

R&D and Firm Size in the Small Industry Sector in India

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Abstract: The relationship between Research & Development (R&D) and firm size is a widely contested research issue. Research findings on this issue are contradictory and diverse. This paper presents an empirical analysis of this relationship in the context of the small industry sector in Karnataka State of India. The analysis is done in terms of R&D objectives, sources, dimensions, inputs and its variance in relation to firm size in the small industry sector. In addition, it probes the relationship between R&D and factor productivities. The paper concludes that when the R&D activities and related factors are similar in nature, R&D intensity exhibits a negative relationship with both firm size and factor productivities.

Introduction

The relationship between Research & Development and firm size is a widely contested research issue. Research findings on this issue, pertaining to various countries, are contradictory and diverse. Other things remaining the same, firm size can have some influence on R&D activities of firms. For example, if the cost of R&D and innovation is continuously increasing over time, large firms would be in an increasingly advantageous position to undertake R&D (Coombs, Saviotti and Walsh, 1987).

Other possible advantages of large size are economies of scale in R&D resulting from such factors as an environment in which researchers can share their findings with more colleagues and greater chances to exploit serendipitous discoveries (Kamien and Schwartz, 1982). If scale economies exist in R&D, large firms could derive greater benefits than small firms by allocating the same percentage of their turnover to R&D (Coombs, Saviotti and Walsh, 1987).

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However, there is no conclusive evidence to say that the larger the firm size, the higher the R&D expenditure and the more the inventions and innovations. Some empirical studies have shown the large firm in a somewhat less favourable light (OECD, 1971). In fact, over 60 percent of the major inventions developed in the 20th century were the work of independent inventors and small companies (Barrow, 1998).

It would be interesting to study such kind of an issue with respect to the small industry sector where the size variation is significant. For example in India, the small industry sector comprises units ranging from a few thousands up to 30 million Indian Rupees of investment in plant and machinery. Also a major study conducted by the authors (Bala Subrahmanya, et al, 2002) revealed that a significant number of these units are engaged in R&D irrespective of their size. However, one could hypothesize that with such a level of large variations in investments, the magnitude of R&D activities also may vary. This study has attempted to probe this issue in greater detail.

But the literature is found wanting on R&D activities carried out in small industries in the entire developing world (Bala Subrahmanya, et al, 2002). Therefore, information is lacking about the nature of R&D activities, its objectives, sources, intensity and achievements and their variance, if any, with firm size within the small industry sector. This study, therefore, assumes significance as it is rather a maiden attempt to probe such issues in the small industry sector in India. The study has been conducted with reference to Karnataka State in Southern India.

This paper is divided into six sections. The major issues related to R&D and firm size based on the existing literature are presented in Section two. The objectives, scope and methodology are described in Section three. Section four analyses how R&D orientation, causal factors and objectives of R&D, sources of external support, nature of R&D activities, R&D inputs and intensity vary with firm size in the small industry sector. Section five deals with the analysis of firm size and R&D intensity variations along with factor productivities not only for the whole small industry sector but industry wise as well. The summary and conclusions are presented in Section six.

R&D and Firm Size: Major Issues

The extent of R&D and technological innovations undertaken by industrial firms may vary in terms of firm size and industry. In certain industries, technological innovations may warrant huge R&D investments and therefore, could be confined only to large firms. But in some others, where scale economies are negligible and where innovations often involve great uncertainties, small firms may play a major role in terms of R&D and technological innovations.

But, so far as professional R&D activity is concerned, there is pretty firm evidence that this is highly concentrated in large firms in all countries for which statistics are available (Freeman and Soete, 1999; DST, 2000). There is fairly conclusive evidence that the vast majority of small firms in Organization for Economic Cooperation and Development [OECD] countries still do not perform any organized research and development (Freeman and Soete, 1999). This is substantiated further in the context of the north east of England (Bala Subrahmanya, 2000). Therefore, the official statistics on R&D expenditures may not capture the research or inventive work performed by small firm entrepreneurs. But there is considerable evidence to show that small firms make significant contributions informally in terms of technological innovations.

In fact, small and medium sized companies are often regarded as being more innovative than large ones because of their flexibility and willingness to adopt new approaches (Davis, 1991). The point is reinforced by well-publicized success stories of innovative entrepreneurs, who were forced to start their own new business because their ideas were rejected by large established companies. Hewlett Packard turned down Steve Wozniak's invention of a small portable computer, which forced him to take the idea to his friend Steven Jobs and together they began making Apple computers in a garage (Stokes, 1995).

Thus, large firms have certain disadvantages for R&D. For example, unexpected research findings, rather than being better exploited, could be wasted due to poor communications or due to lack of management interest; or researchers' motivation might be lower than in a small firm because compensation may be less directly related to their performance (Coomb, Saviotti and Walsh, 1987). There are many examples of entrepreneurs leaving established large firms to set up their own more highly innovative small firms (Coomb, Saviotti and Walsh, 1987).

