STRATEGIC TECHNOLOGY MANAGEMENT IN AN INDIAN AUTOMOBILE CLUSTER

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Abstract

Regional clusters development has been identified as a strategic tool for industrialization and wealth creation by emerging economies. It is not just the geographic proximity but it is the technology that determines the rules of competition at the clusters. Indian (Pune) auto and auto-component firms in the cluster are progressing on technological development path to achieve global competitiveness. Automobile original equipment manufacturers (OEMs) are expanding their production bases to expand their market reach and leverage the existing capacity for auto-component manufacturing and providing opportunities to build unique capabilities leading to better performance. Along with the automobile OEMs, auto component industry has transformed itself from a traditional job fulfiller role to an integrated organization role in India. This paper analyzed the effects of Indian automobile policy reforms on domestic firms in the cluster and examined technological capabilities development in the development stages of the cluster. Competitiveness in a policy regime would, however, depend on the ability of the firm to bring about technological capability level shifts. Hence, our research attempted to explore asymmetry among firms in terms of adoption of technology development path and explain technology variables inter-firm variation in competitiveness.

The empirical qualitative and quantitative methodology applied to evaluate inter-firm differences based on technological capability and technological learning patterns within the cluster. The 56 interviews were conducted from shortlisted firms/executives. Secondary data was collected from CMIE‟s Prowess database and analyzed by using Generalized Least Square (GLS) estimation. A total of 392 datasets were collected about the 12 auto firms and 27 auto-component firms selected for the study. The research findings for both auto and auto-component firm indicate that technological variables are emerged very important in the determination of inter-firm differences in technological capability building. As hypothesized, the difference in the role played by technology variables within cluster is also well highlighted by results. It supports the argument that inter-firm differences in technological capability building depends crucially on technological acquisition, product differentiation, import of components and technology variables interaction with in-house R&D of firms within cluster. Also, the result shows that firms in the cluster are building innovation capabilities to integrate in the global value chain and enhance firm innovation performance. Thus based on the insights from the study, we have reported future managerial and policy implications

Keywords: Indian automobile cluster, Technological capability, Policy regime, inter-firm differences, and Strategic technology management

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1. Introduction

Strategic technology management is essential for cluster firms to achieve long-term competitiveness. The economy has been undergoing a series of sweeping changes, driven by rapid technological progress and change in the industrialized economies. The analysts narrate these changes as the emergence of new technological "paradigm" (Lall, 2001). This new paradigm involves not only new technologies but also new management techniques, different forms of enterprise linkages, tighter relationships between industry and science, and intensification of information/knowledge flows between economic agents. In this technological paradigm, technology revolutions have often played a strategic role in creating unexpected opportunities for firms in the clusters and have become a source of competitive advantage.

A cluster is a form of network that occurs within a geographic location, in which the proximity of firms and institutions ensures certain forms of commonality and increases the frequency and impact of interactions (Porter, 1998). It is not just the geographic proximity but it is the technology that determines the rules of competition at clusters. The survival of firms within a cluster depends on it being deemed innovative and how much of its innovations has leveraged through cluster development. Indian cluster firms are progressing on technological development path to achieve global competitiveness. Increase in rate of indigenous product development, while continuing licensing and technology collaboration and creating space in global value chain by firms necessitates building technological capabilities and improves their performance. Thus, the clusters have gained importance in research domain across the industry sectors.

Empirical studies on clusters have been reported majorly from developed nation. Recently, the momentum of studies has observed in developing countries and very few studies are available in the literature that addresses strategic technology management and innovation aspects, specifically in the Indian automobile clusters. Along with the automobile original equipment manufacturers (OEMs), auto component industry has transformed itself from a traditional job fulfiller role to an integrated organization role (Sahoo *et al* 2011) in India. The studies emphasized the need to place firm-level learning at the center of cluster analysis with the objective of understanding the nature and characteristics of a cluster‟s innovative process (Maskell, 2001; Martin and Sunley, 2003; Giuliani, 2005, 2007).

The process of technological development in Indian automobile industry can be seen in the auto-clusters. Automobile clusters are developed in North (NCR-Uttaranchal), East (Jamshedpur–Kolkata), South (Chennai-Hosur-Bangalore) and Western (Mumbai-Pune-Aurangabad) regions. Based on technology dynamism, market liberalization and competitiveness, clusters have experienced all the phases of life cycle: pre-foundation phase (1945-1965), emergence phase (1966-1984), growth phase I (1985-1995), growth phase II (1996-2007), sustenance Phase (year 2008 onwards). Indian government has contributed in automobile industry growth by liberalizing the norms for foreign direct investment (FDI) and import of technology in 1990s. As a result, the production of total vehicles increased from 4.2 million in 1998-99 to 23.36 million in 2014-15 (SIAM 2015).

Due to intense competition and changing customer demand, product development process advances have been more significant than changes in the 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

associated with the flexibility of the technology to constantly 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 emission norms etc. (Nag *et al* 2007). Simultaneously, the gradual opening up of the auto-component sector, government has been 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.

The aim of this research is to evaluate impact of Indian automobile policy reforms on the competitiveness of domestic firms by analysing inter-firm differences based on technological capabilities in the Pune automobile cluster. Our research attempted to explore asymmetry among firms in terms of adoption of technology development path and explain technology variables inter-firm variation in competitiveness. Also our research attempted to investigate technology capability levels along the cluster development and innovation practices, which provides competitive advantage to firms to become global player. Thus based on the insights from the study, we tried to define future managerial and policy implications

The paper is structured as follows. The section 2 covers review of literature on Indian automobile cluster development and policy reforms leading to competitiveness. It covers changing perspective of technology and industrialization. This section also highlights research studies reviews and their contribution in this field, which provides research gaps. In section 3, the determinants of technological capabilities defined as a source of study variables. Section 4 explains mixed research methodology application to this research and data collection and analysis approach provided in section 5. The sample selection, data collection procedure and measures, hypothesis and model are also given in this section. Finally, our research findings presented by showing strategic technology management and innovation practices in the Pune automobile cluster. This section provides contribution to practice i.e. recommendations for policy makers and industry managers. This paper ends with conclusion and scope for future work.

2. Review of Literature

The main objective of literature review is to identify research gaps while investigating recent research work in this field.

2.1 Technology and Industrialization: Changing Perspective

The dynamic evolution of comparative advantage within emerging economies involves effective technology acquisition and diversifying into more complex technologies (Khalil, 2009). Technology is a much more complex bundle of knowledge, with much of it embodied in a wide range of different artifacts, people, procedures and organizational arrangements. India adopted regional cluster development route for industrialization and technology development. Firms in clusters have frequent interactions, which are mainly reflected in the acquisition of knowledge, as well as in sharing, diffusing and creating it. A host of linkages among cluster member‟s results in learning through networking and by interacting is seen as the crucial force pulling firms into clusters and the essential ingredient for the on-going success of an innovative cluster (Breschi

and Malerba, 2001). Innovation related knowledge is diffused in clusters in a highly selective and uneven way (Morrison, 2004).

Until the late 1960s there was little interest in understanding industrial technological change specifically automotive industry in India. This was partly because the process of technological change was presumed to be largely absent, occurring almost entirely in the industrialized world (Kumaraswamy *et al.,* 2012). It was also because technology was embodied in fixed capital and technological progress was therefore achieved by the process of capital accumulation. From that perspective, the technological role of local industry was essentially passive, involving merely the adoption and routine operation of externally supplied technology. The main technological tasks were merely to acquire, and learn how to use - available technologies, and the only "technological capabilities" needed were those for undertaking such routine investment and production activities. Starting from the early 1970s, a growing number of researchers began to explore the realities of technological change in large scale industry in several developing countries (now emerging economy), especially in the countries such as Brazil, China, Mexico, Korea and India (Ivarsson *et al*, 2005).

