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Market Concentration, Firm Size and Innovative Activity

A Firm-level Economic Analysis of Selected Indian Industries under Economic Liberalization

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Abstract

The economic liberalization in India was expected to boost the economy, particularly the industrial sector through faster technological development. The Schumpeterian hypothesis, which studies the relationship between market structure variables such as firm size and market concentration and their relationship with innovative activity, has been exhaustively tested in the context of the developed countries and India. An attempt is made in the paper to study this relationship with reference to India's economic liberalization. Hoping to overcome some of the problems of the earlier studies conducted in India, the paper tries to develop a new analytical framework for studying this relationship. Innovative activity is conceptualized here as a combination of in-house R&D and the import of technology after India's liberalization. Using probit and tobit models, the study analyses the firm-specific, product-specific and industry-specific factors which affect the investment decision to undertake innovation and the intensity of

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Keywords: market structure, firm size, technological change

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the innovative activity. The examination is carried out for two industries from the manufacturing sector, viz. drugs and pharmaceuticals and electronics. The probit and tobit estimates indicate that the factors affecting the decision to invest in innovative activity and its intensity differ for the manufacturing industries under review, highlighting the presence of technological opportunities across industries. The analysis also shows that there is no evidence to support the assumption that large-sized firms with market power are more innovative. There are also inter-industry differences in the factors affecting innovative activity, which confirms the role of technological opportunity after economic liberalization in India.

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1 Introduction

Since the 1940s economists have come to recognize the role of innovative activity in the productivity growth of firms, particularly in competitive market economies. The competitive environment in such economies acts as a major inducement for firms to constantly upgrade their technology through research and development (R&D). Even in less developed countries, innovative activity is increasingly becoming an important factor of growth and survival of firms. The role of technology has assumed added significance in the context of globalization wherein the survival of firms depends mainly on international competitiveness.

However, technological change in the developing countries, as compared to developed economies, has not received adequate attention. Technological activity in the developing countries consists mainly of the import of technology—technology that is generated by the industrialized nations and its adaptation to local conditions. Prior to liberalization, the technology policy in India focussed mainly on the development of in-house R&D. Therefore, the decision by firms to purchase technology was not easy. There were a number of restrictions on industrial licensing, on the import of technology and technology-embodying inputs and on foreign direct investment. While there were additional taxes on technological imports, a number of incentives were provided to firms with recognized R&D units. Since economic liberalization, there has been a shift in focus wherein the import of technology, both embodied and dis-embodied, became an easy option. It was hoped that the ongoing wave of globalization would enhance the flow of technology into India and help to build much-needed technological capability. However, as Kumar and Siddharthan argue:

> While it is true that developing countries can benefit from the global pool of technologies and knowledge by several channels of transfer and diffusion and not reinvent themselves, literature has emphasized the need for some capability of their own even to be able effectively to employ technologies available abroad in the process of their development (1997: 2).

1.2 Problem of the study

Having identified technological change as a major source of growth in the developed country context, the process of technological change has been subjected to intense study. There are studies that try to examine the nature of the process by which economic resources are transformed into technological advancement. Related issues of whether such a process exhibits increasing, decreasing or constant returns to scale and the involvement of significant spillover effects are also addressed.

Determining the most conducive market environment for innovative activity also has become the subject of interest ever since the pioneering work of Schumpeter (1942). Schumpeter hypothesizes that firm size and market concentration induce innovative activity. Since then, the hypothesis has been tested exhaustively in the developed country context.[1] Kamien and Schwartz (1982) summarize some important

[1] A detailed discussion on the Schumpeterian hypothesis and a review of the empirical literature on the test of Schumpeterian hypothesis in the developed country context are given in section two.

issues of concern on market structure and technological change for developed country economists, as follows:

> What is the nature of the market for technical advances? Will the competitive marketplace allocate resources so that the mix and timing of the technological advances will be efficient? Is there a market structure most conducive for technical advance? If so, is it sustainable? What is the effect of technological advance on market structure? (1982: 12).

In the Indian context, studies relating to market structure and innovative activity attained importance only in the 1970s. Since then, there have been numerous attempts to empirically verify the Schumpeterian hypothesis in India. Most of these studies, however, pertain to the import-substituting policy environment. Moreover, these studies generally conceptualize innovative activity only in terms of in-house R&D. Given the liberal policy environment, it is important that innovative activity is understood in terms of both technology imports and in-house R&D. In addition to conceptual issues, there are a number of methodological issues that need to be taken care of.[2] In this context, there arises a number of issues in terms of the relationship between firm size, market structure and innovative activity. How do dynamic policy changes in the economy during liberalization affect the market structure/innovative activity relationship? How have the firm-specific, industry-specific and product-specific characteristics of firms influenced innovative activity? What factors in a liberal environment affect the decision to engage in innovative activity or determine its intensity? Another important issue for analysis is the need to examine whether in the post-liberalization period there are significant inter-industry differences in the relationship between market structure and innovative activity.

Based on the above issues, the current study tries to look at the relationship between firm size, market concentration and innovative activity for two industries of the manufacturing sector: drugs and pharmaceuticals, and electronics. These two industries are chosen because of their high technology-intensive nature.[3]

The specific objectives of the current study are to analyse:

i) The firm-level relationship between market concentration, firm size and the decision to do innovative activity, and

ii) The factors influencing the intensity of innovative activity at the firm level.

The study is organized in four sections, including introduction. A review of the relevant empirical literature on the relationship between market structure and innovative activity is given in section two. The review is carried out against the backdrop of the Schumpeterian hypothesis and highlights the relevance of the current study in present day context, thereby setting the background for the analytical frame of the study. The third section empirically tests the relationship between the variables for size and market structure with the decision to innovate and the intensity of innovative activity for India's

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2 See section three for a discussion of the methodological issues.

3 The specific reasons for choosing these two industries are provided in section three.

drug and pharmaceutical, and electronics industries. Section four summarizes the major findings and presents the concluding observations.

2 Review of literature and analytical framework

Notwithstanding the general consensus on the positive role played by technology in fostering economic efficiency and growth, economists differ in terms of the type of economic structure that promotes innovation and technological progress. To begin with, we have Schumpeter (1942) who believes that the introduction of new methods of production and new commodities is not conceivable with perfect competition. Conceptualizing innovation as the process encompassing new products, new processes, new markets, new organization and new raw materials, Schumpeter underlines the key role of monopoly power in bringing about innovation. However, neoclassical scholars have held a diametrically opposite view: to them, a competitive market structure is likely to be superior in terms of promoting innovation. Arrow (1962) has theoretically articulated this argument, showing that under certain conditions, there is greater incentive for R&D when industries are competitive than when monopolized. Arrow concludes that the incentive to invent is smaller under monopolistic than under competitive conditions, but even in the latter case it will be less than is socially desirable. But Dasgupta and Stiglitz (1980) criticize Arrow on the grounds that he takes market structure as given or exogenous and that he fails to take into account the possibilities innovation opens for firms in an industry. Dasgupta and Stiglitz develop a microeconomic model in which market structures are endogenous and the frontier of technological possibilities specifically influences strategies involved in market competition. They find that high research intensity and high level of concentration go hand in hand. Industrial concentration and research intensity are simultaneously defined in their model and therefore market structure, to a large extent, is determined by the conditions for technological progress. Against this backdrop of diverging theoretical arguments, there are essentially two strands of empirical literature: those exploring the relation between market concentration and innovative behaviour; and studies on the relation between firm size and innovative behaviour.

In this section, a modest attempt is made to critically review the available empirical evidence on these issues. The underlying objective is to develop an analytical framework for the present study.