But Freeman and Soete (1999) found that the role of the individual invention and innovation was relatively stronger before 1928, whereas that of the firm was relatively stronger afterwards. However, since 1945, important contributions to invention and technological innovation continued to be made by small firms (OECD, 1971). Probably, the greatest advantage of the small firm lies in flexibility, concentration and internal communication (Freeman and Soete, 1999).

Freeman and Soete (1999) argue that the major source of variations in research intensity between firms is the industry concerned and therefore, an analysis of the relationship with size is best done industry by industry. In fact, they found a generally weaker correlation between research intensity and size of firm and it was not significant in some industries.

Kamien and Schwartz (1975) revealed that in the chemical industry there is considerable international evidence of a threshold in firm size below which little innovative activity takes place. In other industries, they found, there is a tendency for R&D intensity to increase with firm size up to a certain size, and then to decrease. A similar conclusion has been arrived at by Braunstein, et al. (1980). R&D and innovation would seem to be discouraged by very small size of firm and by extreme competitiveness of the industry. But while increasing firm size and reductions in the number of competing firms do seem to stimulate research and its products, there comes a point beyond which further increases in the size of firm seems not to help while further decreases in competitiveness may perhaps constitute an impediment.

This implies that there is an intermediate firm size, which represents the best compromise between the advantages and the disadvantages of large firms. But Soete (1979) had argued against the conclusion that R&D intensity might decrease beyond a certain firm size. Thus, the existing literature does not provide conclusive evidence on the relationship between firm size and R&D and technological innovation.

In the Indian context, various studies conducted with reference to large firms on firm size and R&D intensity have not come out with unanimous findings either (Goldar and Renganathan, 1999). Of course, Goldar and Renganathan (1999) found positive relationship between R&D intensity and firm size (as measured by the value of output).

Cambridge University (1992) found that for small and medium enterprises in the U.K. major innovations increase with size of firm for all types of innovation, although there is little difference between medium-sized firms and larger firms. The smaller the firm, the less frequent is the adoption of major innovations, new production processes or new systems.

However, there is hardly any literature, which probed the relationship between R&D and firm size among Small and Medium Enterprises, in a developing country. We studied the relationship in totality for the small industry sector of Karnataka in India for different size groups, in terms of investment. We also analysed the relationship for the important industries to ascertain whether such a relationship is industry specific. This would help in ascertaining whether the intensiveness of R&D activities remains the same or varies across the small-scale sector. Firm size and R&D intensity are compared with economic ratios such as factor intensity and factor productivities. This is done mainly to know whether economic performance varies with R&D intensity as well as firm size.

Objectives, Scope and Methodology

The primary objective of this paper is to probe how the nature and magnitude of R&D varies with firm size in small industries in India, in relation to the following issues:

1. Does R&D orientation of firms change with firm size?
2. What are the dimensions of R&D activities of firms of varying sizes?
3. Does R&D intensity vary with firm size? Does it vary with factor productivities? Why?
4. Is the relationship between R&D and firm size industry specific?

The study is confined to small industries in Karnataka State in India in view of the following considerations: Karnataka, which is one of the southern states in India, is considered the pioneer in the field of industrialization in India (Bala Subrahmanya, 1993). Today, Karnataka is in the forefront of high technology industries, particularly electronics, telecommunications and informatics (Government of Karnataka, 2001). As far as small industry growth is concerned, Karnataka is one of the top-ranking states in the country (SIDBI, 1999).

In the present study, we have adopted a questionnaire-based survey approach to gather R&D related information from the Small Scale Industry (SSI) sector. The study covered the "non-tiny sector"¹ small firms on a census basis. That is, almost every accessible and functioning non-tiny small firm, which amounts to 1358 firms in Karnataka has been included in the present study.

The "tiny sector"² small firms are targeted on a sample basis. The sample size was determined so as to comprise at least 20 percent of the number of firms in each industry and district (administrative regions within Karnataka) under the census of the non-tiny sector. This is because it was assumed that the R&D orientation of tiny sector firms would not be much different from that of non-tiny sector firms. The number of firms covered in the "tiny sector" stood at 648. Thus, a total of 2006 small firms have been surveyed for the study. An industry-wise composition of small firms of both the sectors is presented in Table 1.

1 Non-tiny sector refers to firms having initial investment in plant and machinery in the range of more than Rs. 2.5 million (US \$ 60000) and up to Rs. 30 million (US \$ 0.72 million) in 1998-99.

2. Tiny sector includes firms having initial investment in plant and machinery up to Rs. 2.5 million (US\$ 60000) in 1998-99

These 2006 firms have been divided into six groups, in terms of their current investment in plant and machinery, for analyzing their R&D orientation, determining factors, objectives, sources and nature of R&D activities. (vide Table 2).

