automakers. The degree of scale economies in the industry is closely linked to the technological flexibility to produce different models from the same platform. Some of the major technological issues of current importance are increasing energy efficiency, competency of internal combustion engine (ICE), reducing the weight of vehicles, incorporating high-tech safety features, and complying with emission norms [25]. Simultaneously, the gradual opening of the auto component sector, government extending support to the development of domestic critical component and sub-system suppliers through improvement in the investment environment, stronger patent regimes and incentives for R&D.

Recent perspectives in management literature, such as innovation systems and the global value chain perspective, have highlighted the importance of the dual structure of internal change—generating innovative resources locally and establishing links to external sources of technology. The innovation systems perspective is based on the assumption that technological learning and innovation include not only economic transactions but also interactive processes with key players, institutions, and social norms [24, 28]. It emphasizes the crucial role of technological trajectories and institutional assets in collective learning, giving special importance to an environment that stimulates technological learning and innovation. Thus, the organizational and cultural proximity of agents becomes crucial in local capacity building.

The global value chain perspective focuses on the international linkages among firms with worldwide production and distribution systems, emphasizing the role of leading companies that carry out functional integration and coordinate internationally dispersed activities [12]. Global chains operate in highly competitive global markets, fostering the need of MNCs/TNCs to transfer technical and managerial capacities to their local affiliates and suppliers, so that these firms can meet the quality standards and lower their production costs. Once the local firms manage to raise their capability levels, the new standards serve as an incentive to delegate more sophisticated knowledge and processes to these local suppliers [8, 9, 38]. Although the innovation processes at the firm level have been widely studied and documented, some aspects of innovation capability have not been analyzed.

The aim of this research is to develop a research framework for building innovation capabilities among the auto component manufacturing industry, using both the innovation systems and the global value chain perspectives. We use this framework to evaluate the innovation performance of firms within the automobile cluster in Pune and determine the competitiveness of the cluster. The innovation capabilities analyzed as part of the study help identify practice domains, which further explain the innovations made in the tier firms of the Pune automobile cluster. To conclude, we propose a T-shape competence assessment model for the development of core competencies and innovation ecosystems to help leverage firm-level innovation capabilities, which in turn enhance firm performance and competitiveness.

The paper is organized as follows. Section 2 presents a review of literature on *how* inter-firm linkages within the cluster support the creation of innovation resources and capability in the Indian automobile industry. Section 3 explores the link between externalities at the cluster level and the firm innovation system. Accordingly, the research framework and hypotheses are developed. The research methodology, sample selection, data collection procedure, and data analysis are covered in Section 4. The results and findings that validate the research framework are discussed in the last section.

II. REVIEW OF LITERATURE

Porter [31] noted that technology is one of the most prominent factors that determine the rules of competition at the cluster level. Technological development and innovations influence the cluster development process in developing countries.

A. Inter-firm linkages, innovation capability and the development of firms in a cluster

The innovation capability of a firm is a major factor contributing to the enhancement of its performance [6, 7, 36]. Typically, firm capabilities are focused on product and process innovations, which may be incremental or radical. The meaning and impact of these innovations changes according to the type of firm. Firms within a cluster also strive to possess technological and innovation capabilities. It is unlikely that all these capabilities can be found in the same firm, and they do not innovate in isolation by focusing on in-house R&D. Instead, they involve other firms in the innovation process. The literature highlights functional, procedural, and strategic approaches to secure capabilities in addition to the relationship between the capabilities and firm performance. These approaches and capabilities are summarized in Table 2.1.

Kumaraswamy *et al.* [20] studied the development of Indian domestic auto supplier firms through catch-up strategies aimed at integrating the firms with the industry's global value chain. They found that for continued performance, domestic supplier firms need to revise their strategy from catching up through technology licensing or collaborations and joint ventures with MNEs to developing strong customer relationships with downstream firms. Technology acquisition in developing countries can be of three kinds: basic or innovative research through in-house R&D efforts, arm's length purchase of design and drawings through payment of royalty or fees, and the import of capital goods with embodied technology [27]. The ability of these firms to innovate also depends on the level of access they have to external sources of innovation. For instance, in the Pune automobile cluster, joint ventures and technical collaboration have been a vital source of innovation among local auto component supplier firms.

Over the years, the auto component industry in India has been progressing successfully toward its goal of localization and becoming a global supplier. In general, technology acquisition from developed nations through collaborations and alliances has been one of the preferred routes to build capabilities [26]. However, of late, Indian auto and auto component firms have started acquiring strategic technology management capability [33] and their focus is shifting toward building their internal innovation capabilities.

TABLE 2.1: STUDY APPROACHES AND MAJOR FACTORS OF TECHNOLOGICAL AND INNOVATION CAPABILITIES

Study approach	*Technological and innovation capability factors*	*Proposed by*
Functional	▪ Investment capability ▪ Production capability ▪ R&D capability ▪ Learning capability ▪ Resource availability and allocation capability ▪ Manufacturing capability ▪ Marketing capability	Lall Sanjay (1992) Narayanan K (1998, 2001) Yam *et al* (2004)
Process	▪ Concept generation capability ▪ Process innovation capability ▪ Product development capability ▪ Technology acquisition capability ▪ Catch-up strategy: technology license/ collaboration, customer relationship and knowledge creation ▪ Capability in the effective use of system, processes and tools ▪ Linkage and network capability	Lall Sanjay (1992) Chiesa *et al* (1996) Narayanan K (1998) Guo *et al* (2010) Sudhirkumar *et al* (2010) Kumaraswamy *et al* (2012)
Strategic	▪ Organizational capability ▪ Strategic planning and execution capability ▪ Understanding competitor innovative strategy and market ▪ Structural and cultural affecting internal innovative activities ▪ Leadership capability	Chiesa *et al* (1996) Burgelman *et al* (2004) Yam *et al* (2011)

B. Determinants of Innovation and Competitiveness: Pune Auto Cluster

The leading auto and auto component firms in a cluster act as technological gatekeepers and serve a source of new knowledge for smaller firms [30]. Technology support organizations in India like Automotive Research Association of India (ARAI), Automotive Component Manufacturers Association of India (ACMA), Society of Indian Automobile Manufacturers (SIAM), and National Automotive Testing and R&D Infrastructure Project (NATRiP) have played important roles at the boundary of cluster knowledge-systems, receiving varying degrees of support from local firms. The cluster has witnessed a paradigm shift in technology use from new product launches to the introduction of differentiated products involving updated technology. Improved efforts at knowledge integration, forming networks, and building technological capability have enhanced the overall performance of the cluster.

The competitiveness of the Pune cluster has improved with the arrival of global OEMs and the establishment of local capacities to develop and manufacture engines and transmissions, with a strong focus on vendor development. The auto cluster project offers SMEs facilities for design, rapid prototyping, calibration, environment testing, and polymer component testing. Manufacturing facilities are largely flexible, and new firms have also established a modern shop floor that integrates technology for differentiated vehicles. This arrangement has enabled the firms to effectively utilize their capacity by changing their product mix and to ensure quality and timely delivery by building manufacturing capabilities.