After liberalization during 1990s, technological change is not simply something which firms choose and import from outside. On the contrary, it is rooted in a specific set of change-generating resources or capabilities which are located within the structure of technology using firms (Kumaraswamy *et al*., 2012). Consequently, the learning processes which contribute to building and strengthening those capabilities are seen as playing an important role in the long-term dynamism and sustainability of industrial production (Guo *et al*., 2011). The presence of global OEMs in Indian automotive clusters created new technological learning and dynamism (Sudhirkumar *et al* 2011). This means that for those interested in understanding industrial technological dynamism in emerging economies, there is after all something to observe i.e. apart from the acquisition of externally sourced critical components and technology. Moreover, these processes of technological change and capability accumulation exhibit wide differences between firms, industries and economies, with some of these differences apparently associated with different long-term paths of economic performance.

2.2 Indian auto and auto-component industry: Policy implications

Indian automobile industry comprises of the auto and the auto-component industries. The automobile industry in India has witnessed changing technological landscape in the global automotive industry (Narayanan 1998) and working in terms of the dynamics of an open market (Sahoo *et al* 2010). India is currently world‟s second largest market for 2-wheelers (2W), 9th in passenger cars (PV) and 8th in commercial vehicle (CV) production globally (SIAM 2012). Further the Indian automobile cluster life cycle has been influenced by policy framework of the government and has considerable impact on growth of industry fostering innovations and global competitiveness. In all clusters auto manufacturing industries are few in number but cluster dominates by auto-component firms.

The few research studies (Narayanan, 1998; Okada *et al* 2007; Sudhirkumar *et al* 2011 and Kumaraswamy *et al* 2012) has given attention towards evaluating technological capability issues and strategies of domestic firms in Indian automobile industry to create a space in global value chain and improve firm performance. These all studies have performed in specific period of time and reflect character of automobile industry in India along the policy reforms. Naraynan (1998)

attempted to analyse the effect of de-regulation policy on technology acquisition and competitiveness in the Indian automobile industry and found that variables capturing technology paradigm (design and configuration which provides framework for production or operation) and trajectories shifts (problem solving methods used by firm in the process of diffusion and establishment of the manufacturing system) are emerged as very important determination of inter-firm differences in competitiveness.

Similarly, Kumaraswamy *et al* (2012) identified technology capability factors in-terms of catch-up strategies by Indian auto-component firms in three different phases. They found that Market Share, GDP growth, Firm Size and Firm Location has emerged as important parameters influencing firm strategies to build capabilities. Okada *et al* (2007) analysed firm performance within and outside the three major Indian automobile clusters and evaluated relative importance of capability variables. They have proved that inflow of FDI has transformed this industry. Drawing upon insights from recent and exclusive research work, Table 2.1 provides the highlights of these studies. Moreover, it shows that *how* auto and auto-component firms performed actions in the given environment and transformed over the period of time. The future indicators of industry environment change will be dominated by hybrid cars, sophisticated public transport, fuel efficient vehicles, safety and emission norms etc. This requires strategic thinking and nurturing excellence practices to build competence among firms.

In the rapidly changing global scenario, the concept of attaining competitiveness on the basis of abundant and cheap labour, favourable exchange rates and concessional duty structure is becoming insufficient and therefore, not sustainable. The key questions are: how quickly the industry is able to adapt to the challenges of the fast changing environment and how well the industry is able to integrate the technology management and innovation with the business strategies of the firms.

Hence, the main research gap identified from literature review:

a. There are very few studies found on the inter-firm differences based on technological capability building having strong influence on innovation process of firms in the automobile cluster.
b. Strategic technology management and innovation practices at tier industries are not studied critically to provide insights to build capabilities and improve firm performance within the cluster.

The Indian (Pune) automobile cluster has identified to evaluate the Indian automobile policy effects on domestic firms within the cluster and impact of technology variables to achieve competitive advantage.

Table 2.1: The research work highlights in an Indian automobile industry

	Foundation Phase Period: 1985 to 1991	**Transition Phase** Period: 1992 to 1997	**Consolidation Phase** Period: 1998 to 2002	**Global Integration Phase** Period: Post 2002
Research Studies	Narayanan (1998)	Narayanan (1998) Kumaraswamy *et al* (2012)	Kumaraswamy *et al* (2012) Okada *et al* (2007)	Kumaraswamy *et al* (2012) Sudhirkumar *et al* (2011) Okada *et al* (2007)
Environment	Pre de-regulation period with controlled policy regime Entry to passenger cars discouraged and restriction on import of few components Permitted technical and financial collaborations in Little motivation for technology up gradation	Post de-regulation period with capacity re-endorsement and liberalization Technology licensing and transfer from MNEs permitted MNE entry allowed with 100% ownership	Renegotiation of terms for entry and operation to ensure that MNE entrants do not rely exclusively on CKDs and imported components. Foreign exchange neutrality dropped for new production units. Emission Norms imposed CBU and SKD/CKD imports put under OGL	Auto Policy 2002: Emphasis on safety and environment standards, higher fiscal incentives for R&D efforts, and automatic approval for 100% foreign equity. Automotive Mission Plan 2006 (AMP) and NATRiP project introduced Global OEMs impact on domestic firms
Actions	Telco and Bajaj focused on indigenization Auto ancillary sector started organizing for indigenization Bajaj „Tempo Trax" technical collaboration with Daimler Premier Automobiles technical collaboration with Nissan, Japan TELCOs new products (LCV) – as a result of technology trajectory development and arm-length purchases of	Technological up-gradation and new vehicle model launches with Japanese collaboration TELCO used in-house R&D to facilitate paradigm shifts Firms preferred to import the designs to produce up-graded component rather than component itself. New firms/MNEs adapted vender development strategy MNEs expanded wide network	MNEs started rationalizing their supply chain Major MNE Tier 1 component firms set up subsidiaries or JVs Industry became more formally "tierized" New markets exploration and tie-ups Productivity and profit margin measures by firms	Core group on automotive R&D (CAR) set up to establish technology development priorities Auto and auto-component firms began investing in R&D and acquiring auto operations and brand abroad TNCs increased opportunity of sub-contracting relationship with domestic firms

	components	and marketing capability		
Impact	The new technology paradigm – „conveyor-belt" system of production, adaptation of IT, and little use of automation and robotics. The change in use of different materials (aluminum, plastics and fiber) R&Ds were inadequate to bring trajectory shifts Technology imports brought incremental changes in product or process	Competition enhanced with market structure change Modern shop-floor arrangements Shift from access to market to competence of partner Asymmetry of firms in adoption of technology paradigm and trajectories Technology capability through learning by doing and in-house R&D efforts R&Ds reoriented itself and became substitution for technology imports	MNEs more collaborative relationship with Indian auto component firms in improving quality and productivity. Component firms started locating near assembly plants Enhanced focus on exports with increasing competition in the domestic market Operational efficiency of domestic firms improved MNEs strict control on domestic firms Increasing market share of MNEs and beneficial to component domestic firms	Tier 1 companies like Kalyani Group and TVS group started investing heavily in in-house R&D to achieve competitive advantage Tier 2 companies have started providing end-to-end solutions to Tier 1 companies Firms started getting active product related and purchase process related assistance
Major Observations form analysis	SKILL component has not given significance. R&D alone turn out insignificant The interaction of disembodied technology imports and R&D, and embodied technology imports and R&D were predominant Foreign Exchange (FDI) was insignificant	SKILL component has not given significance. The variables capturing technology imports emerged significant Foreign Exchange (FDI) emerged as significant towards technology paradigm shift Advertisement emerged positive but not significant Technology licensing and collaboration (arm length or JV) as a dominant strategy Firm location – imp factor	Integration into the industry value chain as a part of strategy Firm Size ceased to be critical Market Share emerged as important determinant for performance Ability to develop complex product emerged insignificant Internal R&D referred to localization of materials, licensed technologies and incremental improvement FDI factor emerged significant	Knowledge creation through in-house R&D become part of strategy Investment in R&D is crucial for firm performance FDI factor emerged very significant

