

DYNAMICS OF NEW TECHNOLOGY DIFFUSION

A STUDY OF THE INDIAN AUTOMOTIVE INDUSTRY

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Thesis Summary

Recent developments in economics of technology have ventured from the simple recognition of the importance of innovation and its diffusion to the exploration of mechanisms governing the processes. Because the mechanisms are almost always based on the micro units, a micro-based research of the mechanism is imperative to reach a satisfactory explanation of the underlying dynamics. Rooted in this tradition, this dissertation looks at the diffusion of innovations at the firm level and attempts to address some key issues in the process of diffusion. The central objective is to provide an in-depth analysis of the pattern and process of diffusion of new technologies such as Advanced Manufacturing Techniques (AMTs), India being chosen as the specific case for empirical illustration. The framework of the dissertation is an eclectic one heavily drawing upon the interface literature of innovation theory from systemic perspective, and network theories and economic geography literature. Diffusion is understood to have a very complex core which requires a multi-dimensional approach for a fair and indepth understanding of the underlying mechanism of the process. Due to the interplay of various socio-economic, cultural as well as spatial dynamics at play, it is both conceptually and operationally very difficult to model the process and pattern of diffusion, specifically, the ways firms interact and adopt new technologies under different institutional setups. This dissertation is a modest attempt to explain the intricacies and core of the process of diffusion of AMTs in a developing country setting.

The leading aim of the dissertation is to identify a set of key issues related to the process and pattern of diffusion of AMTs and to study the factors affecting the process. This entails analyzing the various determinants of diffusion and understanding their implications for the innovative behaviour of firms. The specific research objectives guiding this study can be outlined as follows:

- a) To assess the scope and the extent of the diffusion of AMTs in Indian automotive industry.
- b) To analyse the dynamics of ‘inter-firm networking’ (buyer-supplier networks) in the Indian automotive industry and to understand their implications for the diffusion of AMTs.
- c) To investigate the factors which affect the diffusion of AMTs and to quantify the magnitude of their impact on the adoption behaviour of firms.
- d) To examine the role of geographical proximity in the process of new technology diffusion.

- e) To study their implications for the innovative behaviour of firms in the Indian automotive industry and draw some lessons for the new technology diffusion/development.

Two interdependent developments both in theory and empirics of innovation economics form the basis of our analytical framework: the 'systems of innovation approach and, knowledge flows through inter-firm networks, as a specific aspect. These relationships provide a framework for interactive learning, which is a major aspect of knowledge creation and diffusion connected with new technology development and diffusion. Given this structure, the study is a multi-disciplinary one drawing on economic, sociological and regional economic theories of innovation. Using an eclectic methodology based on the above framework, the study analyzes firm-level adoption processes of Advanced Manufacturing Technologies in Indian automotive industry. Balancing firms' ability to adapt to the new technologies and their linkages with the external environment, the thesis puts forth a dynamic view of diffusion considering a broad set of determinants - structural, organizational, market-centric and spatial - that aptly reflect the multi-dimensional nature of diffusion processes. The empirical analysis is based on firm-level data from both primary and secondary sources. The primary data set was collected through a structured questionnaire survey of the auto component industry in India. The final data set covered about one third of all the organised sector firms in the industry.

The thesis comprises of ten chapters segregated into three complementary parts. In the first part (Chapter 1 through Chapter 3) we present the research outline of the thesis, critically examine the various theoretical strands of the literature and put forth the methodological roadmap of the study. In Chapter 1 we introduce the context that motivated the research and outline the main research problems. The second chapter reviews the extant literature and summarizes them by pointing out the many neglected aspects which needs further attention for a comprehensive study. In pursuance with the objective, the next chapter discusses the conceptual foundations of the study and develop the analytical framework. The second part (Chapters 4 through 6) presents a macro-milieu of the industry setting (or broad environment) based on which the micro-level adoption phenomenon was to be examined (in the ensuing part of the dissertation). Part three consists of three chapters that forms the core of the thesis providing the empirical backbone of this dissertation. Specifically, Chapter 7 provides a descriptive analysis of the adoption of AMTs based on an in-depth survey of firms in the Indian auto component industry. Chapter 8 studied the determining factors of adoption of AMTs which is carried further in Chapter 9 where we investigate the impact of geographical proximity on the adoption behaviour of the firms in the Indian auto components industry.