The investment ranges have been determined taking into account the official investment limits for a small industry firm that prevailed in India at different points of time (SIDBI, 1999). For a quantitative analysis, only three groups of firm sizes are considered: (1) Firms having investment up to Rs. 2.5 million (tiny small firms), (2) Firms having investment more than Rs.2.5 million up to Rs.10 million (smaller SSI), and (3) Firms having investment more than Rs.10 million up to Rs.30 million (larger SSI).

Data was gathered relating to R&D and other activities through a questionnaire during November 1999-April 2001. The structured questionnaire was evolved after consultation with experts and Government officials in small industry promotion organizations, scientists, literature survey, etc. A pilot study was conducted to further refine the questionnaire.

The most significant purpose of the questionnaire is to identify the activities of R&D in a small firm. Based on literature review and consultation with experts, eight possible dimensions of R&D activities in small firms were identified (Table 3). While developing new products and processes could be considered radical, the remaining dimensions indicate varying degrees of incremental innovations in small industries. The development of new products and processes constitute radical innovations as they could give a new dimension to the industrial development of the region/country, whereas the remaining dimensions would enable either quality improvement or cost reduction or both and thus enable a firm to improve its competitiveness.

It needs to be noted that some of the dimensions identified by us may not form part of the conventional definition of R&D activities. But the small firms, particularly in the developing countries, with their constraints of capital, information and even accessing external support might be limited in their ability to continuously upgrade their technology to meet high standards. As an alternative they might limit their focus to incremental innovations such as modifying the existing machinery, or using alternative materials, or changing product performance by technical efforts, etc. to enhance their performance. We feel that these activities require significant amount of dynamism as in the case of radical innovations and conventionally defined R&D activities. Therefore, we feel it is appropriate to include these activities under the broad umbrella of R&D.

The analysis of objectives in this paper is done in terms of the number of small firms (based on a frequency distribution). That is, the factors that prompted a small firm to undertake R&D, its R&D objectives, sources of R&D, role of external

support to R&D, dimensions of R&D activities and achievements are analyzed in terms of the number of firms. The number of personnel devoted to R&D activities is calculated based on full-time personnel. R&D expenditure has been estimated taking into account both direct and indirect expenditure. Direct R&D expenditure refers to expenditure incurred on equipment, testing facilities, training/consultancy, material inputs and wages and salaries to full-time R&D personnel. Indirect expenditure consisted of labour spent on R&D activities, on a part-time basis.

The different ratios used in the analysis and their formulae are as follows:

$$\text{Capital Intensity} = \{ \text{Capital} / \text{Number of Workers} \} \quad (1)$$

$$\text{Labour Productivity} = \{ \text{Value of Output} / \text{Number of Workers} \} \quad (2)$$

$$\text{Capital Productivity} = \{ \text{Value of Output} / \text{Capital} \} \quad (3)$$

$$\text{R\&D Intensity (labour)} = \{ \text{R\&D Workers} / \text{Number of Workers} \} * 100 \quad (4)$$

$$\text{R\&D Intensity (expenditure)} = \{ \text{R\&D Expenditure} / \text{Value of Output} \} * 100 \quad (5)$$

The relationship between R&D intensity (expenditure) and firm size (as represented by values of investment and output) and R&D intensity (expenditure) and factor (labour and capital) productivities is estimated by correlation analysis.

Firm Size and R&D: Objectives, Dimensions and Intensity

The number of firms that do R&D, formally or informally, the factors that influence a firm to engage in R&D, R&D objectives, sources, dimensions, R&D inputs and intensity can all vary with firm size. The following sections discuss the extent of these variations with respect to firms of different sizes.

Firm size and R&D: relative importance

The relative importance is estimated in terms of the proportion of firms, which performed R&D to those, which did not, for different size groups (Table 4). It could be observed from the table that the proportion of R&D firms steadily increases as the investment size increases. This shows that the larger the firm size, the greater the probability of a small firm engaging in R&D and technological innovations.

What is more interesting to note is that a higher proportion of firms in the larger size groups (having investment in the range of Indian Rupees 6 million to Rupees 30 million) perform R&D formally as compared to smaller size groups. These firms have exclusive R&D departments within their firm premises. By large, however, excluding this minority, small firms of different sizes carry out

R&D activities informally. This is in tune with the observation made by the researchers with reference to R&D activities carried out by small firms in developed countries (Freeman and Soete, 1999; Ghobadian, et al, 1995; NAE, 1995; Rizzoni, 1991; Rothwell and Zegveld, 1982; University of Cambridge, 1992).

Firm size and R&D: causal factors

In general, a small firm may initiate R&D activities due to either internal drive or external pressures. That is, it could be due to internal factors such as the entrepreneur's self-motivation and in-house technological capability or external factors like competitive pressure, technological changes that take place in the industry concerned or customer/user requirements or based on information provided by machinery/equipment suppliers, etc.