Global OEMs have access to their own R&D centers, which has allowed the cluster to improve its outsourcing capabilities in R&D. These changes constitute a technological paradigm shift, and firms use various knowledge acquisition channels, which has led to inter-firm variation. A conceptual framework explains the relationship between auto component suppliers/ subcontractors and global and domestic OEMs (contractors) (Figure 2.1). They found that subcontracting firms receive assistance from the contractors, and they investigated the diversity of assistance that SMEs received through subcontracting in the Indian automobile industry and the effect of this assistance on their economic performance.

Research literature with an Indian context does not show how these types of assistance build innovation resources and capability among domestic firms to enhance cluster competitiveness. The MNEs entering the market possess sophisticated technological and managerial capabilities that domestic firms lack. Consequently, domestic firms need to "reorient" themselves changing their strategies, structures, technologies, systems, and organizational practices and routines. Acquiring such capabilities, which depends on the local cluster firms' absorptive capacity and technological learning patterns [13], can reduce the technology gap between domestic and foreign firms, increasing the probability of linkages and spillovers.

C. Need for the Present Study

The emergence of global OEMs in the Indian automobile industry, specifically in the segment of passenger vehicles, and new products launched by large domestic auto players have introduced technological dynamism within the industry, placing greater emphasis on technological and innovation capabilities of both auto and auto component supplier firms. Further, the industry has adopted safety and emission regulations on par with international standards for sustained growth to become a global export hub.

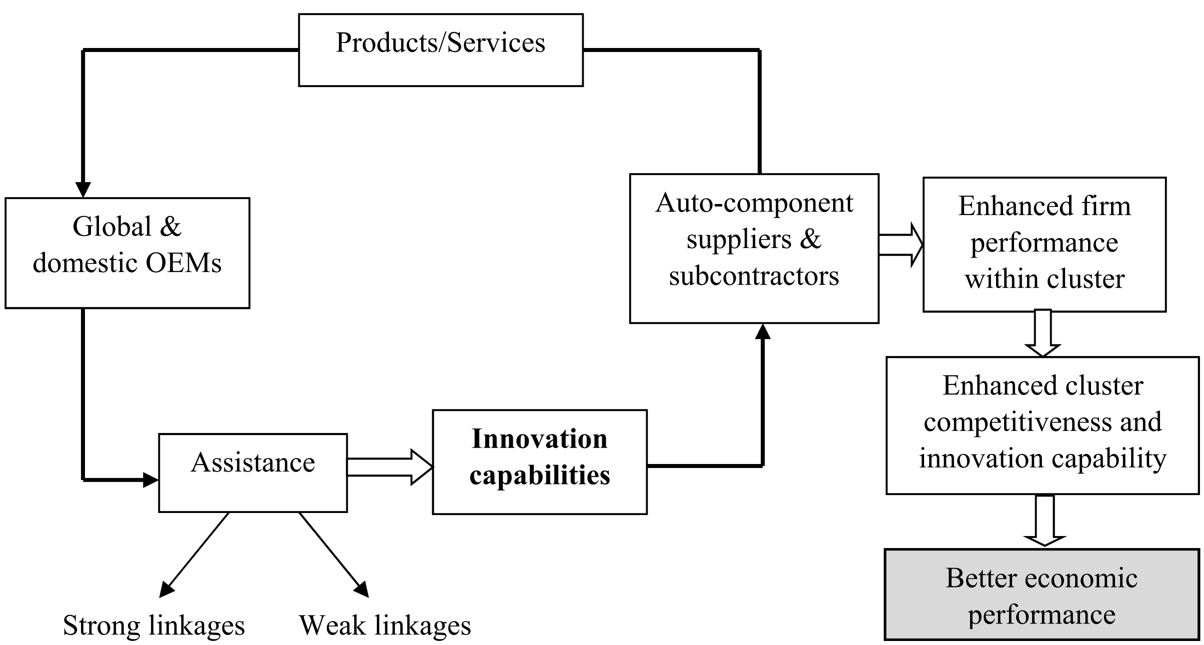

Figure 2.1: Conceptual framework of OEMs' influence on innovation capabilities of firms and economic performance

Thus far, most studies on the Indian automobile sector have been theoretical discussions on the composition of innovation actors. However, measuring innovation effectiveness at the regional level continues to remain an issue [37]. The extant literature lacks an empirical analysis on how a firm, in the automobile sector, can employ the innovation systems and global value chain perspectives to enhance its capacity to innovate and achieve global competitiveness.

The key research gaps identified from literature review are as follows:

a. In emerging economy like India, different aspects of technological and innovation capabilities such as R&D capability, specialized skills for R&D, manufacturing capability, organizational capability, strategic planning and marketing capability of firms have not studied at the level of an automobile cluster.
b. Sustainable competitiveness of firms, influenced by innovation capability factors (mostly technology dimensions), has not been studied within the context of an Indian automobile cluster.

III. DEVELOPMENT OF RESEARCH MODEL AND HYPOTHESIS TESTING

A. Link between innovation systems and global value chain perspectives

Literature on the innovation systems perspective identifies a link between innovation and competitive and economic outcomes at the national level [28, 31]. Various studies have used the RIS approach to examine how innovating firms participate in the generation and diffusion of knowledge among RIS players, which takes place outside the boundary of the firm. The critical factors in building a cluster firm's innovation capability are external sources of innovation. The global value chain perspective is concerned with *how* the dispersal, coordination, and re-integration of value chains among groups of firms across regions are governed, *how* the institutions seek to influence this governance, and the regional competitiveness and social standards [14]. It also emphasizes that learning from external sources is critical for emerging economies so that they are not locked-in at the low end of the value chain. Thus, knowledge spillovers and collective learning are critical to clusters. Also, knowledge spillover has an influence on the sources of innovation and creates "competitive linkages" and "collaborative linkages" [5].

Hypothesis H1: Knowledge spillover has a positive relationship with external sources of innovation in the Pune automobile cluster.

Hypothesis H2: External sources of innovation have a positive relationship with knowledge spillover in the Pune automobile cluster

B. External sources of innovation

The source of an innovation is important because it determines the capabilities a firm must possess to adopt the necessary innovations and achieve success in the marketplace. Earlier studies on sources of innovation have focused on firm-specific determinants such as in-house R&D activities, manufacturing innovation, and firm size. However, innovations emerge from not only factors internal to firms but also through interactions between firms and different players involved in the regional innovation system.