3. Determinants of Technological Capability

Technological capability building and learning is widespread with externalities and inter-linkages. It is driven by links with suppliers of inputs or capital goods, competitors, customers, consultants, and technology suppliers. There are also important interactions with firms in unrelated industries, associations and training institutions. Where information flows are particularly dense, clusters emerge with collective learning for the group as a whole. Technological interactions occur within a cluster and with other clusters. Imported technology is generally the most important initial input into learning in developing countries. Since technologies change constantly, moreover, access to foreign sources of innovation is vital to continued technological progress. Technology import is not, however, a substitute for indigenous capability development.

3.1 The Structure and linkages of Pune automobile cluster

The present structure of Pune automobile cluster expresses development of cluster and future opportunities. Pune has been emerging as a prominent location for the automobile sector and having advantage of large supplier base as well as proximity of the Nhava Sheva port. It is home to the Automotive Research Association of India (ARAI), which is responsible for the homologation of all vehicles available in India along with automobile R&D, testing and certification organization. ARAI has tied up with TUV Rheinland, a 130-year-old German multinational and one of the world's largest testing, inspection and certification agencies. With this association, the Indian manufacturers will have an edge in exports of vehicles and vehicle parts as all the aspects of testing and certification as per international standards like EEC/ECE will be handled locally by qualified experts. Automobile and related industry in Pune comprises 189 firms (SIAM and ACMA, 2011). We observed that major products from the cluster are clutch components, gear components, brake components, shafts, axles, valves, engine components, electrical components, etc.

Pune cluster has gained strength from the arrival of global OEMs and creating competitiveness through setting up capacities to locally develop and manufacture engines and transmissions with vendor development as a key part of their strategy. The Auto Cluster Project was set up to support SMEs in design, rapid prototyping, calibration, environment testing, and polymer component testing facilities. The manufacturing facilities are largely flexible, where new firms also established a modern shop-floor arrangement which integrates technology for differentiated vehicles. This arrangement enabled the firms to effectively utilize their capacity by changing their product mix and to ensure quality and timely delivery. Also there is change in use of advanced materials to reduce a vehicle weight and improve fuel and drag efficiency. Technology development in the auto industry worldwide has been primarily driven by the automobile manufacturers, regulations and changing customer preferences.

We have noticed that a very large number of joint ventures have been set up in the auto components sector by increasing automation at Tier I industries and intensity of knowledge flows transformed Tier II industries. Global OEMs have established their R&D centers and Pune cluster is gaining outsourcing capabilities in R&D space. These all changes constitute a Technological paradigm shifts and firms following various knowledge acquisition channels

leading to inter-firm variation. The typical structure and linkages within Pune automobile cluster is shown in Figure 3.1.

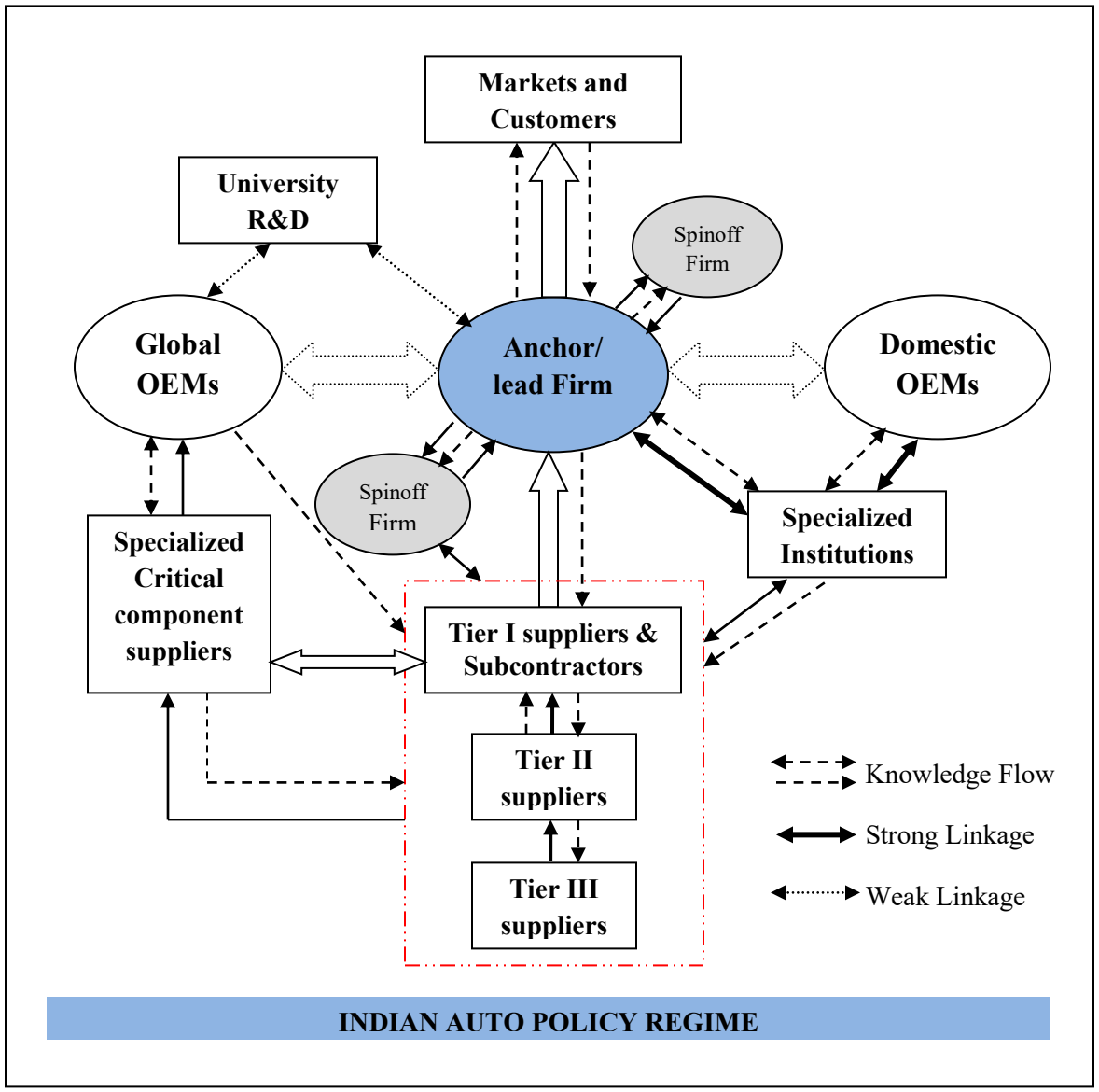

Figure 3.1: Typical structure and interaction/linkages of actors at Pune automobile cluster

3.2 Determinants of technological capability: Study variables

Pune automobile cluster is emerged as competence centers and engines of new economic growth by building technological capabilities. This part of research focuses on firms within a Pune cluster creating competitive advantage in the spatial distribution of industries by building technological capabilities. The Pune automobile cluster has been empirically investigated inter-firm differences on technological capability building. Auto Policy 2002 played important role in the automotive sector of India. Understanding the market potential in India, global OEM‟s has established in Pune auto Cluster. The determinants of cluster performance based on

technological capabilities are Technology acquisition, import of components and product differentiation.