In India, the influence of external factors in the general business environment has gained prominence due to the radical shifts in the macro economic policies of the government. The government has been pursuing the path of liberalization and globalization since 1991 through de-licensing of industries, dismantling of controls and regulations for existing and new investments, removal of constraints for foreign investment, radical reduction of tariff barriers for imports and phasing out of quantitative restrictions (Government of India, 1992 and 2000). This has intensified local competition and exposed domestic industry to international competition. As a result, responding to technological changes and satisfying the expectations of customers have become decisive for a SSI firm to survive and grow. This assumes special significance because in the meantime, there has been an implicit shift in the thrust of small industry policy from protection towards competitiveness (Bala Subrahmanya, 1998). It is in this regard that it is interesting to find out the factors which prompted small firms of different sizes to engage in R&D activities.

Firms irrespective of their size are driven to R&D mainly because of competition (Table 5). Technology change, self-motivation and user signal are the other important factors that prompted firms to engage in R&D. On the whole external factors are predominantly responsible for tiny and small firms of different size groups to undertake R&D. Overall, we found that the causal factors remain the same irrespective of variations in firm size.

Thus, the competitive environment emerging due to dismantling of licensing, removal of restrictions on expansion and diversification of private investment, dilution of barriers to foreign investment, scaling down of import duties and gradual elimination of quantitative restrictions has been affecting firms of different sizes. Accordingly, firms are getting motivated to take account of technological changes and meet customer requirements.

Firm size and R&D: major objectives

The strategy adopted by small firms of different sizes in the competitive atmosphere is uniformly similar. The majority of these have resorted to R&D with the objectives of quality improvement, cost reduction and meeting customer requirements (Table 6). Thus, enhancing competitiveness has been the primary objective of R&D for the majority of firms in all the size groups.

Overcoming operational problems, exploiting market opportunities and expansion/diversification are the other objectives of R&D for some of the firms. It is interesting to note that, on an average, about one-third of the firms in all the size categories perform R&D as a means of expansion/diversification, among others. Thus, growth has been an important objective of R&D of small firms, irrespective of size.

Firm size and R&D: sources of technological support

How small firms do R&D is a matter of significance. While some firms may have in-house technological capability, others might rely on external support in carrying out R&D. Moreover, the internal innovative capacity and the small firm's potential for utilizing and exploiting external sources might be complementary in certain contexts and industries. It would be of interest to know the relative importance of internal and external sources of support for R&D of small firms of different sizes.

Our study clearly indicates that firms irrespective of size, rely largely on in-house technological capability and self-effort for R&D and technological innovations (Table 7). More than 80 percent of the firms in all size categories have done R&D through self-effort. External support, particularly from national agencies, has not played any major role in any of these size groups in R&D. The negligible role of parent companies in promoting R&D can be attributed to lack of ancillarisation in small-scale industries.

Not many can have access to international support and therefore, support of international agencies for R&D is quite insignificant. But other sources such as machinery suppliers, friends and relatives having technical knowledge do contribute considerably to R&D. On the whole, there appears to be a gap between government promoted technology organizations and small firms of all sizes as the latter have not sought "technology transfer" assistance from the former to any significant extent.

Firm size and R&D: dimensions of R&D activities

Improving product quality or performance is the most important R&D activity done by firms of different sizes (Table 8). About two-thirds of the firms in all size groups are engaged in improving their product performance or quality. Solving common

problems or changing product shapes and dimensions are the other important R&D activities carried out by firms in the SSI sector.

Thus, incremental innovations are the striking features of R&D activities of small firms of all sizes in Karnataka. Of course, process and product innovations do account for a considerable share among firms of all sizes. But, on an average, the proportion of firms, which are engaged in process innovations is the highest in the largest size group (about 59 percent) and lowest in the smallest size group (about 39 percent). But there is not much of a difference between the proportion of firms which are into product innovations in the tiny and small scale sectors. Using alternate material, modifying existing machinery and other innovations are the other significant dimensions of R&D in SSI.

The major dimensions of R&D in firms of different sizes in SSI are in tune with their R&D objectives and causal factors. Competition, technology change and customer requirements being the primary factors which drove the majority firms to engage in R&D; and quality improvement, cost reduction and satisfying customer needs being the R&D objectives, these firms are primarily involved in quality improvement, changing product changes/dimensions and solving commonly encountered problems in a novel way.

Firm size and R&D inputs

Personnel (i.e. labour) and equipment (i.e. capital) are the two major factor inputs required for R&D. In general, firms can either devote full time staff or carry out R&D activities as part of their day-to-day manufacturing/servicing operations. However, one could say that the larger the number of full-time staff devoted, the greater the commitment on the part of the firms for R&D.