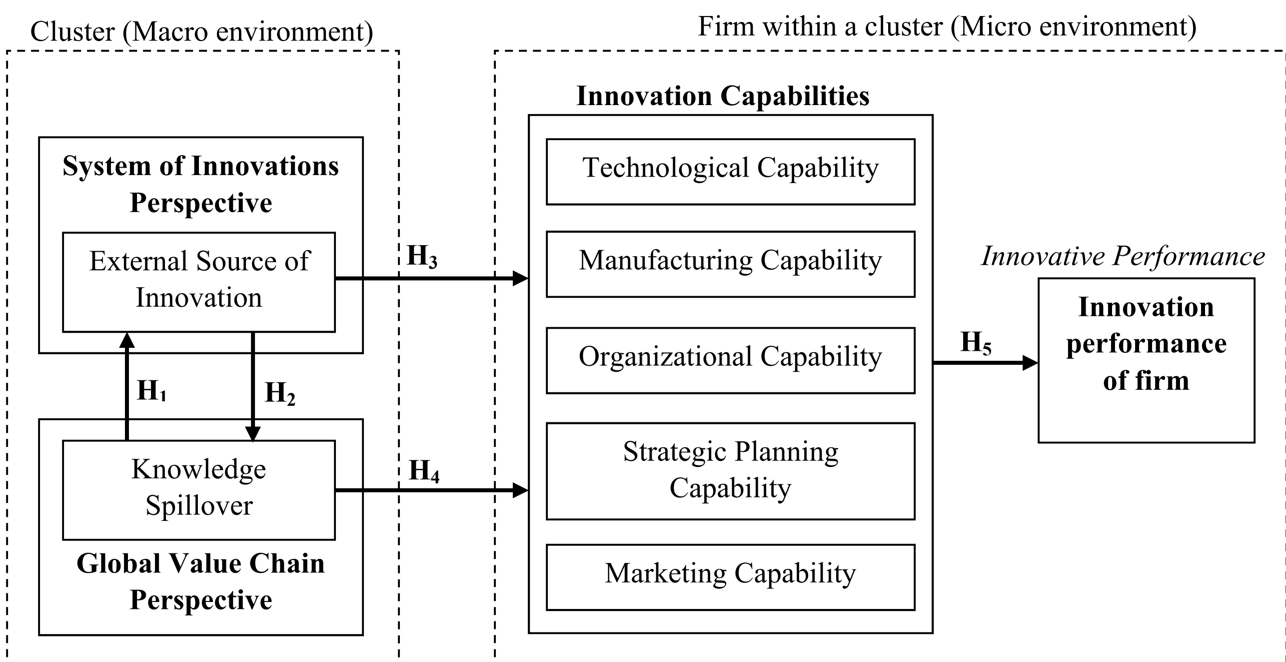

Figure 3.1: Research Model and Hypotheses

Firms cannot innovate in isolation; they tend to complement their ability to create knowledge in house by utilizing knowledge from external sources of innovation. Interaction with such external sources is a fillip for the firm's learning process, which helps improve firm performance [3]. Thus, firms can reinforce their innovation capability by importing technologies and then diffusing, assimilating, communicating, and absorbing them into their organizations [15]. Capabilities developed this way are highly related to the acquisition of knowledge external to the firm and its integration.

Hypothesis H3: External sources of innovation have a positive relationship with the innovation capability factors of firms within a cluster.

C. Knowledge Spillover:

Knowledge spillovers play a dual role in the building of innovation capabilities: at the cluster level as well as within firms. A knowledge spillover results from dynamism in information and knowledge flows about products, processes, technologies, consumers, and markets, which informally circulate within the system (Lorenzen and Maskell, 2004).

Hypothesis H4: Knowledge spillover has a positive relationship with the innovation capability factors of firms within a cluster.

D. Relationship between innovation capability and innovation performance:

An increase in product and process innovation is attributable to the accumulation of capabilities in firms and contributes to innovation outputs. Improving innovation capabilities can be beneficial to the firm and lead to enhanced competitiveness [36]. Narayanan [26] regarded R&D activities as the central component of firms' technological innovation activities in the automobile industry and as the most important intangible form of innovation expenditure (Evangelista *et al* 1997). A firm's specific competencies contribute substantially to its sales growth and competitive advantage. There is a causal relationship between a firm's resources and its technological innovation performance. The OSLO Manual (OECD, 1997) proposed that technological and innovation performance can be measured by the proportion of sales coming from the technologically new or improved products. This indicator has also been widely adopted by recent innovation studies [37].

Hypothesis H5: Innovation capabilities have a positive influence on the innovation performance of firms in the Pune automobile cluster.

IV. RESEARCH METHODOLOGY: DATA COLLECTION AND ANALYSIS

Mixed methodology, empirical qualitative and quantitative research methodology is adopted to test the hypotheses.

A. Sample Characteristics

The Pune automobile cluster is spread along the Pune-Mumbai-Aurangabad belt of the state of Maharashtra, India, and consists of 19 auto firms and 170 auto component supplier firms [34]. For this study, 56 interviews were conducted and the discussion guide modified according to suggestions of senior managers. The propositions were formulated and tested successfully. The interviews were reordered and later transcribed. Data were analyzed on MS Excel 2010 and simple patterns were explored through Matrix Format Data. A primary survey was conducted among 108 auto component firms (large Tier I & II firms, medium Tier I & II firms, and small Tier III firms), which constitutes 64% of the firms in the cluster.

A questionnaire survey was conducted to gather data about firms in the Pune cluster. The survey respondents consisted of the following: (1) engineers and managers who had worked in the cluster for more than ten years; 2) cluster members with rich mobility experience through training, trade fairs, membership of associations, etc.; 3) owners of local firms; 4) seven experts with an R&D background; 5) one expert each from ARAI, Pune; the Auto Cluster Project; MCCIA; UNIDO; and UoP.

B. Data collection and measurement

In the three-part questionnaire, the first part covered basic information about the firm and the respondent, such as the firm's year of establishment, number of employees, and lines of business, and the respondent's job title, tenure, number of years of work experience in the line of business, and mobility within the cluster. The second part focused on the extent of the firm's innovative sales performance over the last three years. This was calculated as the sum of the firm's expenditure on R&D, import of components and raw material, expenditure on advertising and sales promotion, foreign expenditure on technological know-how and services, and import of capital goods and skills divided by the sales turnover multiplied by 100. The proxy variables defined and used depended on the type of firm and were normalized because of the sales turnover. The third part of the questionnaire pertained to the degree of influence or impact exerted by the firm's innovation capabilities on their innovative performance in the Pune auto cluster.

The questionnaire was pretested from March 2012 to April 2012 and modified on the basis of inputs from the managers. We conducted the primary survey between June 2012 and September 2012. Multiple responses were collected from each firm, so as to increase the reliability of the data. A total of 400 questionnaires were distributed, 366 completed surveys were received, and 344 responses—from 108 firms—were used for data analysis.

We asked respondents to answer questions using a 5-point Likert ordinal scale (1 = very low, 2 = low, 3 = average/moderate, 4 = high, 5 = very high). The variables were measured as percentages coded to the ordinal scale of 1, 2, 3, 4, and 5 (0 to 20 – 1, more than 20 and up to 40 – 2, more than 40 and up to 60 – 3, more than 60 and up to 80 – 4, more than 80 and up to 100 – 5) so as to be consistent with other variables.

The surveyed auto component suppliers were classified into sub-groups on the basis employee strength. Generally, in the Indian automotive industry, there are no size differences between Tier I and Tier II large, medium, and small firms, and nearly all the Tier III firms are small (Uchikawa and Roy, 2010). For the present study, the Pune automotive cluster was divided into the following subgroups: large auto component suppliers comprising Tier I and Tier II firms (subgroup 1), medium auto component suppliers comprising Tier I and Tier II firms (subgroup 2), and small auto component suppliers comprising Tier I, Tier II, and Tier III firms (subgroup 3). The size of the firm was used as a control variable in this study. Previous studies suggest that firm size and innovation performance could be positively correlated. We controlled for the possibility of industry effects in our analysis by using dummy variables for the type of industry. This was because firms from different industries may have differing levels of performance in innovation capability and efficiency.