2.1 Market concentration and innovation

According to Schumpeter, a monopolistic market structure induces greater innovation than a competitive market structure. Technical advancement affects market structure in two ways. The first is through influencing the optimal scale of production in an industry. If the minimum efficient plant size (for example, the level of output at which average cost is minimized) increases as a result of technical development, then there is a tendency for the industry to become more concentrated. Second, market structure is affected by the erection of entry barriers. The first firm to introduce a successful major innovation may gain a significant advantage over its rivals. The advantage may be derived from patents that cannot be easily circumvented, the development of expertise that cannot be easily duplicated, the realization of extraordinary profits that are available for additional R&D, the development of a favourable reputation and a loyal consumer base.

Kamien and Schwartz (1982) further articulate the manifold ways in which market concentration and innovative behaviour interact. The first is between innovation and the anticipation of monopoly power and its concomitant profits. The second source of interaction is between innovation and the possession of monopoly power. A firm that has a monopoly over its present products can simply extend it to new output, thanks to its control of the channels of distribution, or through its reputation. The possession of monopoly power and the associated profits may also enable the firm to respond more quickly to rival innovations than it would otherwise. Another source of interaction between the possession of monopoly power and innovation is alleged to be through the necessity to finance innovation internally. A firm realising extraordinary profits is presumably in a better position to undertake internal financing than a firm deriving its profits from normal operations. Another advantage of the possession of monopoly power is that firms can hire the most innovative people.

But Schumpeter cautions that sometimes monopoly power can act as a major disincentive to innovation. It is possible that a firm enjoying monopoly profits has less incentive or 'hunger' to seek additional profits through innovation than a normally operating firm or a new entrant. Thus, the question that remains to be answered is: Monopoly power is advantageous to innovation, but how much is considered optimal? Moreover, as Usher (1964) and Arrow (1962) point out, these firms are already reaping monopoly profits and would prefer to capitalize as much as possible from the present product rather than attempt to gain entry into a new market. For a new firm, if it is to enjoy monopoly power, there is only one option.

Other than this, factors like technological and market opportunities are perceived to have considerable influence on the level of technological activity. If firms find that the returns from undertaking research in a specific area are greater than investments in another area, then the innovative incentive would be different in each industry. Similarly, if the market demand calls for changes in the nature of the product manufactured, then firms catering to this market would be forced to respond to these expectations or face the risk of being overtaken by rival improvements.

2.2 Empirical evidence on the relationship between market concentration and innovative activity

Empirical studies on the Schumpeterian hypothesis in the developed countries have mixed results to offer. Initial studies, like those of Scherer (1965) and Hamberg (1964) report a positive but weak link between market concentration and R&D activity. Studies by Williamson (1965), Bozeman and Link (1983), and Mukhopadhyay (1985) report a negative relationship between concentration and R&D activity. Scherer (1967), for the first time, observes a non-linear (inverted U) relationship between R&D intensity and market concentration. Using data from the Census of Population, Scherer notes that R&D employment as a proportion of total employment increases with concentration[4] up to a certain point, after which it decreases. Later studies by Levin *et al.* (1985) and Scott

4 Scherer here uses four-firm concentration ratios as the proxy for market concentration.

(1984), using the Federal Trade Commission data, also report the same non-linear relationship.

Braga and Willmore (1991) find an inverted U-shaped relationship for a sample of 4,342 establishments in Brazil, for example. This implies that the extent of concentration (measured in terms of the Herfindahl index) affects the probability of a firm actively engaging in a specific product development programme up to a certain level, after which market concentration has an adverse effect on the probability of development.

Phillips (1966, 1971) was the first to propose that there could be causality between market concentration and R&D, as 'success breeds success'. Taking the case of the aircraft market in America, he concludes that not only could concentration affect innovation, but that the process could also work in reverse. Later studies by Farber (1981), Connolly and Hirschey (1984), and Levin and Reiss (1991) examine the relationship between market structure and R&D activity, treating both variables as endogenous to avoid the simultaneity problem.

The study by Nelson and Winter (1982) uses simulation models to explain the positive relationship between market concentration and innovative activity. They find that market structure and innovative activity are both determined by such basic factors as demand conditions, technological opportunities, government appropriability and the nature of capital markets.

Geroski (1989, 1990, 1991) and Acs and Audretch (1991) study the relationship between market ratio and innovation, with entry also taken into consideration. They report that in the presence of entry, concentration has a modest negative relationship with R&D intensity. Shrieves (1978) Comanor (1967) and Angelmar (1985) observe that the market structure/innovative activity relationship is affected by other factors such as technological opportunity, product differentiation, and entry barriers.

It was Scherer (1970) who notes that when inter-industry differences (due to technological opportunities) are taken into account, the correlation between R&D and other explanatory variables tends to become weaker and statistically insignificant. Others, including Shrieves (1978), Levin and Reiss (1991), Cohen and Levinthal (1989) and Geroski (1990), also use technology opportunity as a major variable to explain the relationship between market structure and innovation.

Similar studies conducted in the developed country context do not verify a positive correlation between market concentration and innovation, as envisaged by Schumpeter. While some studies find a weak positive link, many others give a negative relationship. The major argument of these studies is that market concentration alone does not induce innovative activity, but is supplemented by other factors. In addition to firm size and market concentration, empirical studies also identify technological opportunity and appropriability as important variables affecting innovative activity.

In India, the correlation between market concentration and innovative activity has been empirically tested mainly in the 1980s. The Indian studies, similarly to those for the developed countries, also give mixed results.[5] Desai (1988) analyses the relationship between market structure and technological change on the basis of statistical correlation as well as on the basis of a series of case studies for different industries. Based on the 1978-79 data from the Centre for Monitoring Indian Economy, he calculates the Herfindahl concentration indices for 42 industries and an 'E' index[6] of inequality. He report s that market structures with a limited number of firms (two to six) are more conducive to the adoption of new technology. Desai believes that the long tailed market structure (large number of firms), which is common in India, is not especially conducive to technological progress, nor are the government-established monopoly firms in high technology industries.

Desai concludes that whilst technology imports on their own tend to create oligopolistic market structures, R&D reinforces the competitive advantage of large firms. But the leakage of technology within the country has led to the emergence of many small firms, and they have appreciably increased their market shares. Due to inadequate firm-level data, the analysis was limited to the industrial sector, and this could have constrained the analysis, as the firm-level characteristics which might have affected innovative activity were missing.

In a comprehensive coverage of industrial R&D in India, Kumar (1987) analyses 1,143 companies in 43 manufacturing industries, based on RBI data from 1976-77 to 1980-81. Using a four-firm concentration ratio, Kumar explores the Schumpeterian hypothesis with regard to the role of market structure. He aggregates the company-level data to obtain the industrial-level data. The author controls for technological opportunity by introducing proxy variables such as capital intensity, skill intensity, dummy variables for engineering, chemical, consumer and consumer convenience goods, as well as advertising intensity. The results show that the market structure variable (the four-firm concentration ratio) attains a modest level of significance (10 per cent) with negative sign. The neo-Schumpeterian expectation of a positive relationship between the seller concentration and R&D intensity is, therefore, contradicted for the Indian industry. This inverse relationship is explained by the presence of entry barriers. The government, through its industrial licensing policy, protected firms from domestic as well as foreign competition. Tariffs, non-tariff barriers and exchange controls shielded the industry from foreign competition. Thus, existing firms faced virtual no actual or potential threat from competition, and the principal motivation for pursuing innovation was to gain monopoly power with its accompanying quasi-rents. Kumar, therefore, argues that in the absence of any potential threat of competition, high concentration is not the motivation for innovation. Capital intensity, a proxy variable for technological opportunity, does show a significance, but negative relationship. This suggests that capital-intensive industries do not offer technological opportunities. Other variables denoting technological opportunity show no significance.[7]

5 For more detailed surveys on market structure/innovative activity relationship in the developed country and Indian context, please refer to Kamien and Schwartz (1982), Kathuria (1989), Cohen (1995), and Kumar and Siddharthan (1997).