Technology Acquisition:

Technology acquisition by a firm can be facilitated through imports (technology transfer from abroad) and in-house R&D efforts. Technology acquisition from abroad consists of technology imports through the market or "arms-length" purchase of technology against lumpsum and royalty payments, intra-firm transfer of technology through foreign direct investment (foreign equity participation) and technology transfer through the supply of machinery and equipment, where the technology is embodied in the imported capital good itself. An in-house research and development effort of firms is one of the important methods of location, adaptation, assimilation and development of the imported technology.

Technology Interaction:

Firms operating in a restrictive regime directed their in-house R&D efforts either to complement imported technology to facilitate technological capability shifts or to locate their technology imports. Some firms in the process of diffusion of imported technology, as a result, could have used the interaction between technological imports and in-house efforts. With the entry of leading multinationals and transfer of design and drawings as well as product development assistance, resulted in bringing about cost reduction and technological up-gradation of vehicles to face global challenges. This could have been undertaken by managing technological change effectively. The study, therefore, analyses the difference in the role played by technology interaction (between imported technology and in-house R & D).

Imports of Components:

Firms use imported components and parts either as a part of a 'package' in the transfer of technology or due to certain costs and quality advantages. Higher imports could also be because firms would choose the quicker option of importing the parts and components rather than encouraging parallel technology transfer to component manufacturers as well.

Product Differentiation:

Advertisement is an important aspect of non-price rivalry among firms. The absence of effective competition during the first period could have been a source of low advertisement intensity. The presence of a number of OEMs after the 2002 policy, and the resultant scope for non-price competition may have led to an increase in advertisement expenditures.

4. Research Methodology and Model

Mixed methodology (combination of qualitative and quantitative research methodology) is adopted for the research. Methodological perspectives and literature published on clusters are indicated to growing attention to use combination of „theory and empirical" analysis to give sound basis for research (Cruz *et al*, 2009). In Pune automobile cluster, the auto and auto-component firms (SIAM and ACMA members) were selected for this research investigation. Total 19 auto firms, 170 auto-component firms and 6 specialized institutions are available within the Pune automobile cluster.

Qualitative research methodology:

The interviews and survey is conducted and received 70 % response from shortlisted firms/executives. The discussion guide and survey questionnaire is pretested and modified according to suggestions of senior managers. The total 56 interviews were conducted during October 2011 to September 2012.

Quantitative research methodology

Quantitative research methodology was employed to study the inter-firm differences based on technological capability building and to evaluate the innovation performance of firms within the cluster. The study variables are identified based on literature review and insights from qualitative phase of study.

Hypothesis: Technology Acquisition, Import of components, Product differentiation, skills, and in-house R&D efforts of auto firms within cluster strengthens technological Capabilities.

$$\boldsymbol{MS} = \beta_0 + \beta_1 RDI + \beta_2\, MKI + \beta_3\, SIZE + \beta_4\, FE + \beta_5\, MCI + \beta_6\, SKILL + \beta_7\, ADI + \beta_8\, D_{auto} + \beta_9\, RDI \times FE + \beta_{10} RDI \times MKI + \mu_1$$

……………………………………… (4.1)

5. Data Collection and Analysis

5.1 Sample Characteristics

The secondary data was collected from Centre for Monitoring India Economy (CMIE) Prowess database and individual organization annual reports. The 12 auto firms and 27 auto-component firms selected for the study and 392 dataset collected. The panel data from the year 2001 to 2011 was analysed through Generalized Least Square (GLS) method and STATA software used. The sample selected has found satisfactory as per Gujarati *et al* (2006).

Table 5.1: Qualitative and quantitative methodology application

	Qualitative Research Methodology			**Quantitative Research Methodology**		
	Interview Based (56)			**Secondary data based (392)**		
Population	Sample	Measurement	Analysis	Sample	Measurement	Analysis
Sp. Inst. (6)	5 (80%)	Data transcription	Content Analysis (MS Excel 2010)	CMIE Prowess Data pooled from year 2001 to 2011		
Auto (19)	5 (26%)			12 (64%)	Hypothesis testing	GLS Estimati- -on (STATA)
Auto-component (170)	32 (19%)			27 (16%)		

5.2 Data collection and measurement

The empirical evidences are collected from 12 auto firms and 27 large auto-component firms (listed in CMIE Prowess Database) for the period of 2001-2011 and 392 secondary observations organized based on dependent and independent variables. For the empirical quantitative analysis, the observations for 11 years (2001-2011) were pooled as it was panel data (time series data and cross section data). Whether data needs to be pooled or not to be pooled, understood with the help of Madala‟s (1971) approach. Also study looked at impact of automotive segments with the help of slope dummy variables D*auto* for auto firms and D*auto-comp* for auto-component segment (Tier I/Tier II/Tier III).

Investment in R&D for technology development will be one of the most important aspects of future strength of automotive industry. Understanding India‟s strength in the skills set required for technological development, the industry needs to invest in research and development to increase innovative breakthroughs for vehicle design as well as in manufacturing technology. This empirical examination of study incorporated “Market share” as a major of cluster firm competitiveness in relation with technology variables.

Table 5.1: The variables used for quantitative secondary data analysis

Variables	***Measures***
MS	Market share in terms of the annual sales turnover of a firm to that of the total sales
RDI	In-house R&D intensity of a firm in percentage calculated as the ratio of R&D expenses to sales turnover multiplied by 100
MKI	Import of capital goods (embodied technology imports) intensity of a firm in percentage calculated as the ratio of foreign expenditure on capital goods to sales turnover multiplied by100
MCI	Import of designs, and components value of imports of components to sales turnover multiplied by100
FE	Foreign equity participation in the firm in percentage calculated as the ratio of foreign equity in the total equity multiplied by100
SIZE	Size of a firm calculated as sales turnover of the firm in crores of rupees
SKILL	Skill intensity of a firm in percentage calculated as the ratio of salaries and wages to expenditure of firm multiplied by 100
ADI	Advertisement intensity defined by expenditure on advertisements and sales promotion as a proportion of sales
Interaction Terms	MKR=MKI*RDI; FER=FE*RDI

Source: Variables are extracted from Narayanan (1998)

5.3 Data Analysis

Generalized Least Square (GLS) estimation is employed. GLS allows small sample sizes to do an acceptable analysis for theoretical and empirical fit (Chen *et al*, 2011). The most importantly,

it considers interaction effects and panel data accurately as compared to OLS. Our research has three interaction terms, so we have applied this Feasible GLS estimation. The results are checked for heteroscedasticity, using Cooke-Wiesberg test for heteroscedasticity. This deals with the variance of the error in the cross section data, we found good fit for our model.