The adoption of new technology by firms is understood to be rooted in the broader economic and institutional setup in which firms are based. Therefore, it was imperative to examine first the breadth and elasticity of the economic scenario of the automotive industry in India. By breadth we mean the different organizational and market features concerning the market conditions (both domestic market conditions and export-import trends), technology and product specialization, investment and economic growth prospects. Elasticity hints at the industry and economy's strength to stand up to the domestic and global market and industry pressures. It depends on the industry's state of the current

technological know-how and also the flexibility of the institutional mechanism to undertake technological challenges associated with AMT adoption. This broadly paints a picture of the inside-story of the industry concerning the cohesiveness and relational structure among firms. Next, drawing on these endogenous and extraneous features of the industry, robust set of determinants of adoption were identified. Further analysis was conducted to examine the spatial dimensions of the technology adoption pattern among firms. Following this rather logical sequence of our thematic divisions in the dissertation, the main findings and conclusions can be summarized under the following headings which correspond to the sequence.

I. Breadth and Elasticity of the Economic Opportunities

After years of restrictive trade and industry practices the Indian economy was liberalized starting in 1980's and early 1990's with the objective to bringing life and vibrancy into her already persistently sluggish economic conditions. As expected it gave rise to spectacular economic growth performance, very clearly visible in sectors like automotive industry. The volume of production has been observed to grow rapidly since then. Exports also picked up over time and most importantly the opened market encouraged world industrial luminaries which set up collaborative and/or independent production facilities in India. Ever since the liberalization took effect, macroeconomic fundamentals have caused little worries thus hinting at the prospects for a sustainable growth of this economy and giving a signal to the foreign firms and investors that the remarkable growth of the economy since 1990s was built upon the strength of economy's internal resources and ability to stand up to external challenges.

An immediate effect of structural change is prominent in the automotive and auto components industry. The growth of the auto components industry is visible not only in the domestic market but a significant export orientation has also been observed (about 19 percent in the past six years). The competitiveness of the industry can be gauged from the fact that about 60 percent of the total components exports are directed to the top developed countries, while of course these countries account for about 90 percent of the imports of component parts. Thus, the overall performance of the economy is found to be steady and the automotive industry is marching ahead though with both advantages of being integrated into the global market and at the same time with the challenges for fast up-gradation of their technologies to cater to the domestic and global demand of their products. The milieu seemed to be right, but it needed to be seen to what extent the auto component firms are able to take on the challenges with a greater innovativeness. In this context, a more detailed analysis of the organizational structure of the automotive industry, the nature of the firms, their cohesiveness and relational structure needed to be understood.

II. Cohesiveness, Regional, and Relational Structure of the Industry

The geographic spread of the automotive industry shows that there is clear regionalization of this industry comprising of different clusters scattered over mainly in three regions of the industry, viz., North, South and West. It is apparent (from the analysis in Chapter 5) that large firms comprise the largest share among all firms in all the regions while the distribution of them shows that Southern regions consist of greater share of large firms and Western region have more small firms. From the entry-profile of firms, it is also evident that

Northern region experienced more of new entries of firms in the last two decades while during the same time Southern region persisted more with experienced firms with relatively less entrants after 1980s. However, the competitive strength seems to lie more with Southern firms, as they operate on larger scale and that they specialize in the upper-end of the product segments indicating firms in the South have an edge over others with respect to improved technology usage while North has more potential adopters due to high entry of new firms in that region. Western firms lie in between the above two cases. From the analysis in Chapter 5 thus it can be said that regionalization is a distinct feature of the Indian automotive industry and that the advantages of a firm being placed or choosing to base operation in a region is varied. Particularly, while experience, specialization, and expansiveness is a trait with Southern firms, Northern region contains more of potential adopters and that the steady rise of new entrants in this region has to do with locational or spatial synergies. Clear distinction arise for the adoption probability of new technologies; since large firms are shown to be the majority of adopting firms of AMTs, South region is at an advantage.