6 E-measure of inequality refers to the Gini coefficient.

7 Kumar (1987), Siddharthan (1988) and Kumar and Saqib (1996) have taken care of appropriability and technological opportunity in their studies.

Vijayabhaskar (1991) deviates from earlier studies and tries to explore the association between changes in concentration levels and sector performance in terms of output growth and innovative activity in the 1980s. His logic is that as the liberalization measures relaxed entry barriers, firms facing the threat of possible entry would respond differently. The results show that low-intensity industries do benefit from high concentration levels, as correlation coefficients are positive and significant (for both periods). However, for high-intensity industries, the inverse is true, especially in the post-liberalized period. The author concludes that high concentration or a monopolistic market structure is hardly conducive to innovative activity in industries where they really matter. Research intensity decreases with growing concentration levels, and there is no positive correlation between concentration and innovativeness, as envisaged by the proponents of liberalization. However, as the period of analysis was from 1980 to 1990 and economic liberalization in India took place only after the 1990s, it was not possible for the study to obtain a clear picture of the relationship between market concentration and R&D activity. The author also does not consider any form of technology import as a measure of innovative activity. Data limitations confined the examination to an industry-level analysis.

Prasad (1999) reports a negative relationship between in-house R&D and market concentration, proxied by the market shares of firms in the chemicals sector and industrial machinery sector, thus contradicting the Schumpeterian hypothesis. This firm-level study, conducted in the late 1990s, does not consider the import of technology as a significant measure of innovative activity, even though companies in the chemicals and industrial machinery sectors have been technology import-intensive after liberalization in India.

Kumar and Saqib (1996) find that both market concentration variables, proxied by four-firm concentration ratio and profit margin, are negative but insignificant. This is true for both the probit and tobit models used to analyse the probability and intensity of doing in-house R&D.

2.3 Firm size and innovative activity

Although identified by Schumpeter, the firm size/innovative activity hypothesis was fully developed by Galbraith (1952). According to the hypothesis, large firms are proportionately more innovative than small firms. In other words, in a mature capitalist economy, large firms generate a proportionately larger share of society's technological development.

Larger firms achieve certain advantages from greater innovative activity. One claim is that capital market imperfections confer certain advantages to large firms in securing finance for risky R&D projects, because size is associated with the availability and stability of internally generated funds. Second, the scale of economies is associated with industrial R&D. In addition, returns from R&D are higher in enterprises where the innovator has a large volume of sales, over which to spread the fixed costs of innovation. Finally, R&D is said to be productive in big companies because the complementarities between research and development and other manufacturing activities are better developed in these firms. Researchers are more productive when they have numerous colleagues with whom to interact. A large group also permits the division of labour. A large firm also has an advantage over its smaller counterparts in research and development due to its superior ability to exploit the output of its research efforts. Based on these arguments, it is hypothesized that large firms generate more innovation.

2.4 Empirical evidence on the relationship between firm size and innovative activity

The hypothesis relating to firm size and innovative activity has been empirically tested in the context of both the developed and developing countries, India included. The size of firm has been alternately measured on the basis of employees, capital assets and sales volume, and R&D intensity on the basis of related R&D expenditure, scientific personnel engaged in R&D, patents received and sales associated with new products. But there is no consensus on what exactly is the relationship between firm size and innovative activity. In the developed country context, firm size has been measured as the sales volume, the assets or the number of employees. Some studies by Comanor (1967), Horowitz (1962) and Hamberg (1966) report a weak positive link between firm size and innovative activity. All the above studies use a linear regression analysis or correlation to arrive at the respective conclusion. However, with the exception of Comanor (1967), these studies do not control for industry effects,[8] and a later study by Baldwin and Scott (1987) finds that this omission is likely to distort estimates on the effects of firm size on innovative activity.

It was Scherer (1965) who first notes a negative relationship between firm size and innovative activity. With a sample of 448 of the 500 largest firms in 1955, Scherer regresses R&D employment with firm size to check for non-linearities. He finds that for the smaller firms, firm size increases more than proportionately with innovative activity up to certain threshold level. R&D employment intensity tends to decrease among the larger firms.

Grabowski (1968) empirically tests the firm size and R&D intensity relationship in a regression analysis, taking the size and square of size, for the drug and chemical firms. He finds that the research intensity initially increases for the drug companies, but then declines for most of the relevant range of firm sizes. In the case of chemical firms, research intensity increases proportionately with firm size.[9]

Mueller (1967), Kelly (1970), Loeb and Lin (1977) all report that research intensity is not positively correlated to firm size. While Mueller finds a negative relationship, Kelly observes no relationship at all. The study by Loeb and Lin, analysing a 1961-72 time series data relating sales to R&D expenditures for six major pharmaceutical manufacturers, observes a non-linear relationship. Small firms are more research intensive in Shrieves' (1978) and Rosenberg's (1976) analyses.

The 1980s witnessed the use of more comprehensive data to study firm size/R&D relationship. Bound *et al.* (1984), using a sample of American firms, finds that R&D intensity declines slightly with size among the smallest firms and then rises with size among the very largest firms. Cohen *et al.* (1987) utilizing data from the Federal Trade

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8 These studies use crude measures to control for industry effects.

9 Further data examination by Grabowski himself suggests that the observed relationship between firm size and R&D intensity in the two industries is due to other factors affecting R&D intensity.

Commission's (FTC) line of business programme, and with due attention to industry effects, report that firm size is not correlated to R&D intensity.

The studies examining the relationship between firm size and innovation used R&D intensity, an innovative input, as a proxy for innovative activity. Fischer and Temin (1973) argue that the empirical analysis should be done between firm size and R&D output as proxy for innovative activity. They find that the elasticity of R&D with respect to size in excess of one does not necessarily imply an elasticity of innovative output with respect to size more than one.

The studies by Pavitt *et al.* (1987) and Acs and Audretsch (1990, 1991) show a U-shaped relationship between R&D intensity and firm size. These indicate that very small firms and very large firms have proportionately higher R&D intensities and that the relationship pattern varies across industries.

Firm size and R&D relationship analyses in the developed country context are not in tune with the positive relationship envisaged by Schumpeter. The general conclusion of these studies is that research intensity (R&D/size) increases until a certain firm size, but is then followed by a constant or declining period of intensity. Some studies also find a negative relationship between firm size and innovative activity. Thus empirical evidence does not offer a consensus to support the Schumpeterian hypothesis of large firm size leading to greater innovation. The studies also conclude that firm size alone cannot affect R&D intensity, and that other variables such as technological opportunity and appropriability have an influence on R&D intensity.

The first attempt in India to empirically verify the Schumpeterian hypothesis is made by Subrahmanian (1971a). He observes no evidence in the Indian chemical industry to suggest a positive relationship between R&D intensity and firm size, nor between R&D intensity and relative firm size (used to indicate market power). The major problem with this analysis is that factors other than firm size are not considered. In a subsequent study with the same dataset, Subrahmanian (1971b) includes other variables such as profits, retained earnings, depreciation, gross investment and lagged R&D expenditure, and reports that absolute R&D expenditure is positively related to firm size as well as to lagged R&D and depreciation.