Table 5.2: Empirical Results – Dependent variable as Market Share

	Auto Firms in Pune Cluster		***Large Auto-component firms***	
Variables	Coefficient	t values	Coefficient	t values
Constant	3.2462	0.7431	4.1248	2.069
SIZE	14.7930	**2.2401**	5.7031	0.6673
FE	- 0.08813	- 1.0482	-0.01842	- 1.2083
RDI	7.4164	**2.8911**	2.4451	**1.8962**
MKI	11.237	**1.863**	1.1596	1.078
MCI	3.7746	0.6875	10.774	**2.281**
SKILL	9.60013	**3.21**	4.0179	**2.013**
ADI	11.774	0.9978	-3.4410	-0.42
FER	- 0.0971	- 0.42	-0.2273	-0.6312
MKR	33.9301	**2.445**	9.9410	1.072
Dauto	7.1943	0.8846	--	--
Dauto-comp	--	--	12.008	0.6645
R- Squared	0.8255		0.8597	
Adjusted R^2	0.7632		0.7798	
Observations	126		266	

Note: *t values printed in bold are significant at 0.05*

6. Results and Discussion

The research findings for both auto and auto-component firm indicate that technological variables are emerged very important in the determination of inter-firm differences in technological capability building. As hypothesized, the difference in the role played by technology variables within cluster is also well highlighted by results. Further, technology acquisition, the interaction between imported technology and in-house R&D effort seems to be the most important determinant. In both in-house R&D efforts and skills are emerged as dominant factors proportional to technological capability.

The firm size comes up with positive sign and significant in auto segment, which suggest that organizational capability to invest into R&D efforts and acquire specialized skills is essential. Most importantly, in auto-component cluster import of designs and components has significant impact on technology capability enhancement. This may be because of global and domestic OEMs assistance to subcontractors to effective in-time delivery of quality products and services.

Domestic firms within the cluster has influenced by technology acquisition and product differentiation characteristics due to arm length purchases, active technology transfer from MNEs and captive sourcing of components. The findings clearly indicate that Auto Policy 2002 seems to have played crucial role to enhance competitiveness of automobile firms and auto-component firms.

These results support the argument that inter-firm differences in technological capability building depends crucially on technological acquisition, product differentiation, import of components and technology variables interaction with in-house R&D of firms within cluster. The capability to manage technological change will be important to meet the challenges of an increasingly globalized automobile market, as well as local and global environmental challenges (Sagar Ambuj *et al* 2004). The figure 6.1 shows the interaction of various internal and external actors and provides conducive milieu for business growth, called as ecosystem. The cluster firms experiences dynamism due to technological complexity and knowledge flow linkages. This technological complexity has influence on technological leaning patterns within the cluster and depending on absorptive capacity of firm, technological capability gets build among firms.

6.1 Strategic technology management through cluster development stages

Strategic technology management is essential for long term competitiveness of firms within the cluster. In order to achieve competitive advantage, firms need to continuously upgrade themselves on technology front. Sahoo *et al* (2011) studied the two cases (TVS Lucas and Bosch) and suggested that the long-term success of organizations will depend on how well they integrate their technology strategy with business strategy and develop their in-house capability to absorb, adapt and develop new technologies. This capability of firm referred as absorptive capacity (Cohen *et al,* 1990 and Zahra *et al*, 2002) in the literature and understanding its impact on organizational change as well as strategic nature. Absorptive capacity explained as a dynamic capability pertaining to knowledge creation and utilization.

The strategic nature of dynamic capability (Teece, 2004) can be understood by its origins through routines of organization, improved business models, investment choices and entrepreneurship. Thus absorptive capacity possess two subsets of capabilities as potential capability (knowledge acquisition and assimilation) and realized capability (knowledge transformation and exploitation). The ratio of realized capabilities to potential capabilities is an indicator of firm‟s innovation ability (Zahra *et al*, 2002). This shows an influence of absorptive capacity on innovation process of firm. Moreover, Narvekar and Jain, (2006) proved that all these four sub-capabilities of absorptive capacity may not be employed fully in the innovation process depending on the innovation project and innovating company specific variables.

This research also found the positive influence of absorptive capacity in inducing technological change (refer figure 6.1) and strengthening innovation process of firm within the Pune automobile cluster. This provides competitive advantage to firm through building technological capability. Our finding shows that absorptive capacity and technological capability of the firm have strong interdependence and encourages inter-firm linkages through strategic technology management practices within the cluster. Such efforts help firms to reduce gap between advanced technological path (mostly followed by developed nations) and present technological path following by developing countries as shown in figure 6.2.

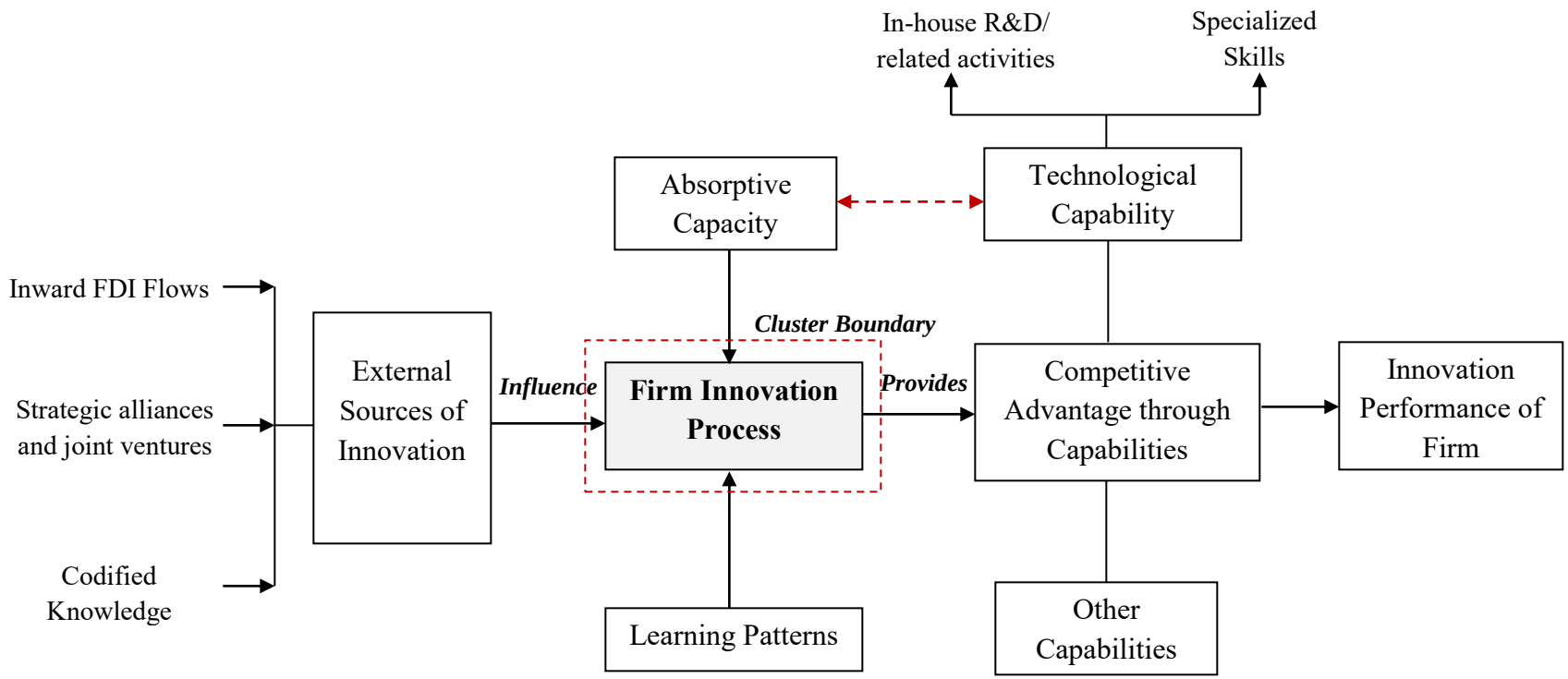

Figure 6.1: Impact of critical dimensions of cluster development on firm innovation performance within Pune automobile cluster