C. Data analysis

A two-stage structural equation model (SEM) was used to test the proposed model [1, 18]. In the first stage, we developed a measurement model and performed confirmatory factor analysis (CFA) to verify the model's reliability, validity and dimensionality. In the second stage, we tested the hypotheses through covariance structure models. SPSS-AMOS was used to estimate the structural models, and the maximum likelihood method with robust estimators was used to estimate the parameters to improve the requirements of normality.

Confirmatory factor analysis

We assessed the scale reliability, convergent validity, discriminant validity, and unidimensionality of the research constructs. Cronbach's alpha was used to assess the scale reliability of each construct in the research model. The Cronbach's alpha for every factor (Table 4.1) was greater than acceptable threshold value of 0.7 [18]. The convergent validity of the research constructs was assessed using exploratory factor analysis (EFA). The EFA results showed that all the constructs had eigenvalues exceeding 1.0 and factor loadings exceeding 0.3.

Thus, convergent validity of the research constructs was confirmed. Discriminant validity and unidimensionality were assessed using confirmatory factor analysis (CFA) (Table 4.2). The measurement model constructed for CFA had a relative chi-square value of 2.325 < 3, an incremental fit index (IFI) of 0.946 > 0.9, and a comparative fit index (CFI) of 0.916 > 0.9. The standardized loadings (λ) for all constructs were high (λ > 0.5), and the corresponding t-values were statistically significant. These results indicated good unidimensionality of the research constructs. Modification indices for the measurement model assessed during the CFA showed no significant cross loadings among the variables (λ > 0.85), suggesting good discriminant validity [18]. The scores for valid variable items in each construct were then averaged as a single score to be used in the model analysis.

D. Hypothesis Testing

SEM was used to test the hypotheses as it allows several multiple regression equations to be tested at the same time, making it useful for assessing overall model fit with a low degree of measurement error. In the model analysis, maximum likelihood estimation (ML) and standardized regression weighting were used for interpretation. Multiple indices of fit including IFI, CFI, and cmin/df were used to specify the overall model fit. The IFI and CFI values were over 0.9 and that of cmin/df was below 3, indicating a good degree of model fit (Bentler, 1990). An RMSEA value of less than 0.7 indicates an adequate degree of model fit (Bollen, 1989). The research hypotheses were tested according to the significance of the t-test result in each path, with parameter estimates obtained from the SEM process.

TABLE 4.1: RESULTS OF EXPLORATORY FACTOR ANALYSIS (EFA)

	Cronbach's Alpha (α)	***Eigenvalues***	***Factor Loading for items***				
			1	**2**	**3**	**4**	**5**
External sources of innovation	0.7362	1.483	0.876	0.876			
Knowledge spillover	0.8144	1.935	0.817	0.881	0.888		
Technological capability	0.7622	1.457	0.909	0.909			
Manufacturing capability	0.8031	2.338	0.880	0.876	0.823		
Organization capability	0.8224	2.425	0.830	0.912	0.840	0.749	
Strategic planning capability	0.8407	2.367	0.875	0.868	0.896		
Marketing capability	0.8891	2.984	0.883	0.890	0.885	0.850	0.849

Cronbach's alpha (Reliability) >0.7; Eigenvalues >1; Factor Loading >0.3

TABLE 4.2: RESULTS OF THE CONFIRMATORY FACTOR ANALYSIS (CFA)

	Standardized Loading (λ)	Error Term	t-value
External sources of innovation			
TECHEMBOD	0.78		
PATENT	0.74	0.12	10.12
FDIFLOW	0.89	0.09	9.42
CUSTOMERINNO	0.82	0.16	12.48
INTLINKAGE	0.83	0.07	11.44
Knowledge spillover			
SPILLSCIENCE	0.71		
SPILLINFORMAL	0.83	0.09	10.38
PEOPLEMOBI	0.87	0.11	10.60
LOCALSPILL	0.68	0.17	13.24
SUPPLYCOMP	0.82	0.13	9.55
SPILLMNC	0.72	0.14	12.11
Technological capability			
RNDPRODUCT	0.72		
RNDPROCESS	0.79	0.07	11.42
RNDEQUIP	0.73	0.11	14.88
TECHAQUISITION	0.82	0.09	12.23
RNDSKILLS	0.78	0.10	9.56
COMPLEXCOMP	0.65	0.13	11.78
SPECIFICS	0.86	0.08	8.89
FEEDBACK	0.84	0.09	9.75
LEARNING	0.83	0.10	10.61
Manufacturing capability			
RNDPRODUCTION	0.88		
ADVMFGMETHO	0.76	0.08	12.02
FLEXILEADTIME	0.79	0.07	10.34
LEARNCURVE	0.68	0.07	12.59
SKILLMFG	0.72	0.12	13.33
INNOVATION	0.66	0.18	11.45
Organizational capability			
MULTIPROJ	0.77		
COORDICOOPER	0.64	0.08	12.73
FUNCCONTORL	0.70	0.10	11.62
ABSORPTIVE	0.83	0.07	9.88
ORGROUTINES	0.71	0.12	10.39
Strategic planning capability			
STRENTHWEAK	0.81		
OPPORTHREAT	0.80	0.13	12.73
GOALS	0.81	0.12	10.12
ROADMAP	0.74	0.22	13.90
RESOURCES	0.77	0.17	12.62
EXTENVIRON	0.72	0.12	11.24
TECHSTRATEGY	0.69	0.14	10.77
TECHLINKBUSI	0.70	0.13	11.68
Marketing capability			
CRM	0.79		
TIMETOMARKET	0.67	0.09	12.52
MARKETSEGM	0.76	0.12	10.78
SALESFORCE	0.83	0.11	9.35
AFTERSERVICE	0.71	0.15	11.28

All t values are statistically significant

TABLE 4.3: CONFIRMATORY FACTOR ANALYSIS OF THE CONSTRUCT MEASUREMENT MODEL

Goodness-of-Fit Indexes		
RMSEA	0.09	Below 0.7
Incremental fit index (IFI)	0.946	Greater than 0.9
Comparative fit index (CFI)	0.916	Greater than 0.9
Chi-square value (Cmin/df)	2.325	Less than 3
Standardized loading λ	λ > 0.5	

V. RESULTS AND DISCUSSION

A. Findings and insights from the study

Our study examined the innovation capabilities of auto component firms and analyzed how firms in the Pune automobile cluster integrate technology management and innovation strategies with business strategy. We found that auto component firms such as Rane Group, TACO Group, and Kalyani Group have successfully forged strong Tier 1 relationships with domestic and MNE auto manufacturers to become an integral part of the auto industry's global supply chain. Descriptive statistics are shown in Table A.2. A good degree of model fit was observed for the proposed model from the overall fit of indices. The model yielded cmin/df of 1.259 < 3, CFI of 0.943 > 0.9 and RMSEA of 0.043 < 0.07. The results support the research framework: the utilization of external sources of innovation enhances innovation capabilities, which in turn influence the innovation performance of firms. The data show that all innovation capabilities can be enhanced by external sources of innovation, which cannot be realized without the effective utilization of knowledge spillover. The innovation systems perspective positively interacts with the innovation capabilities of firms in clusters.