Given this spatial structure of Indian auto component firms, in Chapter 6 we investigated if the same can be observed when the industry is studied from the perspective of firms' relational attributes. We found that the automotive industry's dynamics is mostly led by the presence of some leader firms (both automotive and auto components). However, regionalization of the relational attributes was not found suggesting that features of spatial distance (based on geographic measurement) may not always be reflected by their relational characteristics. Moreover, the investigation in the 'relational space' of the firms pointed to other characteristics as well, viz., the dynamics of this industry is mainly guided by 'buyer firms', i.e., automotive firms and hence the demand side of the market. This speciality of the typical Buyers-Suppliers network as depicted by our analysis indicates that the automotive industry dynamics will be governed by the influence of some leader firms and that adoption of a new technology will be motivated critically by buyer-led factors. This is not surprising as for any economy, especially in an emerging economy like India where a greater security of demand (or commitment and certainty from the buyers) makes it possible for the auto component firms to invest in advanced manufacturing technologies.

III. Determining Adoption: A Treat Beyond Convention

Having insights from the automotive industry dynamics and assessing the inner strength of the auto components firms along side their production capabilities, in Chapters 7 and 8 we studied the adoption of AMTs by automotive firms and examined the factors governing their adoption. At the aggregate level (i.e., all India level), the use of AMTs is more common among large firms than in medium and small sized firms. While the same is also true even at the regional levels, we found that, more (large) firms in the Southern region are using AMTs followed by West and North. Southern firms enjoy more economies of scale (majority being large firms) which provides a favourable condition for new technology adoption. Moreover, highly skilled labour pool with technical and managerial experience also makes 'organizational' and 'operational' side of AMT simple and easily accommodative. This also indicates a high absorptive capacity on the part of the firm to adopt and successfully implement advanced technologies. From our analysis it is found that Southern firms are at a premium in this regard too.

Besides the above internal factors, adoption of AMT's also depends heavily on the market or demand side since a stable demand ensures sustainability of production in the firms. Capacity utilisation of a firm reflects on the demand side opportunities of the firm – higher capacity utilisation indicates that the firm's product is in large demand in the market, and this would induce the firm to innovate more and go for more advanced technologies. Not surprisingly, our results show that firms in the Southern region have higher capacity utilisation than North and West. Moreover, from our analysis we found that the mean number of AMT use is also larger for the Southern firms than for the rest of the regions. Thus, we observe inter-regional variation in adoption behaviour. Particularly, Southern region is found to possess high potential for higher AMT use; a large proportion of firms in the South have adopted AMT's followed by West and North.

Overall, about 69 percent of the firms (all firms irrespective of the establishment sizes) have adopted one or more AMT's. Considering the regional and cluster-wise analysis, Western clusters seem to have more small firms adopting AMT's whereas Northern-cluster dominates in medium and Southern cluster in the large firm category. This conclusion is evidently congruent to the discussion above. Going by the use of mature technologies and incidence of AMT use we found that more 'Mature technologies' are used by nearly 2/3rds of the firms and small firms have the lowest incidence of AMT use.