Considering the proximity to advance technology path and absorptive capacity of the firm, we propose 3×3 matrix showing the technology capability development shown in figure 6.2. The firms can analyse technology life cycle positioning of their core technologies to understand proximity to advanced technological path and map with absorptive capability to understand present position in the matrix. Thus firms would develop various strategies to achieve competitive advantage through technological capability building. The technological capability construed in this research as in-house R&D or related efforts, and specialized skills needed to execute R&D activities, collaboration networks, linkages and learning‟s effectively. The figure 6.3 explored the capability levels (TC levels) in emergence, growth and sustenance phase of the cluster development.

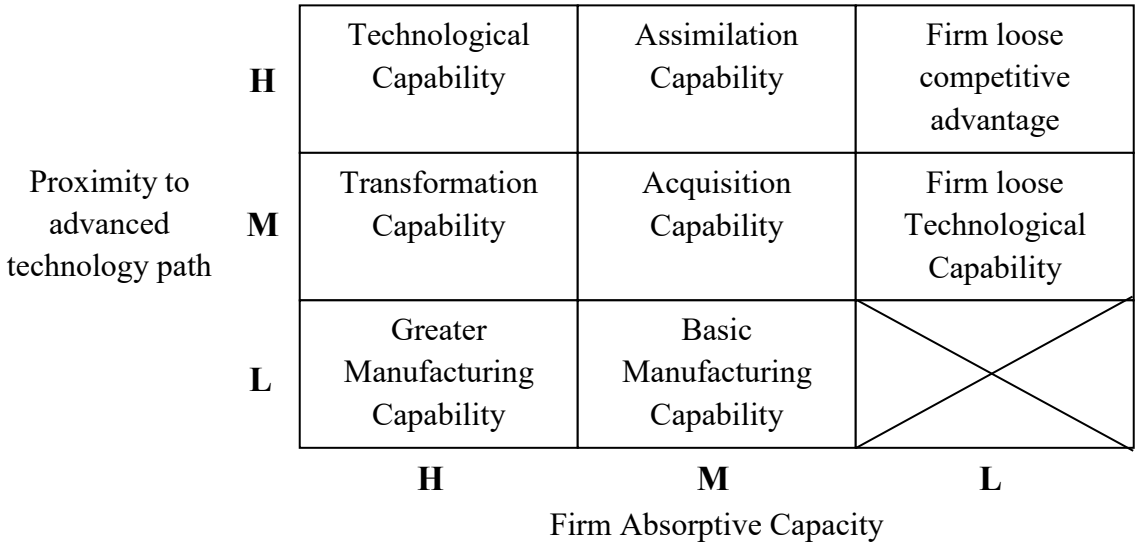

Figure 6.2: Technology capability building matrix through absorptive capacity

Similarly, Kumaraswamy *et al* (2012) studied evolution of the Indian auto-component industry in transition phase (1992 -1997), consolidation phase (1998 – 2002) and global integration phase (post 2002). They have found that as market liberalization progresses, Indian domestic firms were adapted catch-up strategies by initially through technology licensing and absorptive capacity development, and through integration into industry value chain and relationship development during consolidation phase. In the global integration phase, firms followed knowledge creation through R&D strategy to enhance performance and become global player. However, they have neither looked at inter-firm differences in capability building and technological learning patterns, while following these catch-up strategies nor innovation capabilities which help domestic firms to integrate into global value chain and enhance their performance. Thus, our research attempted to fill this gap and also studied innovation firm performance through building technological capabilities in the influence of internal and external factors.

In this current research, inter-firm differences based on technological capability analysis shows that technology variables play decisive role and suggested that Pune automobile cluster is still in process of gaining indigenous R&D capability to develop critical/complex components. Technologically innovative products within the cluster are developed by technology acquisition

as well as indigenous efforts and domestic firms are leveraging excellence manufacturing practices through active assistance in the cluster from Global OEMs and large domestic firms.

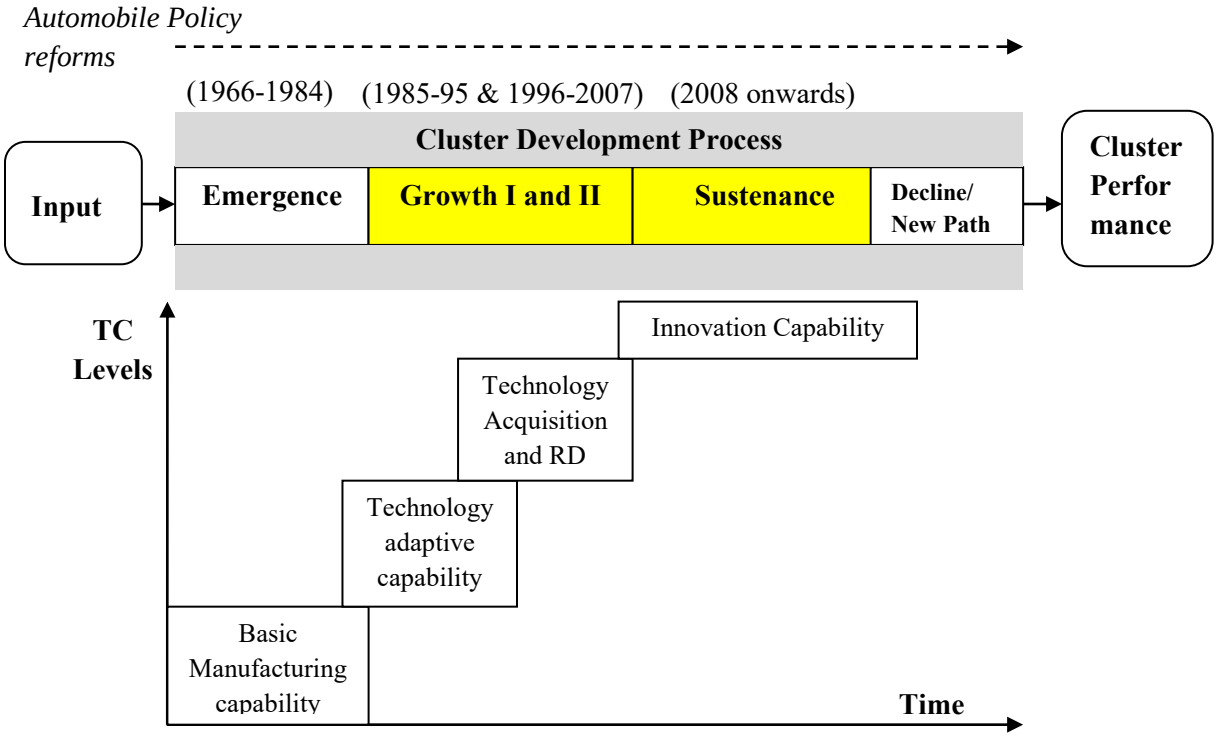

Figure 6.3: Technology building blocks in the Indian (Pune) automobile cluster

This assistance benefits to domestic firms by TNCs are studied by Sudhirkumar *et al* (2011) and their research found that product related and purchase process related assistance emerged as strong linkages and production process, organizational know-how, marketing, finance and human resource related assistance emerged as weak linkages. Also they emphasized that TNCs could be important source of technological innovations as well as enhanced economic performance in Chennai automobile cluster. However, they have not given an emphasis on *how* this assistance helps firms to gain innovative resources and leverage it to build innovation capabilities. It is also imperative to see that how firms within the cluster gain ability to handle multiple R&D projects and innovation projects. Moreover, how effectively they transform R&D output into the production and implement excellence practices with the help of assistance and critical linkages.