Our empirical findings suggest that the Pune automobile cluster is still in the process of acquiring indigenous R&D capability to develop critical components. Technologically innovative products are usually developed through technology acquisition from developed nations and through active assistance for the automation of manufacturing processes within the cluster. The ability of ensure technology acquisition, patent disclosure or scientific knowledge, strategic technology alliances, knowledge spillover through assistance from domestic and global OEMs, and technology transfer are the major sources of innovation in the Pune automobile cluster. It is evident that cluster firms position themselves in the global value chain, and knowledge spillover can act as a bridge enabling firms to improve the effectiveness of their knowledge transfer activities. The results of hypothesis testing are shown in Table 5.1 and Figure 5.1.

TABLE 5.1: HYPOTHESIS TESTING AND STRUCTURAL EQUATION MODELING RESULTS

Hypothesized paths	*Regression estimate*	*Standardized regression estimate (r)*	*Critical ratio*	*Hypothesis supported*
H1: Knowledge Spillover → External sources of innovation (ESI)	0.175	0.156***	3.882	Yes
H2: External sources of innovation →Knowledge spillover (KS)	0.064	0.060	1.453	No
H3-a: ESI → Technological capability	0.127	0.147***	3.355	Yes
H3-b: ESI → Manufacturing capability	0.217	0.223***	5.336	Yes
H3-c: ESI → Organizational capability	0.282	0.391***	10.026	Yes
H3-d: ESI → Strategic planning capability	0.560	0.362**	9.164	Yes
H3-e: ESI → Marketing capability	0.432	0.452*	10.750	Yes
H4-a: KS → Technological capability	0.287	0.239**	5.802	Yes
H4-b: KS → Manufacturing capability	0.173	0.134**	4.396	Yes
H4-c: KS → Organizational capability	-0.044	-0.056	1.336	No
H4-d: KS → Strategic planning capability	0.038	0.062	1.572	No
H4-e: KS → Marketing capability	-0.042	-0.070	1.724	No
H5-a: Technological capability → innovative performance of firm	0.166	0.263***	6.637	Yes
H5-b: Manufacturing capability → innovative performance of firm	0.152	0.112**	2.797	Yes
H5-c: Organizational capability → innovative performance of firm	0.132	0.235***	5.781	Yes
H5-d: Strategic planning capability → innovative performance of firm	0.482	0.688*	3.691	Yes
H5-e: Marketing capability → innovative performance of firm	0.367	0.574*	4.228	Yes
Control Variables				
Size → Innovation firm performance	-0.035	-0.044	-1.044	
Age → Innovation firm performance	-0.057	-0.046	-1.344	
Goodness of fit indexes				
Cmin/df	1.259		Less than 3	
CFI	0.943		Greater than 0.9	
IFI	0.958		Greater than 0.9	
RMSEA	0.043		Less than 0.07	

****P < 0.01; **p < 0.05; *p < 0.10*

In Figure 5.1, the unidirectional arrows represent the regression relationship between two variables. Our results show that the firms' capability to employ external sources of innovation builds their innovation capability, which has an impact on the in-house R&D activities, innovative manufacturing practices, and absorptive capabilities in the cluster. Further, our findings indicate that knowledge spillover plays a dual role: it has become one of the sources of innovation for effective transfer of knowledge, and it is positively related to manufacturing as well as technological capability.

These firm capabilities are enhanced by formal and informal knowledge transfer, socio-professional and local markets, and technical and managerial support from auto firms. Knowledge spillover does not have a direct impact on the other capabilities of the firms. Experts claim that new problem-solving methods have been adopted by the Pune cluster because of the support extended by global OEMs in terms of technology acquisition and strategic technology alliances. Hence, both external sources of innovation and knowledge spillover externalities have had a dominant influence on building their innovation capabilities.

Of all the innovation capabilities, technological capability (which includes in-house R&D, learning, and R&D resource allocation), manufacturing, and organizational capability are the most positively related to innovative performance (sales performance) of firms in the cluster. Sales performance is measured as the percentage of sales generated by technologically new or improved products in the last three years, and it is concerned with not only the design and manufacture of new or improved products but also the production of new or improved products that are marketable. Yam *et al* [37] adopted a similar approach to measuring the firms' innovation performance in their study on the technological innovation performance of Hong Kong's manufacturing industry.

CFA results for covariance showed that the capability variables are not highly correlated. Further, technological capability (in-house R&D capability and organizational capability) exerts a greater influence on enhancing a firm's innovative performance than marketing and strategic planning capability. The innovative performance of firms in the cluster is enhanced mainly because of in-house R&D efforts toward product and production process development, extent of technology acquisition, specialized skills, and learning orientation. Interestingly, large auto component firms are developing their ability to manufacture complex or discrete components and are receiving active support for product development in some cases. Manufacturing capability has a positive effect on performance because it enables firms to apply advanced manufacturing methods (mostly specified by OEMs), maintain flexibility and lead time on the shop floor, effectively use learning and experience curves, and facilitate incremental innovations.

Organization capability also plays a decisive role in enhancing innovative performance by developing the firms' ability to transform R&D and design output into production and ensuring coordination among departments like manufacturing, marketing, and R&D within an organization. Large auto component firms are engaged in developing organizational routines for innovation and better absorptive capacity development. Moreover, experts have asserted that the overall sales performance of firms has an impact on marketing; however, our hypothesis on the innovative performance of firms was not strongly supported. This is mainly because automobile OEMs are more focused on the performance characteristics of auto components and their timely delivery.