Table 9 presents the distribution of firms having full time R&D personnel, total and per unit number of R&D personnel between different firm size groups. It is clear that the majority of the firms in all the three sectors-tiny, smaller SSI and larger SSI-do not employ full-time R&D staff. They carried out R&D activities as part of their day-to-day operations. The proportion of firms having full-time R&D staff varied from about 44 percent in tiny and smaller SSI sectors to about 45 percent in the larger SSI sector. The average full-time R&D staff increased with firm size from about two in the tiny sector to close to four in the smaller SSI and to about nine in the larger SSI sector.

The number of firms and quantum of expenditure on training/consultancy, equipments/machinery and labour/materials as well as total R&D are given in Table 10. A greater proportion of larger SSI firms incur expenditure for training/consultancy and equipment/machinery as compared to tiny and smaller SSI firms. On an average, a larger SSI firm incurs more expenditure on either training/

consultancy or equipment/machinery or total R&D. It may be noted that in the case of smaller and larger SSI, the expenditure on R&D related labour/material accounts for the major share in the total R&D expenditure. However, this is not the case with tiny units. One of the reasons could be that these units employ less full time R&D staff compared to larger sized units. Thus, in Karnataka, in the SSI sector, both average R&D staff and average R&D expenditure of firms increase with firm size. With this we may be able to conclude that the R&D orientation of SSI units increases with the firm size. However, what may be more appropriate to see is how R&D personnel as a proportion of the total labour force and R&D expenditure as a proportion of value of output vary with firm size.

Firm size and R&D intensities

As described earlier, R&D intensities are estimated in two ways (i) R&D labour as a proportion of total labour force and (ii) R&D expenditure as a proportion of the value of output. Our earlier analysis showed that the average R&D personnel and average R&D expenditure increased with firm size, but their R&D intensities both in terms of labour and expenditure decreased with firm size (Table 11). That is, both R&D personnel and expenditure increased less than proportionately with firm size. This might be an indication of negative relationship between R&D intensities and firm size in the SSI sector in Karnataka.

Given the nature of R&D activities carried out by small firms of different sizes, it is not surprising that a larger SSI needs a lesser proportion of its labour force as well as turnover for R&D as compared to smaller SSI and tiny firms. As seen earlier, by and large, small firms of all sizes are primarily engaged in incremental innovations' through their R&D activities. This being the case, a larger SSI firm might require a less than proportionate share of its labour force and turnover in relation to smaller firms. Therefore, R&D intensities of larger SSI are lower than its smaller counterparts.

Firm Size, R&D Intensity, Factor Intensity and Factor Productivity

How R&D intensity (expenditure) varies with capital intensity and factor productivities is an issue of significance as far as the relationship between R&D and firm size is concerned. If a firm has to incur more expenditure on R&D, particularly on equipment and machinery, it is very likely that its capital investment will go up. But such R&D investments may enable firms to produce more and be more productive. If that is so, then a larger firm will be more capital-intensive and less R&D-intensive but will have higher factor productivities. These issues are analysed in this section.

R&D intensity versus factor intensity and productivities

The figures on R&D intensity, capital intensity, labour productivity and capital productivity for tiny, smaller and larger SSI sectors are given in Table 12.

A larger SSI firm, on an average, is more capital intensive and less R&D intensive as compared to a smaller and a tiny sized firm. Similarly, a smaller firm, on an average, is more capital intensive and less R&D intensive than a tiny sized firm. Further, a larger sized firm has higher labour productivity and lower capital productivity as compared to a smaller sized firm. That is, the larger the firm size, the higher the capital intensity, the higher the labour productivity, the lower the R&D intensity and the lower the capital productivity. Based on the t-test results, the differences in R&D intensity, capital intensity, labour and capital productivities between tiny and larger SSI sectors are found to be statistically significant, but not so between tiny and smaller SSI and between smaller SSI and larger SSI sectors.

To further determine the relationship between R&D intensity and size as determined by the value of investment and value of output, respectively, and labour and capital productivities, correlation analysis has been done using SPSS (Statistical Package for Social Sciences) package. The results of the analysis are presented in Table 13. As hypothesized earlier, there is a negative correlation between R&D intensity and size, as represented by the value of output as well as value of investment. Though the negative correlation is not high, the relationship is statistically significant. This is quite possible because R&D investments would enable small firms to produce more and R&D expenditure may not increase proportionately with output. Similarly, a larger sized firm may not proportionately increase its expenditure on R&D. With the same percentage of total investment devoted to R&D, a larger firm may be able to perform R&D as effectively as a smaller firm. Therefore, negative correlation between R&D intensity and size (value of investment) is possible.

In the context of SSI firms in Karnataka, there is a negative correlation between R&D intensity and capital productivity and this negative relationship, though very much less, is statistically significant. Further, there is a statistically significant negative correlation between R&D intensity and labour productivity. This is because the larger the size of the firm, the more capital intensive it is, as we have seen earlier. Conversely, this means the larger the size the lower the labour intensity. Therefore, larger the investment, larger the output, but proportionately less labour force implies higher labour productivity.