This current research has attempted to explore the answers of above questions, as shown in figure (6.2) and found that various technological capabilities have strong influence on innovation performance of firms within Pune automobile cluster. The few research studies (Narayanan, 1998; Okada *et al* 2007; Sudhirkumar *et al* 2011 and Kumaraswamy *et al* 2012) has given attention towards evaluating technological capability issues. Naraynan (1998) attempted to analyze the effect of de-regulation policy on technology acquisition and competitiveness in the Indian automobile industry. The comparison of technology variables results with this current research results are shown in Table 6.1.

In pre-deregulation period, the interaction of disembodied technology imports and R&D, and embodied technology imports and R&D were predominant to bring technology paradigm shift, while individual firm R&D efforts were having insignificant. The in-house R&D efforts were inadequate to bring trajectory shifts. Also foreign exchange (FDI) was insignificant indicating more liberal regime would encourage firms to import technologies to accomplish technology impact. In post-deregulation period, the variables capturing technology imports emerged significant and now foreign Exchange (FDI) emerged as significant towards technology paradigm shift. Surprisingly, Skill component has not given significance during these periods.

Table 6.1: Comparison of results from two studies in continuum period for technology variables

	Narayanan (1998) results		This current research results	
	Model Analysis: OLS Panel data (1985-1991) (1992-1996)		Model Analysis: GLS Panel Data (year 2001 – year 2011)	
	Pre-deregulation	Post-deregulation	Auto firms in Pune cluster	Large auto-comp firms in Pune cluster
Variables	*Coefficient*	*Coefficient*	*Coefficient*	*Coefficient*
LRI	- 76.682	+25.563	-	-
MKI	-15.177	+29.061	+ 11.237	+1.1596
MCI	+10.842	+1.6877	+3.7746	+10.774
FER	-1.0015	+1.129	+ 2.005	-0.2273
MKR	+2562.8	-36945	+33.9301	+9.9410
LRR	+8703.7	-37380	-	-
SKILL	-	-	+9.006	+4.0179
SIZE	-0.3358	-0.3030	+14.7930	+5.7031

Source: These coefficient values are taken from Narayanan (1998) paper and current research analysis

In this research, the inter-firm differences based on technological capability analysis shows that technological variables like technology acquisition, specialized skills, size of company, the interaction between imported technology and in-house R&D effort are emerged very important in the determination of innovation and performance of firm within the Pune automobile cluster. The technology acquisition through licensing and collaboration has been observed as continued strategy to enhance R&D efforts.

In the auto-component industry, import of designs and components has significant impact on technology capability enhancement. Due to proximity to assembly plants and supplier development became part of strategy, auto-components firms are gaining active inputs to develop their new products and enhanced R&D operations. This has reduced disembodied technology import within the cluster and hence this factor considered to be insignificant and not considered in this research. In this global integration phase of industry, talent management gained important space and firms are focusing on global talent reach as well as investing more in learning and development practices and in-house R&D efforts.

The Size of company emerged as very significant factor as increasingly firms are investing into in-house R&D efforts, handling multiple projects, nurturing innovations and enhancing linkages to leverage advanced technological path. Also, the advertising factor has emerged significant in auto firms and this might be due to intense completion due to presence of domestic and global OEMs products in the market. So, the customer centricity has been gaining importance within the cluster. Hence, asymmetry in the firms within the cluster in enhancing technological capabilities explain much of the firm level differences in competitiveness and has put emphasis on building innovation capabilities to integrate in the global value chain.

In the interview with executives we have identified innovation excellence practices among Tier firms within the cluster to critically analyse the industry technological development path adoption and future challenges. Experts claimed that new problem solving methods have been adapted within cluster due to technology acquisition, strategic technology alliances and support from global OEMs rather than consultancy firm or universities. Hence both external sources of innovation and individual in-house R&D efforts has dominant influence on building technological capabilities of firm within a cluster.

The Pune auto component industry has the potential to achieve global leadership by building innovation capabilities and leveraging these capabilities through operational excellence practices. The innovations in advanced materials, electric and electronic technologies, business models, advanced manufacturing processes, new products, and safety and emission norms have transformed auto industry value creation process. This research observed emergence of innovative large, medium and small firms participating in the supplier network of the automobile cluster, most of them providing various types of industrial services. The innovativeness of these firms depends on how effectively they leverage innovation and excellence practices through cluster benefits and lead firm support.

Apart from Tata Group‟s TACO, we observed that the 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 etc. played significant role in the region by successfully integrating into industry value chain with standardized component supply.

The competitive advantage has been acquired by these firms from cluster based development having systemic effect and linkages, not horizontal and vertical linkages. Increasingly long term competitive advantage for organization is coming from stable ecosystems. The process of creating stable ecosystems within the cluster needs to build needed capabilities and strategic thinking across the firms. Also this process of creating ecosystem is challenging which requires perseverance, different skill sets and needs inter-firm collaboration, sometimes across the sectors. It adds significant value to all stakeholders and develops high performance senior management team to nurture creativity and innovations.

The research contribution indicates that strategic thinking should become a part of organizational DNA since strategy and execution are increasingly becoming inseparable. While the ecosystem perspective focuses on creating and sustaining innovation. Sustaining innovation in the entire

ecosystem requires an environment where players remain exited, passionate and inspired with interdependence. However, innovation ecosystem varies from case to case. For instance, product development ecosystem of firm would be quite different from other firm within the same cluster. It can be observed in development of Tata SUV and Mahindra SUV or Tata Nano. The firms within the cluster should build ecosystem, as shown in figure 6.4. The proposed framework for dominant or lead firm within the cluster, for instance Tata Group, explains the linking of business strategy of firm with technology/innovation strategy. Normally, top management receives consolidated final figure on business progress and our research explored that the requirement of deep involvement of CXO‟s through strategic platform to achieve global competitiveness.

The cluster benefits can be leveraged effectively by developing innovation ecosystem and linkages. The framework suggests that corporate strategy of firm should reflect to create value to all stakeholders by focusing on specific area of excellence and markets with geographic experience. The most importantly, exclusive cross-firm collaboration platform need to develop for product development ecosystem, which is still in its infancy at Pune automobile cluster. The government also needs to play an anchor role in creating long term vision for industry by supporting R&D and by extending various fiscal incentives. The linkage between academia has to be considerably strengthened and backed through high quality testing and validation infrastructure.

Finally, firms have to build innovation culture and nurture excellence practices with focused domain knowledge as well as expertise. The linkages between supplier and firms in complementary business are important to develop stable ecosystem and achieve competitive advantage. Thus this strategic thinking develops needed foundation to leverage capabilities and enhance firm performance within Pune automobile cluster.