In another econometric study of R&D activity covering 100 engineering firms, Lall (1983) observes that R&D intensity is positively influenced by the firms' size, age and technical absorptive capacity (proxied by the percentage of total wages and salaries paid to employees earning more than Rs 3000 per month). Lall attributes this to the fact that the largest firms tend to be more diversified, more technologically complex and could afford more investment in R&D activities. However, Lall does not have a quadratic term to check for non-linearities. Katrak (1985) observes that the elasticity of R&D expenditure with respect to sales is less than unity for cross-section data at the industrial level and his result contradicts Lall's observations.[10]

Siddharthan (1988) argues that the relationship between the size of firm, and its conduct and performance is seldom linear, as tested in earlier works. He uses published data

[10] Kathuria (1989) argues that Katrak does not employ a variable, which would control for technological opportunity and the study is based on industrial data, unlike Lall's. However, Katrak (1989) again reports a negative relationship between firm size and in-house R&D.

from 166 manufacturing firms (both private and public firms) for the year 1983-84, and reports a U-shaped non-linear relationship between R&D intensity and sales turnover taken as a proxy for size. The turning point occurs at the sales level of Rs 600 million. Non-linearity is mainly due to the fact that the nature and type of R&D activity between large and small firms are different and thus not strictly comparable. He reports that the increase in R&D expenditures for the smaller firms is slower than the increase in size, while in the case of very large companies, it is faster than the growth in size. Testing this relationship in industries such as electronics, machinery, textiles and chemicals, Siddharthan observes a non-linear relationship between R&D intensity and firm size in all industries, with the exception of chemicals where he notes a negative relationship. But it should be noted that in this study, only firms which did some in-house R&D were considered. Had non-R&D firms been included, it would have reduced the sample selection bias and the result would have been different. Deolalikar and Evenson (1989) analyse the determinants of inventive activity proxied by the average number of patents (per firm) granted to Indian nationals. They report a negative relationship between innovative activity and firm size.[11]

Katrak (1990) analyses the relationship between firm size and R&D activity for firms in the electrical and electronics sector and in the industrial machinery sector, and observes that an increase in firm size does not lead to a greater than proportionate increase in R&D expenditure. Katrak (1994) is of the opinion that the influence of enterprise size on technological effort depends on the industries concerned and the methodology used. Katrak attempts to determine whether larger enterprises have a proportionately higher output of in-house R&D based products. This is examined with a multiple regression analysis using R&D based products as the dependent variable and the total value of the enterprises' total sales as a proxy for the size of the firm. The multiple regression analysis indicates that the share of R&D based products decreases as the enterprise size increases. The author assumes that this result could be due to the effect of government policies. The industrial licensing policies (the data were for 1987) could have adversely affected large-scale enterprises, which may have discouraged the R&D based production.

Identifying the importance of technology imports as a major component of innovative activity, Siddharthan and Krishna (1994) show that size is a positive and significant variable in determining technology imports for firms belonging to six broad industry groups, except in electrical and electronic goods and automobiles industries. With data compiled from the annual reports of public limited companies, Basant (1996) studies the technological strategies of large-scale enterprises in India by analysing 438 industrial machinery firms and 651 chemical firms for the years 1974-84. The study, using multinomial logit model, reports that large firm size improves the profitability/utility of being technologically active (undertaking one's own R&D, import of technology, or both) relative to the reference state of no action. This is true in both the chemicals as well as the machinery industries, but the choice of conducting R&D only is positively affected by firm size in the chemical industry.[12]

11 A problem with this study could be that the analysis based on patents data need not give reliable results and moreover India had a weak patent regime.

12 However, the author himself agrees that there is heterogeneity among the industry groups, especially in chemicals. The firms are classified on the basis of their principal products and data limitations do

Kumar and Saqib (1996) approach the problem using a probit and tobit model. They observe from the probit model that firm size is positive and the quadratic term of firm size is negative, with both being significant. This implies that the probability of doing R&D increases up to a certain point and then declines. The tobit model shows that firm size increases with R&D intensity in a linear fashion, with the quadratic term being insignificant.

Subrahmanian *et al.* (1996) and Prasad (1999) report evidence of a positive and significant relationship between firm size and in-house R&D for post-liberalization data on the industries in chemicals and electrical machinery. However, both studies consider R&D intensity only and do not include the import of technology as an important measure of innovative activity.

Empirical studies on firm size/innovative activity relationship in the Indian context also show, as in the developed country context, widely diverging results. The results mostly indicate a negative relationship between the two, but there are also studies, which show a positive correlation. Siddharthan (1988) reports a U-shaped relationship between firm size and in-house R&D activity, while Kumar and Saqib (1996) observe an inverted U-shaped relationship between the two.

2.5 Towards an analytical framework

As is evident from the discussion so far, there is a vast body of literature in both the developed countries and in India that empirically explore the Schumpeterian hypothesis. However, there is no consensus with regard to the results of the analysis. The diverging results could probably be explained by measurement problems associated with the concept of innovation and market concentration on the one hand and empirical procedures used in the estimation. Schumpeter conceptualizes innovation as a process involving the introduction of new products, new processes, new markets, new raw materials and new organization. However, the studies, in both the developed and developing countries, consider only R&D expenditure, R&D employment or patents as a proxy for innovation. Such a narrow measure of innovation can hardly represent the innovation concept as used by Schumpeter. All measures of innovation used in empirical studies have problems. According to Kamien and Schwartz (1982), patent statistics, a common measure used to proxy innovation in the developed countries, has the following problems:

i) Patents are used for major as well as minor innovations; giving equal weights for both is inappropriate;

ii) Many patented products and processes are never commercialized; and

iii) Many innovations are never patented.

The input measures of innovation (R&D employment and R&D expenditure) are also widely used in studies in the developed country context. Scientists and research support staff are at the core of the research organization and are directly involved in the conduct

not permit a detailed analysis of their levels of diversification. Given the heterogeneous nature of the sample firms, the empirical exercise undertaken could not be a conclusive one.

of research. In this case, time units spent on research must be identified, which is always difficult. Kuznets (1962) calls for a study of specialized human capabilities to measure the inventive capacity of personnel. Exact time units, mental effort and human ability measures are beyond the scope of economics (Rajeswari 1992). Thus, the measure of the research efforts of personnel fails to be a complete measure of its own. Research expenditure is the most important quantifiable measure of research effort that is used in empirical studies. It is a logical and direct measure, but can still be incomplete. Thus, the diverse and incomplete measurement of innovation could be one of the reasons for the observed variation of results in empirical studies.

The measurement of concentration is yet another problem faced by researchers. It is not possible for a single concentration measure to capture all components of market structure. The most commonly used index in the empirical studies in the developed and Indian context is the K-firm concentration index, defined as the cumulative share of the Kth firm. Its popularity is mainly due to easy availability of data and ease of computation. The choice of K is, of course, arbitrary. Conventionally in developed economies, K takes the value between 3 to 8. The problem with the measure is that it does not disclose any information on firms ranked after K.

A more comprehensive measure of market concentration is the Hirschman-Herfindahl index. It is defined as the sum of the squared shares of 'n' firms; its advantage is that it takes into account the shares of all the firms in the market. At the same time, the squaring up of the values means that smaller firms contribute less than proportionately to the value of the index. This is a valid approach, as the entry of a number of small firms with minuscule market shares would hardly affect the market power of the top firms. But a prerequisite for this index is that information on the market shares of all firms be available, a fact which restricts its use.

A problem common to these two measures is that they are static in nature and do not capture movements in concentration levels, as top firms keep on changing their ranks over the years. This is an obvious defect as the intensity of competition depends largely on the ability of the top firms to maintain their position (Vijayabhaskar 1991). Still, most of the empirical studies have taken a four-firm concentration ratio or the Herfindahl index, as they are easy to compute and serve the purpose with little defects, which usually can be ignored. However, these incomplete measures of concentration could probably have resulted in the diverse results seen in the empirical studies attempting to verify the market concentration/innovative activity relationship.

The problem deepens when it comes to the proxy used in empirical studies for innovation in the Indian context. The studies have mostly taken R&D expenditure as a proxy for innovation. The studies have assumed that innovation in both the developed countries and in India is the same, a fact not true. It has been argued that R&D activity in India was mainly informal and more adaptive in nature. Deolalikar and Evenson conclude that:

> One shortcoming of most studies on inventive activity in India is that they limit themselves to formal inventive activity, often of the type that takes place in established laboratories and results in patents. A large majority of innovative activities among Indian firms takes place on the shop floor. Often such activities play a more important role than formal R&D in the technological development of the firm (1990: 244).