Thus, on the whole, the larger the size of the firm, the higher the factor productivities and the lower the R&D intensity, there is a negative relationship between R&D intensity and firm size (as measured by the value of output and investment) and between R&D intensity and factor productivities.

Intensities and productivities: important industries

Freeman and Soete (1999), among others, are of the view that the major source of variations in R&D intensity between firms is the industry concerned and therefore, the relationship between firm size and R&D intensity has to be studied industry by industry. If this is true, it will be appropriate to further probe how factor intensity and factor productivities vary with firm size and R&D intensity between industries. In the present analysis we have used only R&D intensity with respect to R&D expenditure. Table 14 presents the estimates of R&D and factor intensities and factor productivities for three major industries-food products, chemicals and machinery and equipment industries.

Table 14 does support the hypothesis that one major source of variation between firm size and R&D intensity is the industry concerned. There is no uniform relationship between R&D intensity and firm size in all three industries. However, as far as capital intensity is concerned, it appears to increase with firm size, in all industries and it is statistically significant (based on the t-test results). But factor productivities present a mixed picture. In the three industries, there does not seem to be any pattern between firm size and factor productivities.

Thus, though capital intensity seems to increase with firm size in all industries, the relationship between firm size and R&D intensity may be more industry specific. Further, it would be very difficult to conclude, based on this evidence, whether factor productivities have any relationship with either capital intensity or R&D-intensity.

It is to further probe the industry-wise relationship between R&D intensity and firm size, and R&D intensity and factor productivities that correlation analysis is done. The results are presented in Table 15. There is a statistically significant relationship between R&D intensity and firm size (as measured by value of investment) only in the chemicals industry. But there is a statistically significant negative relationship between R&D intensity and firm size (as measured by value of output) in all three industries and R&D intensity and capital productivity in the food and machinery industries.

This analysis shows that there is a negative relationship between R&D intensity and firm size (i.e. value of output) not only at the aggregate level but a disaggregated industry-wise picture also substantiates this relationship. That is, the larger the size of output, the lesser the R&D intensity in SSI.

Summary and Conclusions

The relationship between R&D and firm size has been one of the widely discussed yet unresolved research issues. Empirical literature reveals that both large and small firms have advantages as well as disadvantages for carrying out R&D. But, the University of Cambridge (1992) found that major innovations increased with firm size in the Small and Medium Enterprise sector in Great Britain. However, no research has been conducted so far to probe how R&D varies with firm size in the small industry sector in a developing country. The present analysis throws light on these issues with reference to the small industry sector of Karnataka in India.

In Karnataka, within the small industry sector, the larger the size, the greater the probability of a firm engaging in R&D and technological innovations. But firms, irrespective of size, are prompted to perform R&D mainly because of competition. To survive and grow in the competitive environment, firms aim at enhancing their competitiveness through cost reduction, quality improvement and meeting customer requirements by means of R&D.

The majority of firms, irrespective of size, perform R&D through self-efforts. The role of external sources for technological support is minimum, particularly from national and international agencies. However, individuals, i.e. friends, relatives and consultants, play an important role in providing technical advice and other technical inputs. Given the objectives of R&D, quality improvement, changing product shapes/dimensions and solving common problems in a novel way are the major R&D activities performed by firms, irrespective of size. Of course, the development of new products and processes seems to be more important in the larger SSI sector as compared to tiny and smaller SSI sectors.

As far as R&D inputs are concerned, on an average, a larger sized firm has more full-time R&D staff and incurs more R&D expenditure, including capital expenditure. This indicates that, on an average, a larger sized firm is more R&D-oriented than a smaller or a tiny sized firm. But the full-time R&D staff as a proportion of total employment and total R&D expenditure as a proportion of annual turnover declined with firm size. This gave the impression that there is a negative relationship between firm size (as measured by investment) and R&D intensities. Even the correlation analysis showed that this negative relationship, though statistically significant, is not very high.

According to the correlation analysis, there is a statistically significant negative relationship between R&D intensity and firm size (as measured by value of output) not only at the aggregate level but also at the disaggregated industry levels. Further, it is found that there is a negative relationship between R&D intensity and factor productivities. But an industry-wise analysis could prove such a relationship only for capital productivity in food products and machinery industries.

The question is why R&D intensity should decrease with an increase in firm size (as measured by value of output) and factor productivities. This is because the nature of R&D activities, by and large, are similar across firms of different sizes and are confined mainly to product quality improvement, changing product shapes/dimensions and overcoming common problems. Naturally, a larger firm would require a smaller proportion of its total labour force and spend a smaller proportion of its turnover for such R&D activities. Therefore, there seems to be a negative relationship between R&D intensity and firm size (i.e. value of output) and this holds good for industries.