6.2 Contribution to Policy and Practice

Based on our research outcome, we would like to present contribution towards policy and practice.

Managerial Contributions

The firms can nurture/improve/enhance following innovation and excellence practices to auto-component firms within Pune automobile cluster:

- The ability of in-house R&D/related efforts towards products and processes by enforcing development ecosystems. The effective R&D strategy can be nurtured to align R&D goals, budget, programs, resources and roadmaps with business strategy.
- Conscious efforts towards specialized skills allocation to R&D efforts and design and development activities. Enhance efforts towards global talent reach.
- Advanced manufacturing practices with a focus on developing complex/discrete components and enhance incremental innovations in the process.
- Develop organizational routines to nurture innovation culture and strengthen innovation process with high-level integration and control on major functions.
- Nurture skills sets like taking ownership, timely decision making, dare to try (tolerance for failure) and leadership skills among emerging and senior leaders in the organization.

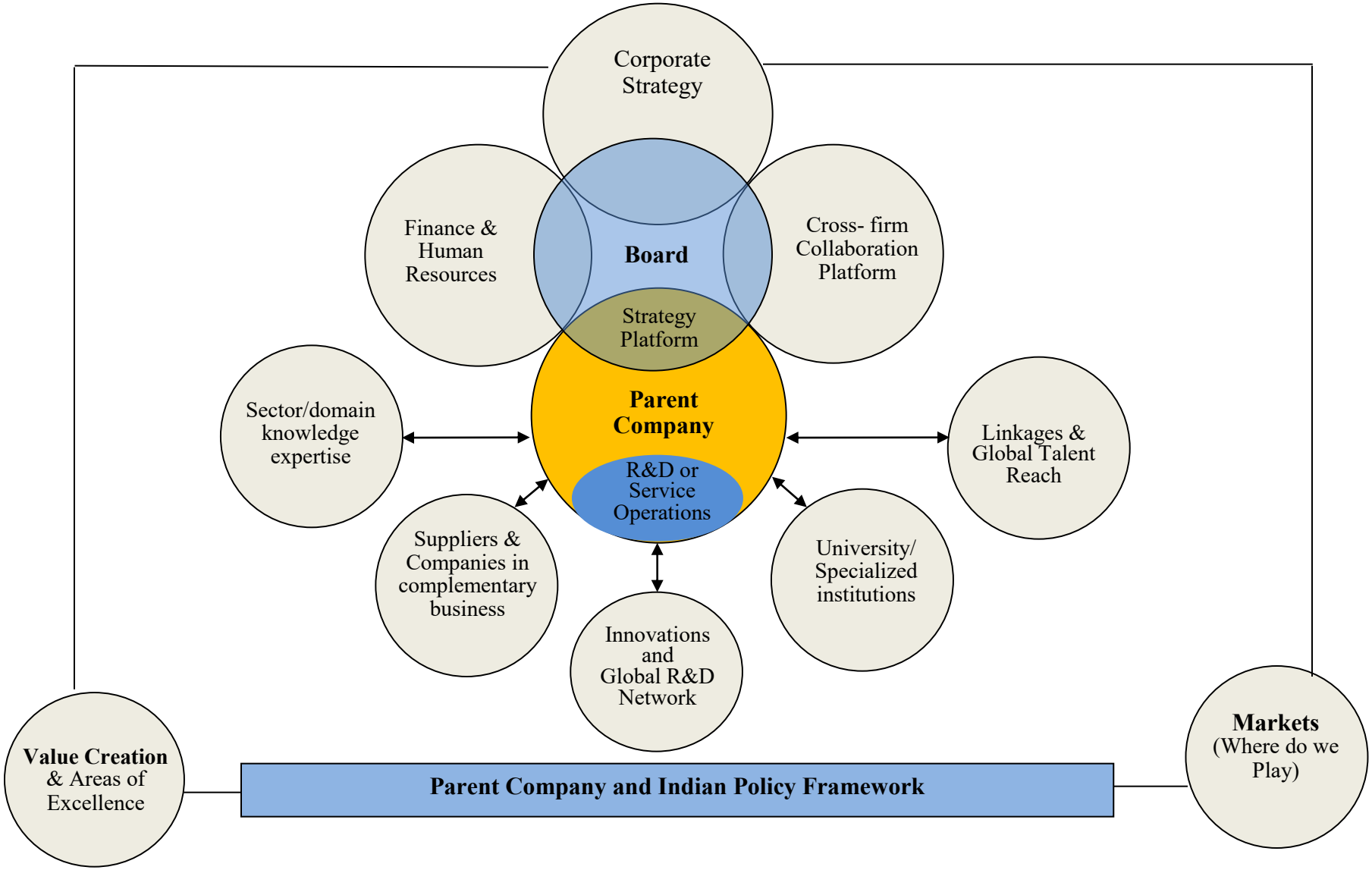

Figure 6.4: Proposed framework to create innovation ecosystem through strategic thinking by dominant/anchor firm

- Develop highly adaptive and responsive platform towards external environment and efforts towards utilizing external sources of innovations.
- Linking technology and innovation strategy with business/corporate strategy
- Industry leaders need to develop strategic thinking to create innovation ecosystem based on these insights to enhance performance of firm and become global players

Policy Contributions:

The Indian National Innovation Council (NInC) has been undertaking measures to strengthen and sustain industry clusters by proposed Cluster Innovation Centres (CICs). This nodal body of government can drive followings:

- Enhance inter-firm linkages/collaborative relationships, and innovate mechanism and systems to increase absorptive capacity of firms within cluster.
- Develops a platform for effective strategic technology management, institutional learning, knowledge management and cross fertilization of ideas and information.
- Establish stable ecosystems for product development, process improvement, productivity enhancement, innovation and standardization, and organizational and cultural issues.
- Generally, the way innovation output get measured, it was evident from our research that it may not applicable to Tier II and Tier III firms. Thus value creation model for such firms should revolve around nature of innovation, visibility of innovation and impact of innovation. This drive from CIC will enhance the moral of SMEs and will help to design better business models based on local conditions.

7. Conclusions

This paper has successfully analysed the effect of Indian automobile industry policy regime and proved that fine tuning of policies has helped Pune automobile cluster firms to integrate in the global value chain and enhance their performance. The auto-component firms within the cluster are increasingly advancing on manufacturing excellence methods and practices. This is evident from increased export intensity has gone-up from US$ 5.2 billion in 2010-11 to US $ 6.9 billion in 2011-12 with major thrust on quality and reliability of components. Also industry witnessed that technology development cycle and product development cycle are shrinking faster and firms are maintaining flexibility and lead times.

The findings suggested that the competitiveness in the cluster and policy regime depends on the ability of the firm to bring out technological capability level shifts. Technology variables are emerged very important in the determination of inter-firm differences and depend on technological acquisition and product differentiation characteristics. The policy regime impacted deeply and firms gained innovation capabilities over the period of time to achieve competitive advantage. Also, firms are nurturing innovation and excellence practices within the cluster to develop critical capabilities (competencies) and core competency to achieve leadership position in this global competitive environment. In this knowledge economy, cluster development and growth looked at from systemic point of view. Thus, firms within the cluster need to focus on developing competencies and ecosystems to leverage innovation capabilities and enhance firm performance.

Our study has limitations as bigger sample size may provide much better accuracy, though we got good model fit. The future research can be focused on exploring innovation

capabilities and understand excellence practice domains to enhance innovation firm performance. The comparative cross cluster and cross sector study would result much better insights and inputs to policy makers.

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