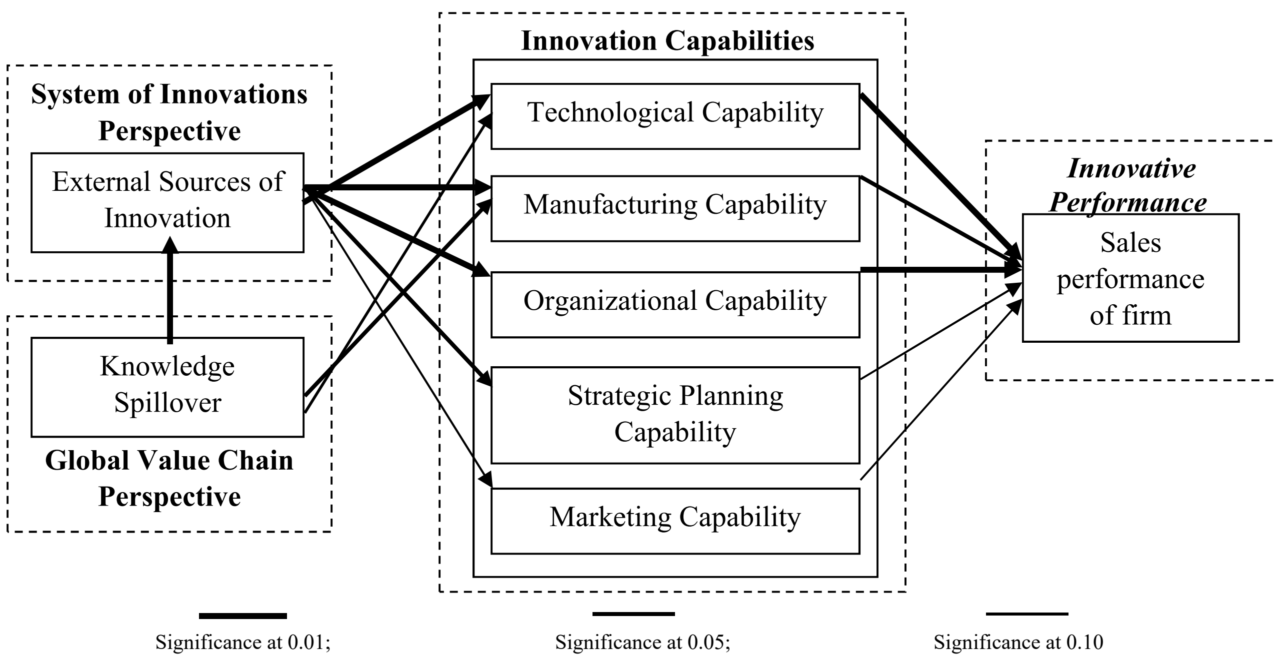

Figure 5.1: Structural equation modeling results for innovative performance of firms

B. Emergence of Practice Domains

The Pune auto component industry has the potential to achieve global leadership by building its innovation capabilities and leveraging these capabilities through operational excellence practices. Innovations in advanced materials, electric and electronic technologies, business models, advanced manufacturing processes, new products, and safety and emission norms have transformed the auto industry's value creation process. Our study confirms the emergence of innovative large, medium, and small firms that participate in the supplier network of the automobile cluster by providing various types of industrial services. Although many influential factors led to formation of these firms in the 1990s, three particular trajectories systematically explain the particular nature of these firms: 1) spin-offs from domestic companies (mainly Tata Motors) and individual experience, 2) the effectiveness of informal networks, and 3) inter-firm supplier linkages and market relations. Today, the innovativeness of these firms depends on how effectively they leverage innovation and excellence practices through cluster benefits and provide effective firm support.

The Tata group established TACO to provide auto component products and services to the automotive industry. Similarly, other important auto component suppliers like Bharat Forge, Autoline Industrial Parks, Endurance Technologies, Gabriel India, Spicer India, RSB Transmissions, Lear Automotive India, Lumax Auto Technologies, Automotive Stampings and Assemblies, Mando India, PMT Machines, KLT Automotive and Tubular Products, PARI, PAE India, Exedy India, Lombardini India, Indo Schottle Auto Parts, Victor Gas, Tulsi Castings and Machining, Mahindra Gears and Transmissions, Spectra Industries, Spaco Carburetors, and Walia Auto ancillaries have all played a significant role in the region by successfully integrating themselves into the industry value chain with standardized component supply.

Figure 5.2 shows the key innovation capability factors and sub-factors identified in the SEM analysis, which broadly indicate the cluster firms' excellence practice domains. These practice domains, which can be linked to their business strategy, are strategic technology management, operational excellence, strategic thinking, and people engagement.

The strategic technology practice domain influences three innovation capabilities: technological, manufacturing, and organizational capability. Pune's auto component industry has focused on in-house R&D efforts for products and processes; as a result, new product launches by OEMs comprise 70% of their locally sourced components. This transformation has been encouraged through active assistance in product design and specifications from TNCs and global OEMs. Knowledge and technology transfer have facilitated the adoption of various learning patterns in the cluster. For instance, auto component firms are gaining proficiency in equipment and manufacturing know-how, formal and informal linkages, training, learning by doing and learning by imitation, and collaboration.

In line with their focus on in-house R&D, the auto component firms have been acquiring technologies through various modes (technology purchasing, licensing, JV, and collaboration) and transforming R&D output into production. Simultaneously, the cluster firms have been developing the ability to handle multiple R&D and innovation projects—an ability that mostly depends on their absorptive capacity and organizational routines.

Operational excellence has emerged as another practice domain, and auto component firms within the cluster are increasingly advancing their manufacturing excellence methods and practices. This is evident from the increased levels of exports, from US$5.2 billion in 2010-11 to US$6.9 billion in 2011-12, driven by a major thrust on quality and reliability of components. The industry has also experienced rapid shrinking of the technology development cycle and the product development cycle, with firms maintaining flexibility and lead times. However, the effectiveness of these two practice domains can only be harnessed by people engagement in collaborations and network development, leveraging learning patterns, and imbibing a global perspective.

Enhanced technical and financial collaborations, linkages, acquisition of foreign companies by domestic firms (outward FDI), relationship with customers and suppliers, and active joint ventures with MNEs have highlighted the importance of people engagement within the Pune automobile cluster. Auto component firms are now recruiting more engineers, designers, and skilled workforce from the region. Maharashtra has 901 engineering colleges, 408 management institutions, and 766 industry training institutions. IBM has also set up a center to support the automobile industry with skilled IT professionals from across the globe. This confirms the high availability of skill in the region.

Firms should engage in strategic thinking to develop stable, wining ecosystems, nurture innovation, deal with uncertainty, and enhance customer centricity. Strategic thinking as part of an organization's strategic management process, which involves generating and applying unique business insights and opportunities, is aimed at creating a competitive advantage for firms in clusters. The OEMs are looking for end-to-end solutions from the auto component industry and being integrated into the cluster ecosystem, which should be stable based on technology, service, and knowledge or science. Also, building an innovation culture is essential to become a global player. Firms have followed different business models but the innovation platform has remained unexploited.