Kumar and Siddharthan (1997) also report that the difficulties in capturing informal innovative activity and the diverse measurements used to denote innovative activity are the reasons why empirical studies on market structure and innovative activity in India give contradicting results.

The studies in the Indian context also overlook the purchase of technology, another important component of innovative effort. Given that the import of technology increased significantly in India during the 1980s, the failure to incorporate this appears to be a serious problem that needs to be corrected. Kumar and Siddharthan (1997: 55) argue that 'R&D expenditures only partially represented expenditures on technology, as expenditures on technology purchases, which could be substantial, especially in the developing countries are not covered, although the two could be related in some cases'.

Particularly after the liberalization of the 1990s, the purchase of technology became a more important component of innovative activity. It can be hypothesized that large firms, apart from doing more in-house R&D, also resort to added purchase of technology than smaller firms because these are expected to have better knowledge of world markets, as well as greater production and marketing experience than smaller firms. Consequently, it is hypothesized that a large firm has more than a proportional increase in technology purchases vis-à-vis smaller firms. It is also argued that foreign companies prefer larger firms in technology licensing agreements (Evenson and Joseph 1997).

Inter-industry specificities or technological opportunities can play a major role in determining the relationship between innovation and firm size, and innovation and market concentration.[13] Very few studies in India recognize inter-industry differences in the Indian context. Understanding the importance of inter-industry differences in the sample, Kumar (1987) introduces industry dummies to control for technological opportunity. The problem is that in addition to technological opportunities, industry dummies also represent other characteristics of the industry. Kumar and Saqib (1996) in analysing the probability and intensity of firms that do R&D, also use industry dummies to counter inter-industry differences. According to these authors, inter-industry differences in the opportunities for product or process innovation play an important role. The opportunities for adaptation vary across industries, depending on many factors, including the maturity of technology, the gap between local and global standards, the degree of monopolistic hold over technology, the nature of intellectual property protection and the need for such adaptation arising from different local conditions. Kumar and Saqib use a total of nine industry dummies to capture inter-industry specificities for a sample of 291 manufacturing firms and find that technological opportunity is very high in the chemicals and pharmaceuticals industry.

The best way to capture the inter-industry differences in the sample is to test the hypothesis in different industries separately. Siddharthan (1988) attempts this in four industries, apart from pooling the whole sample and testing the hypothesis, indicating that inter-industry specificities are an important determinant of research effort and should be included to obtain a reliable relationship between market structure and innovative activity.

[13] It is evident from the empirical studies that verify the Schumpeterian hypothesis in the developed country context that, apart from market concentration and firm size, technological opportunity and appropriability are significant variables, which affect innovative activity.

After a detailed critical survey of studies in India, Kathuria (1989: M120) concludes:

> This strand of the technology literature of India, following in the mould of its developed countries counterpart, suffers from the same limitations as the latter but to an even greater degree, partly because of data limitations. In addition, most of the earlier studies have used industry rather than firm-level data, which tends to wash out the effect of firm-level variables such as size, technical capacity, age and so on.

Goldar (1997) looks at the methodologies adopted in studies on innovative activity in the Indian context. He believes that most of the studies are cross-section analyses with problems of heteroscedasticity. He suggests that the ordinary least squares method used in some of these studies is not a suitable method when variables such as export orientation are related to innovative activity because of the simultaneity problem between these variables. Goldar (1997: 95) observes that:

> It should be noted that in many firms the R&D ratio in the sample is negligible or zero. If such firms are included in the sample to estimate the regression equation, estimation problems will be caused by the fact that the dependent variable has a lower bound. If such firms are excluded, the results get affected due to the sample selection bias. An appropriate solution for tackling this problem is to use a tobit model, as has been done by Kumar and Saqib (1996).

As seen above, the studies in the Indian context tested the Schumpeterian hypothesis in the context of liberalization, using mostly a cross-section of firms or industries. The economic liberalization in India was characterized by rapid policy changes over the years. Thus, the cross-section studies undertaken in this context may not be sufficient to capture the actual market structure/innovative activity relationship. A longer period of analysis could have given better insights on the relationship between market structure and innovative activity.

A number of issues arise, which warrant the need for a detailed study of the relationship between market structure and innovative activity in the context of economic liberalization. Studies based on firm-level data should include technology purchase as a major source of innovative effort apart from in-house R&D, especially after liberalization in India. The market structure/innovative activity relationship should be examined so that, apart from size and market concentration, technological opportunity and appropriability conditions are also considered. The study also should cover a longer period of analysis to account for dynamic policy changes resulting from liberalization. Moreover, there is scope for substantial methodological improvements by using the probit and tobit estimates instead of OLS.

3 Empirical estimation

The previous section highlighted the conceptual and methodological problems associated with the literature on market concentration, firm size and innovative activity. The need to redefine the concept of innovation to capture the actual process taking place in such developing countries as India has to be underlined. While the import of technology has generally been considered an important aspect of the innovation process in most developing countries, India included, the existing literature seems to have underplayed its role. There is need to attach due importance to the technological opportunities of industries as well as the appropriability conditions. A longer period of analysis, based on firm-level data may be more appropriate, especially when the period of analysis is marked by flux in the policy environment. In addition to conceptual refinement and changes, there is scope for improvement in the method of estimation as well.

Against this background, the present section attempts to test the Schumpeterian hypothesis in the context of the Indian economic liberalization for two industries: drugs and pharmaceuticals, and electronics. The selection of these two industries is justified because these are considered technology-intensive not only in terms of in-house R&D but also in terms of the import of technology. While the drug and pharmaceutical industry has attained prominence after liberalization by contributing most of the patents registered in India (Prasad and Bhat 1993), numerous other studies[14] identify the electronics industry as technology-intensive. The study by Prasad (1999) reports that based on empirical analysis, after liberalization these two industries have become the most technology-intensive in terms of in-house R&D and the import of technology, respectively.

3.1 Issues, methods and hypotheses

As stated earlier, the innovative behaviour of Indian firms in the present study is measured in terms of their total expenditure on the import of technology and in-house R&D. A large number of firms do not invest in innovation, and the first issue that arises is determining the probability of the firm engaging in innovative activities and the factors that influence its innovation decision. Following Kumar and Saqib (1996), this issue is approached using a probit model. Having analysed the innovation investment decision, the second question concerns the intensity of innovative activity. This is analysed using a tobit model. Drawing from existing literature, it is hypothesized that a number of firm-specific, industry-specific and product-specific factors shape the decision to invest in innovation and the intensity of innovative activity. Next is a brief account of the theoretical base for incorporating these variables and their expected relationship.

3.1.1 Firm size

Firm size is expected to have a positive influence on the decision and depth of in-house R&D and technology purchases. Larger firms are better able to reap internal profits and devote funds to risky endeavours than smaller firms and consequently are more involved in-house R&D and the import of technology. Larger companies are preferred by technology-exporting firms because of the higher royalty and lumpsum payments made by these, an impossibility for many smaller firms. Large firms also benefit from the economies of marketing, production, as well as greater certainty in information. Lall (1983) is the first to note the positive influence of size on in-house R&D in India. However, later studies (Subrahmanian1971a; Katrak 1985, 1989, 1990) in the

14 The technological intensity of electronics industry in India after liberalization is discussed in detail by Joseph (1997) and Joseph and Subrahmanian (1994).

pre-liberalization regime do not report a positive relation between firm size and R&D.[15] However, it is assumed that under liberalization, large firms are able to take advantage of the above mentioned benefits and thus a positive relationship between firm size and innovative activity is assumed in the current study.