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TABLE 1: Industry-Wise Distribution of SSI Units: Non-Tiny and Tiny Sectors

Sl. No	National Industrial Classification (N.I.C.) Code	Industry	Non-tiny Sector	Tiny Sector
1	20-21	Food products	389	144
2	22	Beverages, tobacco, & tobacco products	5	1
3	23	Cotton textiles	20	8
4	24	Wool silk and man made fibre textiles	12	7
5	25	Jute and other veg. fibre	11	1
6	26	Textile products	45	12
7	27	Wood products	19	22
8	28	Printing and publishing	55	23
9	29	Leather products	10	2
10	30	Chemical products	69	28
11	31	Rubber, plastic, petroleum, etc.	117	59
12	32	Non-metallic mineral products	110	57
13	33	Basic metal and alloys	37	17
14	34	Metal products	143	83
15	35-36	Machinery and equipment	166	102
16	37	Transport equipment	63	21
17	38	Other manufacturing industries	51	35
18		Other service industries	36	26
		Total	1358	648

TABLE 2: Firm Size Groups in Small Industry

Group	Investment Range - in Million Rs.	Number of Firms
1	Up to 0.5 (US \$12000)	179
2	0.5 - 2.5 (US \$12000 up to US \$60000)	469
3	2.5 - 6.0 (US \$60000 up to US \$0.144 million)	923
4	6.0 - 10.0 (US \$0.144 million up to US \$0.240 million)	249
5	10.0 - 30.0 (US \$0.240 million up to US \$0.720 million)	186

Note: Indian Rupees have been converted into US \$ at the official exchange rate of Indian rupee as in 1998 - 99, in this paper

TABLE 3: R&D Activities: Possible Dimensions in SSI

Sl. No.	Possible Dimension
1	Developing new product
2	Developing new process
3	Changing product performance/quality by technical efforts
4	Using alternate/new raw material
5	Changing product shape/dimension to suit customer/market needs
6	Modifying existing machinery
7	Adopting new methods of fabrication, testing, operation, etc. for the first time
8	Solving commonly encountered problems in a novel way

TABLE 4: Firm Size and R&D Versus Non-R&D

Firm Size	Investment Range (Rs. Million)	No. of R & D Firms			No. of Non-R&D Firms	Total No. of Firms	Ratio of R&D Firms
		Formal	Informal	Total			
Tiny SSI	Up to 0.5	5	12	67	112	179	37:63
	> 0.5 up to 2.5	8	183	91	278	469	41:59
Smaller SSI	> 2.5 up to 6.0	27	403	430	493	923	47:53
	> 6.0 up to 10.0	22	124	146	103	249	59:41
Larger SSI	> 10.0 up to 30.0	23	117	140	46	186	75:25

TABLE 5: Firm Size and R&D: Major Casual Factors

Factors	Number of Firms under the Firm Size (Investment in Rs. Million)				
	Tiny SSI		Smaller SSI		Larger SSI
	Up to 0.5	> 0.5 up to 2.5	> 2.5 -6.0	> 6.0 -10.0	> 10.0-30.0
Competition	43	145	312	101	88
Technology Change	33	111	201	76	76
Self-Motivation	30	79	223	71	66
User Signal	32	103	189	59	61
Total No. of R&D Firms	67	191	430	146	140

TABLE 6: Firm Size and R&D: Major Objectives

Objectives of R&D	Number of Firms under the Firm Size (Investment in Rs. million)				
	Tiny SSI SSI		Smaller SSI		Larger SSI
	Up to 0.5	> 0.5 up to 2.5	> 2.5 -6.0	> 6.0 -10.0	> 10.0-30.0
Quality Improvement	59	174	380	128	120
Cost Reduction	51	156	344	115	106
Satisfy Customer Needs	51	145	306	102	102
Overcoming Process Problem	30	106	220	78	79
Exploit Market Opportunity	32	91	173	62	61
Expansion/ Diversification	27	78	145	47	50
Total No. of R&D Firms	67	191	430	146	140

TABLE 7: Firm Size and R&D: Sources

Sources	Number of Firms under the Firm Size (Investment in Rs. million)				
	Tiny SSI SSI		Smaller SSI		Larger SSI
	Up to 0.5	> 0.5 up to 2.5	> 2.5 -6.0	> 6.0 -10.0	> 10.0-30.0
Self-effort	54	185	399	135	119
National	11	21	37	7	8
International	0	1	7	3	6
Parent Company	2	15	31	15	18
Other Sources	8	56	178	21	20
Total No. of R&D Firms	67	191	430	146	140