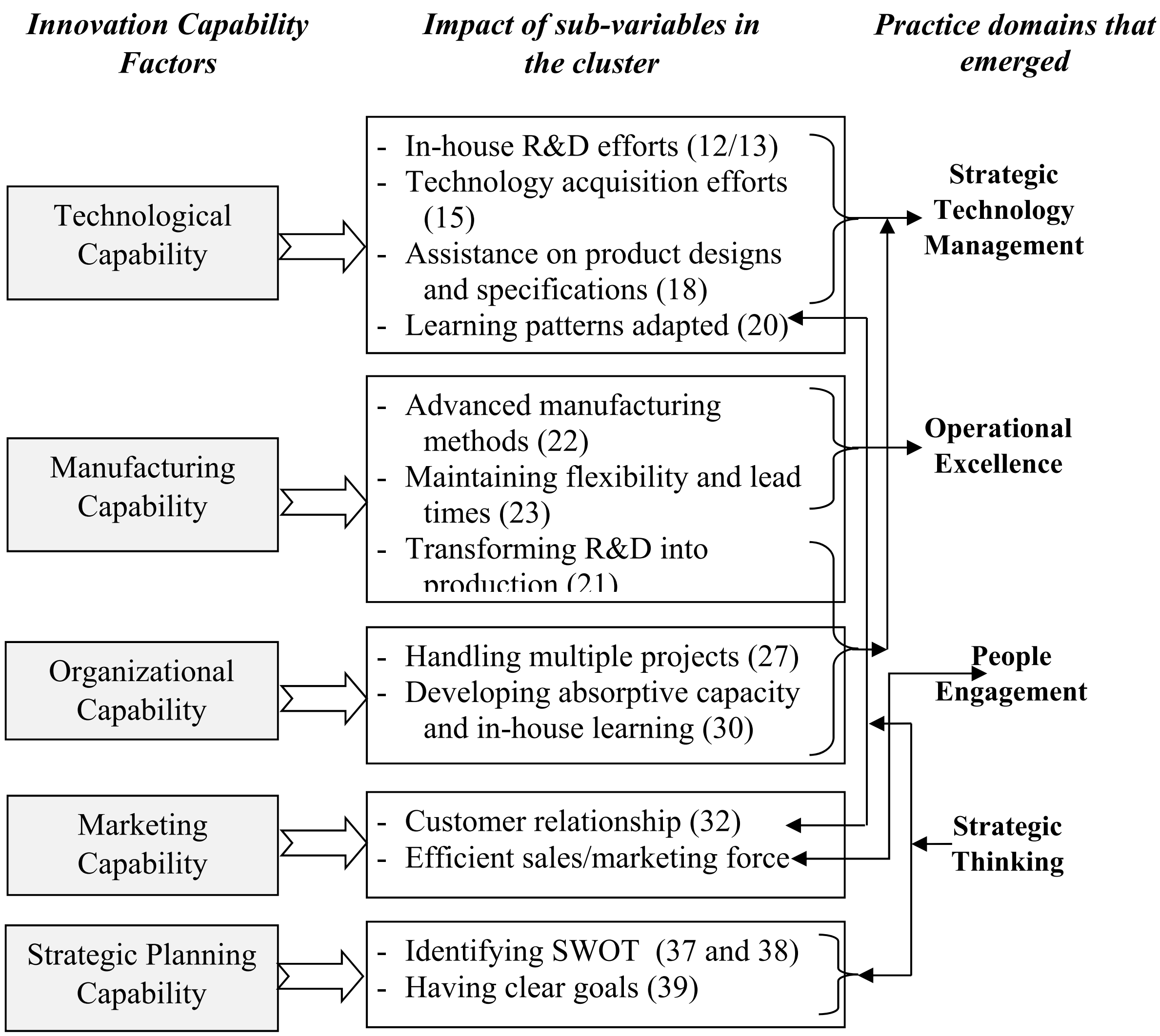

Figure 5.2: Linking innovation capabilities to firm excellence practice domains

C. Horizontal and vertical competencies to leverage innovation capabilities

Figure 5.3 shows the innovation and excellence practice domains identified through this research, which can be referred to as horizontal competencies that provide cluster firms with a systemic view and vertical competencies that provide deep domain expertise to help achieve a competitive advantage. Our research suggests that two types of firms exist in the cluster: firms that are developing the necessary ecosystem (usually dominant firms) and those that are strongly integrating with the existing ecosystem through innovation capabilities (usually auto component firms).

Competitive advantages have been acquired not only by firms with horizontal and vertical linkages that reflect in their supply chain and value chain but also by firms from clusters with systemic effects and linkages. The literature provides enough evidence that clusters of innovative firms form around areas of excellence and sources of knowledge. Thus, in order to gain deep domain expertise, firms need to nurture competencies and expand their reach in market and geographic experience, industry experience, areas of excellence, and business functions. Managers and executives working in the cluster can assess the effectiveness of the innovation capability building and firm performance with the help of this model and accordingly formulate winning strategies.

To achieve sustainable growth and competitive advantage in a cluster, firms need to develop an innovation strategy that enhances their innovation performance. The T-shape competence model suggests that the decision-making process has become a complex phenomenon and requires a systemic approach with specific domain expertise. It also comprises various players in the cluster, and value is co-created within the cluster ecosystem through effective linkages, collaborative formats, complementary innovation assets, and unique solutions. Thus, strategy formulation and execution become iterative in a dynamic business environment.

Figure 5.3: T-shape competence assessment model for firms within the cluster

The executives or senior management of domestic auto component firms in the Pune automobile cluster typically develop a strategic intent for target markets and product offerings and then define their innovation performance expectations. With OEMs demanding end-to-end solutions and reliable component delivery as well the goal of global integration, auto component firms need to continuously assess their strategic risk and build on their innovation capabilities and competencies. Strategic risk is associated with determining strategies for R&D, collaboration or linkages (i.e., interdependence), and integration, as shown in Fig 5.4.

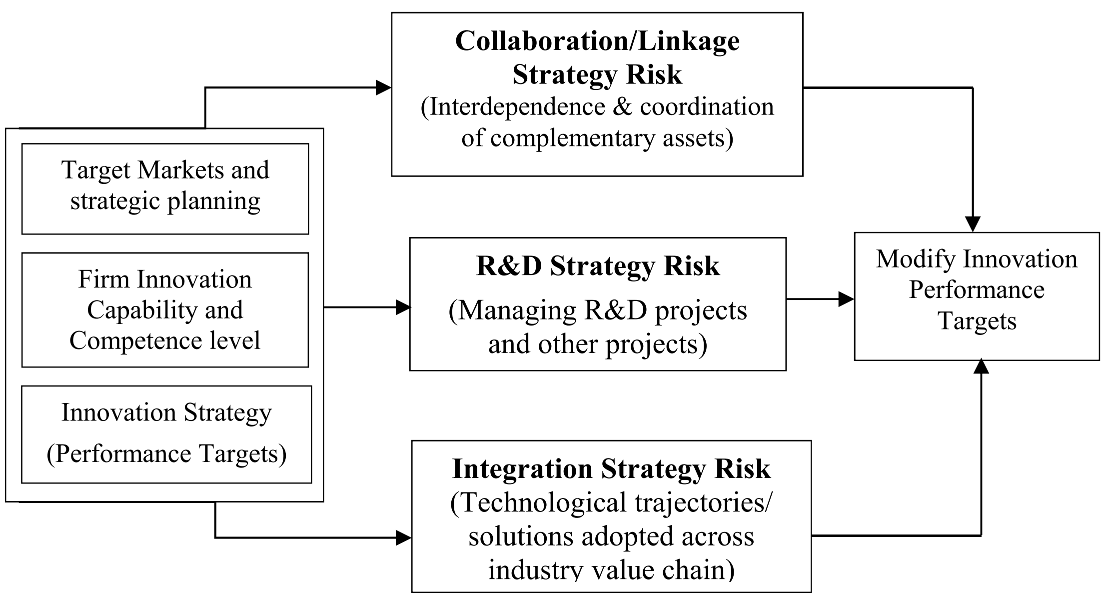

Figure 5.4: Formulating cluster ecosystem strategy to become a part of global value chain

The strategy risk assessment process often influences existing innovation performance targets and helps revise the firms' initial plans. This process might lead firms to accept revised performance targets, alter the allocation of resources, change the target market, lobby for supportive regulatory changes, acquire complementary firms, enhance global talent reach, and re-direct in-house R&D efforts.