Some studies on India show a non-linear relationship between firm size and in-house R&D. Siddharthan (1988) discovers that firm size first decreases with in-house R&D, and then increases, showing a U-shaped relation. Kumar and Saqib (1996) observe an inverted U-shaped relationship where the firm size increases to a certain extent, declining thereafter. Therefore, a quadratic term for firm size is also used in the model to test for any non-linearities between firm size and innovative activity.

3.1.2 Market concentration

The relationship between market concentration and innovative activity has also been tested in both the developed and developing country context. The consensus of the developed country studies is that market concentration has only a weak positive relationship with innovative activity. Furthermore, Kumar (1987) observes a negative relationship in India between market concentration and R&D intensity. He argues that as strong policy barriers restricted new entrants, the lack of competitive pressures in the Indian industries retarded innovative activity. This is not the case in the liberalized environment, in which firms are freer to engage in technological activity. Market concentration in the current study is thus hypothesized to have a positive relationship with the innovation decision and its intensity.

A dummy variable is used to differentiate firms with high market shares as compared to firms with lower market shares for both industries. The top eight firms in each year for each industry are assigned the value one and the value zero for others. This is a better measure for capturing market concentration than conventional measures like the four-firm concentration ratio or the Herfindahl index mentioned earlier.

Kumar and Saqib (1996) argue that a firm's profit margin could also be an indication of the competitive environment it faces. Profit margin is expected to have a positive impact on innovative activity, as it helps to generate more internal funds. However, Geroski (1990) points to the simultaneity bias involved in the profitability/R&D relationship, as more R&D could also lead to more profits. In India, however, the study Kumar (1990) shows no significant influence of R&D intensity on profit margins.

3.1.3 Appropriability

Other things being equal, a firm having a greater part of the production chain in-house would have in-depth knowledge generated by innovative activity. This argument is put forward by Arrow (1962) where he argues that appropriability, more than sales, is best achieved by the internal application of knowledge. Therefore, a firm with a higher value added to sales will have a better chance of investing in innovative activity. The value added to sales differs from industry to industry, and this is accounted for in the current study, as it is industry specific.

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15 On the other hand, Subrahmanian *et al.* (1996) reports a positive relationship between firm size and R&D activity using data from RBI.

3.1.4 Experience

It is assumed that firms with long-term experience will have more intense innovative activity. Older firms benefit because of accumulated learning and better ways of adapting to new products. Consequently firms with experience are expected to have a positive association with the decision to engage in innovation and its intensity. In the current study, the age of the firms is taken as a proxy for experience, and older-aged firms are expected to have a positive influence on innovative activity, both with regard to the R&D decision and its degree of intensity.

3.1.5 Product market factor

Studies by Philips (1966) and Comanor (1967) in the developed country context and Kumar (1987) and Siddharthan and Krishna (1994) report that the possibility of conducting in-house R&D and importing technology is more prominent in industries where products are differentiable. Firms earmark funds for in-house R&D and technology imports to offset risks introduced by competitors in the form of new products or improvements in already available production. Advertisement intensity of the firms is used as a proxy here for product differentiation and it is assumed that there is a positive association between innovative activity and advertisement intensity.

3.1.6 Export orientation

It can be hypothesized that during liberalization export-oriented firms are able to invest more forcefully in in-house R&D and the import of technology. Once firms are in a position to gain access to international markets and to compete with foreign firms, they spend more on in-house R&D and technology imports. Moreover, liberalization has widened the market so that the cost of innovative activity is less than in the era of controls in pre-liberalized regime. Braga and Willmore (1991) report that in Brazil there is a positive significant relationship between exports as a ratio to sales and the probability of doing in-house R&D. Export orientation is posited to favourably affect a firm's innovation decision, the intensity of in-house R&D, and the import of technology.

3.1.7 Foreign control dummy

A dummy variable is introduced to see whether the fact that firms have some permanent foreign collaboration influences the probability and intensity of in-house R&D and the import of technology. It can be hypothesized that firms with foreign collaboration are more likely to spend more on innovative activity. Since the shares of foreign equity in total equity are not available, import dividends paid abroad are used as a proxy for measuring foreign collaboration. Siddharthan and Krishna (1994) observe that this variable positively and significantly affects the import of technology in the drug and pharmaceutical firms. Therefore, the dummy variable in this study takes the value one for all firms that remit import dividends in foreign currency, and zero otherwise.

3.1.8 The data and the construction of variables

The data for the study have been collected for a six-year period (1992-97) from Prowess, a corporate-level database published by the Centre for Monitoring Indian Economy. The study is industry-specific and the firms are pooled for the analysis. The sample[16] consists

[16] Data on 105 drug and pharmaceutical firms and 111 electronics firms for six years are considered for the study.

of 626 pooled observations for the electronics industry and 534 pooled observations for the drug and pharmaceutical industry.

3.1.9 Variable construction

In the case of probit model, the dependent variable is a binary (0.1) variable depending on whether or not the firms undertake any R&D or the import of technology. The probit estimates give the conditional probability of an individual firm investing in innovative activity for the given values of the explanatory variables. The dependent variable in this model is PROBRDIMP. It takes the value one if the firms undertake either in-house R&D or the import of technology or both, and zero otherwise. In-house R&D is proxied by the total R&D expenditure to sales. The import of technology is captured by the royalty payments, which constitute a regular flow of income abroad for the purchase of technology. The data on the measures of in-house R&D and import of technology are collected from the Prowess database.

The probit model used to test the above relationships for the two industries can be written as:

$$\text{PROBRDIMP*} = b_0 + b_1\ \text{SALES} + b_2\text{SALES}^2 + b_3\text{DCR}_4 + b_4\text{PROFIT} + b_5\text{ADS} + b_6\text{VALUE} + b_7\text{EXPINT} + b_8\text{AGE} + b_9\text{DFOR}$$

Here the dependent variable is a latent variable, which cannot be observed. Hence a dummy variable, which is observed, is used and is defined by:

$$\text{PROBRDIMP} = 1 \text{ if PROBRDIMP}^* > 0;$$
$$= 0 \text{ otherwise.}$$

The intensity of doing innovative activity (RDIMPINT) is analysed using a tobit model. This model is used to analyse the intensity of spending on innovative activity when a large number of firms are not reporting any innovative activity. Here the dependent variable, RDIMPINT for the tobit model for each industry, is equal to zero when the firms report neither any R&D activity nor the import of technology and to the R&D intensity and import of technology intensity for other firms.

The tobit model is defined as follows:[17]

$$\text{RDIMPINT} = b_0 + b_1\ \text{SALES} + b_2\text{SALES}^2 + b_3\text{DCR}_4 + b_4\text{PROFIT} + b_5\text{ADS} + b_6\text{VALUE} + b_7\text{EXPINT} + b_8\text{AGE} + b_9\text{DFOR}$$

if RDIMPINT >0; and
RDIMPINT = 0; otherwise.

Table 1 gives details of the variables used in the study, including the codes used and definitions of the variables.

As the data on sales in the study are taken for a six-year period, it is necessary to deflate these to standardize the variable. For both industries, sales are deflated with the wholesale price index of the respective industries from 1992 to 1997, taking 1981-82 as the base year.

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17 For a detailed analysis on the probit and tobit models, refer to Maddala (1983), Greene (1993) and on the use of these models in the studies on R&D in the Indian context, refer to Kumar and Saqib (1996).

Since all other variables are standardized by dividing them with sales, there is no need to deflate these.

Table 2 gives the summary statistics of the variables used in the study for the two industries: drugs and pharmaceuticals, and electronics. This highlights the inter-firm differences, and nature, of the variables used in the sample. The correlation matrix of the variables for the two industries shows that there is no presence of multicollinearity among variables of the model. The heteroscedasticity problem has also been avoided as all variables have been standardized by taking a ratio of these variables with sales.