TABLE 8: Nature of R&D Activities and Firm Size

R&D Activities	No. of Firms under the Firm Size (Investment in Rs. million)				
	Tiny SSI		Smaller SSI		Larger SSI
	Up to 0.5	> 0.5 up to 2.5	> 2.5 -6.0	> 6.0 -10.0	> 10.0-30.0
Changing Product Performance/Quality	44	152	297	107	95
Solving Common Problem	39	135	281	85	89
Changing Product Shape/Dimension	33	125	257	80	79
Developing New Processes	26	83	233	76	82
Using Alternate/ New Material	31	92	198	73	66
Developing New Products	35	76	181	72	62
In-house Innovations	26	79	176	65	68
Modifying Existing Machinery/Equipment	23	70	164	74	65
Total No. of R&D Firms	67	191	430	146	140

TABLE 9: Firm Size and R&D Personnel

Firm Size	Total No. of R&D Firms	No. of R&D Firms having full-time R&D Staff	Full-time R&D Staff (No. of employees)	R&D Personnel per firm
Tiny SSI	258	114	255	2.24
Smaller SSI	576	257	935	3.64
Larger SSI	140	63	401	9.24

TABLE 10: Firm Size and R&D Expenditure (Rs. million): 1998-99

Firm Size	R&D Expenditure							
	Training/ Consultancy		Equipments/ Machinery		Labour/ Material		Total	
	No. of Firms	Expen- diture	No. of Firms	Expen- diture	No. of Firms	Expen- diture	No. of Firms	Expen- diture
Tiny SSI	49	9.02 (0.22)	30	2.03 (0.049)	181	1.94 (0.047)	181	12.99 (0.31)
Smaller SSI	141	17.28 (0.41)	71	17.12 (0.41)	469	45.93 (1.10)	469	80.33 (1.93)
Larger SSI	40	6.44 (0.15)	33	9.50 (0.23)	40	26.84 (0.64)	111	42.78 (1.03)

Note: Figures in parentheses are in U.S. \$ million.

TABLE 11: Firm Size and R&D Intensity: 1998-99

Firm Size	R&D Labour				R&D Expenditure*			
	No. of Firms	Full-time R&D Staff (No.)	Total Employment (No.)	R&D Intensity (R&D Staff as percent of Total Employment)	No. of Firms	Total R&D Expenditure (Rs. Million)	Value of Output (Rs. Million)	R&D Intensity (R&D Expenditure as percent of Value of Output)
Tiny SSI	258	255	2293	11.12	157	12.44 (0.30)	1257 (30.17)	0.99
Smaller SSI	576	935	8637	10.83	436	73.65 (1.77)	8183 (196.38)	0.90
Larger SSI	140	401	4877	8.22	103	41.37 (0.99)	6464 (155.12)	0.64

* Only those firms which provided information on the value of output are taken into consideration for the analysis.

Note: Figures in parentheses are in U.S. \$ million.

TABLE 12: Firm Size, R&D Intensity, Factor Intensity and Factor Productivities: 1998-99

Firm Size	No. of Firms	R&D Intensity	Capital Intensity	Labour Productivity	Capital Productivity
Tiny SSI	153	0.92	0.73	4.37	6.02
Smaller SSI	431	0.90	1.43	5.13	3.59
Larger SSI	103	0.61	2.55	7.89	3.09

Note: Only firms which have provided information on R&D investment employment and output are considered for analysis

TABLE 13: Correlation Coefficients between R&D Intensity and Investment, Output and Factor Productivities

Explanatory Variables	1998 - 99
Size (value of output)	-0.229**
Size (value of investment)	-0.144**
Labour productivity	-0.142**
Capital productivity	-0.104**

** Correlation is significant at the 0.01 level (2-tailed)

TABLE 14: Firm Size, R&D and Factor Intensities and Factor Productivities in Major Industries

Industry/Firm Size	No. of Firms	R&D Intensity	Capital Intensity	Labour Productivity	Capital Productivity
<u>Food Products</u>					
Tiny SSI	16	0.35	0.64	5.44	8.47
Smaller SSI	58	0.62	1.63	9.62	5.89
Larger SSI	11	0.22	4.42	18.43	4.17
<u>Chemicals</u>					
Tiny SSI	14	3.05	0.81	3.48	4.30
Smaller SSI	31	0.90	2.13	10.38	4.86
Larger SSI	11	1.00	4.30	12.37	2.88
<u>Machinery & Equipments</u>					
Tiny SSI	30	1.04	1.13	6.58	5.82
Smaller SSI	77	1.10	1.32	4.82	3.65
Larger SSI	19	0.62	1.63	5.56	3.41

Note: Only those firms that have double digit number of firms in all the three sectors are considered for the analysis.

TABLE 15: Correlation Coefficients between R&D Intensity and Investment, Output & Factor Productivities: 1998-99

Explanatory Variables	Food Products Industry	Chemicals Industry	Machinery
Size (Value of Output)	-.273*	-.281*	-.216*
Size (Value of Investment)	-.166	-.278*	-.105
Labour Productivity	-.213*	-.189	-.073
Capital Productivity	-.269*	-.163	-.195*

* Correlation is significant at the 0.05 level (2-tailed)

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