VI. CONCLUSION

This study offers theoretical and practical contributions. Studying the global value chain perspective and the innovation systems perspective in the automobile industry and their interaction with firm innovation capability within a cluster, this work addresses the need for such an empirical investigation on innovation performance in an emerging economy like India. An evaluation of the firms' innovation performance through its innovation capability building shows the following:

a. The study supports the research model by showing the benefit of external sources of innovation on enhancing innovation capabilities, which influence the innovation performance of firms in the cluster. The regional innovation system positively interacts with a cluster firm's innovation system and strengthens its innovation and R&D processes. The hypothesis testing revealed that all innovation capabilities can be enhanced using external sources of innovation and this will not happen without the effective utilization of knowledge spillover.
b. Of all the innovation capabilities, technological, manufacturing, and organizational capabilities are the most positively related to the innovative performance of firms in the Pune automobile cluster.
c. The innovative performance of firms in the cluster is enhanced mainly by in-house R&D efforts toward product and production process development, extent of technology acquisition, specialized skills, and learning orientation. Interestingly, large auto component firms are building their ability to manufacture complex or discrete components and are receiving active support for product development in a few cases.
d. Manufacturing capability has a positive effect on performance because it allows firms to apply advanced manufacturing methods (mostly defined by OEMs), maintain flexibility and lead time on the shop floor, and effectively use learning and experience curves and incremental innovations.
e. Organization capability also plays a decisive role in enhancing innovative performance by developing the firms' ability to transform R&D and design output into production and ensuring coordination among the firms' various departments, such as manufacturing, marketing, and R&D.
f. Most importantly, this research proposes a T-shape competence assessment model for organizations to help them build an innovation culture. It suggests that firms should develop a set of horizontal competencies to develop a systemic view or ecosystem as well as a set of vertical competencies to gain deep domain expertise. The model also fosters social innovations in terms of job generation, improving standard of living and nurturing excellence practices with leadership of trust.

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APPENDIX
A.1 IDENTIFICATION OF STUDY VARIABLES

TABLE A.1: VARIABLES TO EVALUATE INNOVATION CAPABILITY AND INNOVATIVE PERFORMANCE OF FIRMS WITHIN A CLUSTER

I. Knowledge Spillover		***Variable Name***
1.	The ability of knowledge transfer through available scientific base/publication (codified formal knowledge transfer)	SPILLSCIENCE
2.	Extent of information and knowledge flows about products, processes, technologies, consumer & markets circulate informally within the cluster	SPILLINFORMAL
3.	Extent of knowledge transfer due to mobilization of people within cluster firms	PEOPLEMOBI
4.	Knowledge spillover through socio-professional and local markets	LOCALSPILL
5.	The percentage of components/products supplied to specific OEMs	SUPPLYCOMP
6.	Extent of support in terms of technical and managerial capacities from MNCs/global OEMs	SPILLMNC
II. External Sources of Innovations		
7.	The ability of acquisition of embodied technology	TECHEMBOD
8.	The extent of patent disclosure/scientific knowledge/participation in trade and exhibitions	PATENT
9.	The extent of FDI flows/venture funding/other financial support for technology development	FDIFLOW
10.	The extent of lead users/customer innovations	CUSTOMERINNO
11.	Extent of strategic technology alliances/international linkages among production and distribution systems	INTLINKAGE
III. Technological Capability		
12.	The ability of in-house R&D/design and development efforts toward product development	RNDPRODUCT
13.	The ability of in-house R&D/design and development efforts toward production process/engineering development	RNDPROCESS
14.	The level of R&D/design and development equipment used	RNDEQUIP
15.	The extent of technology acquisition efforts like technology purchasing/alliance/proprietary technology	TECHAQUISITION
16.	The percentage of specialized skills allocated to R&D/design & development department	RNDSKILLS
17.	The ability of complex/discrete components being manufactured	COMPLEXCOMP
18.	The extent to which the auto firms (as contractors) provide detailed specifications and designs of the product	SPECIFICS
19.	The extent to which contractor/customer provides feedback on product performance and quality for improvement	FEEDBACK
20.	The extent to which learning patterns/orientation adapted	LEARNING
IV. Manufacturing Capability		
21.	The ability of transforming R&D/design and development output into production	RNDPRODUCTION
22.	The ability of applying advanced manufacturing methods like JIT,TQM, Six Sigma, Toyota production system etc./degree of automation	ADVMFGMETHO
23.	The ability of maintaining flexibility and lead time for shop floor	FLEXILEADTIME
24.	The ability of effective use of learning curves/experience	LEARNCURVE
25.	The percentage of skilled workforce at manufacturing	SKILLMFG

26.	The extent of incremental innovations in process development	INNOVATION
V. Organizational Capability		
27.	The ability of handling multiple R&D/innovation projects in parallel	MULTIPROJ
28.	The extent of coordination and cooperation between R&D, manufacturing and marketing	COORDICOOPER
29.	The ability of high-level integration and control on major functions	FUNCCONTORL
30.	The ability toward developing absorptive capacity and in-house learning	ABSORPTIVE
31.	The ability of effective implementation of organizational routines toward innovation	ORGROUTINES
VI. Marketing Capability		
32.	The ability of relationship management with major customers	CRM
33.	The ability of time to market new products/reduction of new technology development time from concept to market	TIMETOMARKET
34.	The extent of good knowledge about different market segments	MARKETSEGM
35.	The ability of having efficient sales-force/marketing programs	
36.	The ability of excellent after sales services	AFTERSERVICE
VII. Strategic Planning Capability		
37.	The ability of identifying strengths and weakness	STRENTHWEAK
38.	The ability of identifying external opportunity and threats	OPPORTHREAT
39.	The extent of having clear goals	GOALS
40.	The ability to create roadmap of new product and process with measureable milestones	ROADMAP
41.	The ability of effective resource allocation to all SBUs/STUs	RESOURCES
42.	The ability of being highly adapted and responsive to external environment	EXTENVIRON
43.	The extent to which technology strategy is adapted in the firm	TECHSTRATEGY
44.	Ability of linking technology strategy with business strategy	TECHLINKBUSI

Abbreviations: SBUs – strategic business units; STUs – strategic technology units

APPENDIX A.2: DESCRIPTIVE STATISTICS

TABLE A.2: DESCRIPTIVE STATISTICS AND CORRELATIONS AMONG STUDY VARIABLES

Variables	**Mean**	**SD**	1	2	3	4	5	6	7	8
External Sources of Innovation	3.435	1.422	1							
Knowledge Spillover	1.947	1.106	0.390**	1						
Technological Capability	3.660	1.078	0.220**	0.024**	1					
Manufacturing Capability	3.452	1.245	0.315**	0.245**	0.436**	1				
Organizational Capability	3.124	1.067	0.347**	0.209**	0.505**	0.618**	1			
Strategic Planning Capability	3.507	1.128	0.259**	0.113*	0.432**	0.721**	0.624**	1		
Marketing Capability	3.744	1.023	0.172*	0.082	0.484**	0.556**	0.549**	0.483**	1	
Innovative Sales performance	1.896	1.547	0.132^{+}	0.168*	0.081	0.302**	0.310**	0.346**	0.150*	1

*Note: ** P value < 0.01; * p value < 0.05; +p value < 0.1*