Table 1
Variable construction and coding

Variable	Code	Definition
Probability of engaging in in-house R&D plus the import of technology	PROBRDIMP	It takes the value 1 for firms doing either R&D or the import of technology or both, and 0 otherwise.
R&D intensity and the import of technology intensity	RDIMPINT	Ratio of R&D and the import of technology to sales.
Sales	SALES	Value of sales in rupees (crores) deflated by the wholesale price index of the corresponding industry group for the period 1992 to 1997.
$Sales^2$	$SALES^2$	Square of sales.
Market concentration	DCR_4	It takes a value one for firms, which have the top eight market shares each year and zero otherwise.
Advertisement intensity	ADS	Ratio of advertisement expenditure to sales.
Profit margin	PROFIT	Ratio of gross profit to sales.
Appropriability	VALUE	Ratio of gross value added to sales.
Export intensity	EXPINT	Ratio of exports to sales.
Experience	AGE	The age of the firm.
Foreign control dummy	DFOR	It takes a value 1 for firms which pays dividends in foreign currency and zero otherwise.

Table 2
Summary statistics of the variables used in the model
Electronics for the drug and pharmaceutical sector and the electronics sector

	Drugs and pharmaceuticals				Electronics			
Variable	MEAN	SD	MIN	MAX	MEAN	SD	MIN	MAX
RDIMPINT	0.008	0.014	0.0	0.107	0.012	0.046	0.0	0.62
SALES	59.5	78.2	0.21	446.3	72.2	150.8	0.05	977.1
PROFIT	0.005	0.29	-0.05	0.69	0.05	0.37	-0.005	0.45
VALUE	0.212	0.102	-0.28	0.79	0.27	0.19	-1.0	0.89
ADS	0.011	0.02	0.0	0.13	0.011	0.023	0.0	0.438
EXPINT	0.116	0.187	0.0	0.98	0.05	0.117	0.0	0.86
AGE	25.11	19.14	1.0	85.0	16.97	13.7	1.0	68.0

Note: Here SD means standard deviation.

3.2 Empirical findings

3.2.1 Relationship between market structure variables and decision to do innovative activity

The probit estimates for the two industries under review on the relationship between market structure variables and the decision to do innovative activity show some interesting results (Table 3).

The estimation of the probit models for both industries shows that there is a non-linear relationship between firm size and innovative activity. The variable SALES is positively significant and the variable $SALES^2$ is negatively significant. This shows that only firm size influences the decision to do innovative activity up to a certain point, declining thereafter. Thus an inverted U-relationship is observed between the firm size and the innovation decision for both industries. Siddharthan (1988) reports a U-shaped relationship between firm size and in-house R&D. This implies that with liberalization, small firms are more included to undertake R&D and technology imports than larger firms. It is interesting to note that Kumar and Saqib (1996) obtain a similar inverted U-shaped relationship between firm size and in-house R&D for the manufacturing sector as a whole.

The market concentration variable does not show a positive relationship with the decision to undertake innovative activity, as was expected for both industries. Kumar (1987) argues that the lack of competitive pressures in the economy in the pre-liberalization era is the reason for the negative relation between market concentration and innovation. The present study shows that even after liberalization, market power of the firms does not influence the decision to undertake innovative activity vis-à-vis other firms. But the variable is not significant for both industries: on the part of the electronics industry, the profit margin variable (another measure of concentration) shows a positive and significant relationship with the R&D decision. This upholds the hypothesis that firms tend to engage in more innovative activity by generating more internal funds in a liberalized environment with the free entry of firms and no government controls. In the drug and pharmaceutical industry, the variable is insignificant, highlighting the fact that profit margin and its influence on the decision for innovative research vary from industry to industry.

The product market factor, proxied by the advertisement intensity (ADS) variable, shows diverse results for the two industries. It shows a positive weak significant relationship with the innovative-activity decision for drug and pharmaceutical firms. Siddharthan (1988) reports that firms which spend more on advertisement engage more actively in in-house R&D. Drug and pharmaceutical firms have mostly heterogeneous products and the R&D incentive is stronger than in firms with homogenous products. In the electronics firms, advertisement intensity shows a negative, albeit insignificant, relationship with innovative activity.

The appropriability condition of the firms proxied by the value added-to-sales ratio shows different results for the two industries. For the drug and pharmaceutical firms, a positive although not significant relationship is seen between the value added-to-sales ratio, which represents opportunities for the appropriation of innovation, and the probability of doing innovative activity. Contrary to this, the electronics firms show a negative and significant relationship with the value added-to-sales. This invalidates our assumption that a greater production chain in-house has better scope of utilizing the knowledge generated and the probability of doing innovative activity is high.

The relationship with the export orientation of firms and the probability of innovative activity shows some interesting results. Export intensity is found to have a positive, albeit insignificant, effect on the innovation decision in the drug and pharmaceutical firms. Export intensity for the electronics firms shows a positive and significant relationship with the decision to undertake innovative activity. This means that, as hypothesized, the export orientation of the electronics firms has a positive and significant effect on the probability of participating in innovative activity.

The experience of the firms proxied by age and the effect of foreign control have a positive and significant relationship with the innovation probability for both industries. There is strong evidence, therefore, that firms with more production experience tend to provide greater support to innovative activity. Similarly for the firms with some foreign control, the probability of undertaking innovative activity is stronger.

Table 3
Probit estimates on the decision to do innovative activity for the drug and pharmaceutical, and electronics industries

Variable	Drugs and pharmaceuticals	Electronics
Dependent variable	RDIMPINT	RDIMPINT
INTERCEPT	-0.544*	-0.526*
	(-3.89)	(-3.4303)
SALES	0.012*	0.0064*
	(5.391)	(4.070)
$SALES^2$	-0.00001*	-7.68e-06*
	(-3.397)	(-3.70)
DCR_4	-0.562	-0.0037
	(-1.51)	(-.013)
PROFIT	0.0117	1.004*
	(0.129)	(4.396)
ADS	6.923***	-0.034
	(1.793)	(-0.009)
VALUE	0.327	-1.129*
	(0.978)	(-3.94)
EXPINT	0.4122	1.308*
	(1.184)	(3.04)
AGE	0.013*	0.005
	(3.015)	(0.996)
DFOR	0.918*	1.45*
	(3.918)	(5.43)
R^2	0.226	0.1942
Chi^2	150.59	150.13
Log-likelihood ratio	-257.24	-311.6
No. of observations	534	626

Note: Figures in brackets show the 't' ratios.
* Significant at 1% level; ** Significant at 5% level; *** Significant at 10% level.
R^2 for the probit Model is Pseudo R^2

The probit analysis clearly shows some diverse results versus previous studies. There are also considerable inter-industry differences in the factors determining the innovation decision. The inverted U-shaped relation between firm size and the decision on innovative activity highlights the role of small firms in each industry. Market power of the firms does not affect the innovation decision, an observation also supported by other studies (Kumar 1987; Kumar and Saqib 1996). The variables proxying appropriability condition and product market factor show diverse results for the two industries, clearly indicating that technological opportunities vary among the different industries.

3.2.2 Relationship between market structure variables and the intensity in the spending on innovative activity

Table 4 gives the maximum likelihood estimates of the tobit analysis on the market structure variables that influence the intensity of innovative activity for the drug and pharmaceutical, and electronics industries.

It can be noted that similar to the probability of engaging in innovative activity, the SALES and $SALES^2$ variables are positively and negatively significant for both industries. This means that firm size has an inverted U-shaped relationship with the intensity of doing innovative activity. As the firm size increases, so does the intensity of innovative activity to a certain threshold point, after which it declines. Thus the hypothesis put forward by Schumpeter on a positive relationship between firm size and innovative activity is not supported by this result.