Our finding largely conformed to the stylized facts about adoption probability of new technologies. For instance, firm size, R&D activity, stock of human capital and the state of the current level of technology – all were found to have influenced the probability of new technology adoption in that a unit increase in these variables would enhance the probability of adoption more than one. Adoption pattern exhibited large differences across technologies, firm sizes but small differences across regions. As expected, large firms displayed greater propensity to adoption vindicating that a greater potential availability and accessibility of resources can prove vital to the adoption of advanced process technologies. Moreover, both with respect to uncertainty in the market demand and possible production frailties and the associated heavy cost to be incurred for adoption, large firms are always at an advantage. Other structural characteristics such as a quality human capital base, technological outreach (or R&D activities), and current technological level (or past accumulation of technological capacity) also proved to bear positive and significant effect on adoption probabilities.

This conclusion conforms to the large empirical literature already established in the developed country industry setting. The similarity of the results for Indian case reflects that irrespective of the 'degree of development', the likelihood of a firm's decision to adopt a new technology will be conventionally dependent on its own characteristics (which are described as 'supply side or productivity-related' side of technology adoption). Interesting results emerge as we enlarge our model by inducting market dynamics and socio-economic variables. Indeed, greater breadth of market was found to be stimulant for adoption and when other socio-economic indicators are used we also found the consistent effect of buyers' demand on adoption decision. This finding, as a result of extension of traditional model of diffusion and determinants of adoption has significance for developing countries like India as growing market as well as buyers' demand is natural consequences of any emerging economy.

IV. Spatial Influence and Adoption Pattern

Since interactions with buyers were instrumental for facilitating adoption, proximity (both in physical and relational sense) to them was imperative for higher adoption of technologies. In Chapter 9 we studied the possible influence of proximity factor on adoption probability and found that geographical proximity does matter for adoption of new technologies. Two types of 'space' - in 'relational' and 'physical' sense - were considered. In both cases, demand side (specifically buyers) were noticed to be more important than supply side factors (i.e., availability of technologies in the form of presence of local machinery suppliers etc.) facilitating adoption. This echoed our findings from Chapter 8 and 6 that buyers' pressure plays a pivotal role in the adoption decision of Indian auto component firms. We ascertained that locational proximity to customers and sustained relational proximity with them were imperative for adoption. This chapter thus brought out the relevance of social, cognitive and communicational aspects on the likelihood of adoption.

To summarize, we found the contributory role of the conventional firm-specific factors, broader market base (which potentially reduces uncertainty in new technology adoption), the facilitative role of buyers' demand, external learning platforms, and importantly the influence of socio-economic, cognitive and communicational factors for adoption of new technology. A deep insight into the results point to the fact that decision to adopt a new technology is indeed multi-dimensional in nature, affected to a great extent by firms' own ability to stand up to market demand, their absorptive capability, and also factors in the broad environment such as quality of infrastructure, market base, knowledge gain from active participation in external forums, and the like. This actually demonstrates the systemic nature of the diffusion process.

The thesis therefore envisions that, with the intensifying competition in the global automotive industry, those firms which tend to build strong fundamentals and also endogenize the synergies from their external environment would most likely lead the race of higher innovation and faster diffusion. This calls for more industry and policy effort in order to strengthen the R&D and technological base of the industry as well as to fortify the human capital and physical infrastructure in the country. Furthermore, it is imperative for the government, especially in a developing country to look beyond the firm-specific factors to encourage adoption of new technologies. Government policies should aim at creating a broad market base so that firms do not succumb to uncertain demand and limited market opportunities. Moreover, appropriation concerns should not be the only thrust for policy makers. The new vision of knowledge production and use (as being a multi-faceted, cumulative and collective process) implies that a policy oriented towards solving only appropriation problems at the detriment of co-ordination problems would be misleading. In stead of focussing only on appropriation issues (such as incentives to invest in R&D etc.) the policies should be geared to ensure co-ordination between knowledge producers and knowledge users and to facilitate the circulation of knowledge in order to further innovation. At a time when the world manufacturing is gearing towards greater integratedness and/or interdependence frequently redefining its technological contours, the research agenda and findings of the thesis would help illuminating some of the underlying complexities and dynamics involved in the process of technological change.