Table 4
Tobit estimates on the intensity of innovative activity for drugs and pharmaceuticals and electronics

Variable	Drugs and pharmaceuticals	Electronics
Dependent variable	RDIMPINT	RDIMPINT
INTERCEPT	-0.0210* (-6.88)	0.0201** (-2.33)
SALES	0.00015* (5.12)	0.0001** (2.415)
$SALES^2$	-1.40e-07* (-3.26)	-1.85e-07** (-2.03)
DCR_4	-0.0015 (-0.314)	-0.004 (0.318)
PROFIT	0.0027 (1.193)	0.087* (3.46)
ADS	0.181* (3.03)	0.123 (0.646)
VALUE	0.034* (4.71)	-0.0183 (-0.89)
EXPINT	0.024* (3.14)	0.049*** (1.836)
AGE	5.23e-06 (-0.077)	-0.001 (-0.684)
DFOR	0.0028 (0.983)	0.042* (5.531)
Log-likelihood ratio	569.34	313.23
No. of observations	534	626

Note: Figures in brackets show the ‘t’ ratios.
* Significant at 1% level: ** Significant at 5% level; *** Significant at 10% level.

The market concentration dummy variable and its correlation with the intensity of innovation show some interesting results for the two industries. There is a negative but insignificant relationship between market concentration and intensity of innovative activity for the drug and pharmaceutical firms. This implies that the degree of competitive pressures does not add to the intensity of innovation investments, as is seen in the probability or decision to engage in innovative activity. This result substantiates the results of studies conducted during the pre-liberalization period, including Kumar (1987) and Kumar and Saqib (1996), who report a negative relationship. However, there is a positive but insignificant relationship for the electronics firms. Thus the relationship between market concentration and the intensity of innovative activity differs across firms in the two industries.

The other concentration variable proxied by profit margin also shows a positive relationship with the intensity of innovative activity. But it is significant only for the electronics industry, implying that after liberalization, firms in both industries could have generated internal funds to invest in in-house R&D and the import of technology during high profit periods.

Advertisement intensity to sales, which proxies product market factors, shows a positive relationship with the intensity of innovative activity for both industries. However it is significant only in the drug and pharmaceutical firms. This means that expenditures on R&D and the import of technology are higher in firms where products are differentiable and aimed at gaining a competitive edge.

Appropriability condition of the firms for the two industries indicates diverse results in its relation to innovative activity. On the part of electronics firms, the value added to sales is observed to have a negative relationship with R&D and the import of technology. The vertical integration of firms or the in-house production chain of firms does not influence the intensity of innovative activity. But the variable is not significant. In the case of drug and pharmaceutical firms, the value added to sales is noted to have a positive and significant effect on innovative activity.

The export orientation of the firms is observed to have a positive and significant influence on the intensity of innovative activity for the electronics firms. This means that, similar to the innovation decision, the export orientation of these firms significantly affects the depth of innovative activity. This variable is also significant in the case of drug and pharmaceutical firms.

Firms with some permanent foreign collaboration spend more on innovative activity. This is more prominent among the electronics firms, but the variable is insignificant for drugs and pharmaceuticals. While the experience of the firm is found to have a positive relationship with the intensity of spending on in-house R&D on the part of the electronics firms, it is insignificant for the drug and pharmaceutical firms. Thus, the age of the firm is not a major factor affecting the intensity of innovative activity. It only has an effect in the probability of undertaking innovative activity.

The tobit models thus show some interesting results. Deviating factors affect the intensity of innovative activity on the part of the electronics and the drug and pharmaceutical industries, thus highlighting the inter-industry differences. However, as in probit analysis, there is a similar non-linear relationship between firm size and innovative activity for both industries. Furthermore, value added, age and advertisement intensity show a positive significant relationship with innovation intensity for drugs and pharmaceuticals, but a negative relationship for electronics. It is also noted that the foreign control variable and profit margin affect the depth of innovative activity in electronics firms, but not in the drug and pharmaceutical firms.

4 Summary and conclusions

The main focus of the present study is the analysis of the role of market structure variables on a firm's decision to participate in innovative activity and its depth. To test for any inter-industry differences in the relationship, the study reviews two industries: drugs and pharmaceuticals, and electronics. The study also attempts to determine whether the same set of firm-specific, industry-specific and product-specific factors affects the probability of undertaking innovative activity and its intensity for the two industries.

In order to arrive at an analytical framework on the market structure/innovative activity relationship, the available empirical literature is examined both in the context of both developed countries and India. During this review, it is obvious that no consensus on the results exists. An attempt is made to explain this in terms of the innovation concept used in the studies as well as diverging empirical procedures. It is apparent that the studies mainly use R&D expenditure, R&D employment and patent statistics as the major innovation measures which, however, are incomplete with regard to Schumpeter's definition of innovation and pose certain limitations. In the Indian context, the studies do not include the purchase of technology as a major component of the innovative effort. It is also apparent that most of the studies on India utilize the OLS method. This introduces some inherent problems and some methodological improvements (probit and tobit models) could have given better insights.

The present study is based on firm-level data, prepared by the Centre for Monitoring Indian Economy. The selection of this database is guided by its comprehensive nature and easy accessibility as compared to official data sources for the post-liberalization period. For analysing the relationship between market structure variables and the probability and intensity of innovative activity, the period of analysis (1992-97) is extended to account for the dynamic policy changes taking place after liberalization. In the analysis, innovative activity is defined as the combination of in-house R&D and the import of technology.

The study shows that there are significant differences for both industries in the factors that affect the innovation decision and its intensity. Firm size shows a non-linear (inverted U) significant relationship with both the decision and intensity of innovative activity for both industries. This implies that during liberalization the innovative activity of firms increases with size upto a certain point, but declines thereafter. There is, however, an insignificant negative relationship between market concentration and the innovation decision and its intensity for both industries. This shows that contrary to our hypothesis, firms with market power need not necessarily conduct more innovative activity. The value added variable shows some interesting results for the two industries. While the value added has a positive effect on the probability and intensity of innovative activity for the drug and pharmaceutical industry, it shows a negative relationship on the part of the electronics industry. This means that in the context of liberalization, a better in-house production chain in the drug and pharmaceutical industry is observed to significantly increase generated knowledge and to have a positive influence on the innovation decision or its depth. But this finding is invalid in the case of electronics firms. The export orientation of firms has, for the electronics industry, a positive and significant impact on the probability of innovation or its intensity, but for the drug and pharmaceutical firms, it has a positive and significant relationship only with regard to the intensity of innovation.

A similar diverse result is seen in the case of the experience variable denoted by age and the foreign collaboration dummy variable. Age of the firm significantly affects the decision to undertake innovative activity for both industries but does not impact on its intensity. Similarly, foreign collaboration significantly and positively affects the innovation decision in firms in the drug and pharmaceutical industry, but is, on the one hand, insignificant on the part of the electronics firms. On the other hand, in electronic firms, foreign collaboration impacts significantly on innovation intensity, but is insignificant for the drug and pharmaceutical firms. The study indicates that for the drug and pharmaceutical industry, only firm size and advertisement intensity significantly affect the innovation decision or its depth. While age and foreign collaboration dummy are significant in the decision to undertake innovative activity, the appropriability condition and export intensity are the variables which significantly affect the intensity of innovative activity. For the electronics industry, the firm size, value added, export intensity and foreign collaboration dummy are the variables which influence both the decision to engage in innovation or its intensity.

To sum up, the analysis shows that the factors that affect the relationship between market structure and the probability of doing innovative activity are different from those which impact on the intensity of innovative activity for both industries. This result confirms our hypothesis that there are inter-industry differences in the factors affecting innovative activity. There is no evidence to show that in the period of liberalization, firms with higher market power and larger in size are able to do more innovative activity.

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