

Inter-relations among Innovation Performance Variables: Results from Empirical Evidence of Indian Manufacturing Firms

J.S.A.Bhat^a, Sushil^b, P.K. Jain^c

^aDepartment of Scientific & Industrial Research, Ministry of Science & Technology,
Government of India
Technology Bhawan, New Mehrauli Road, New Delhi 110 016
Email: jsabhat@nic.in

^bProfessor, Department of Management Studies, Indian Institute of Technology,
Vishwakarma Bhawan, New Mehrauli Road, New Delhi – 110 016
Email: sushil@dms.iitd.ac.in

^bProfessor, Department of Management Studies, Indian Institute of Technology,
Vishwakarma Bhawan, New Mehrauli Road, New Delhi – 110 016
Email: pkjain@dms.iitd.ac.in

Abstract

With growing realization of the significant impact that innovation performance has on overall firm performance, the need to focus on different measures of innovation performance has been acquiring increasing importance in recent years. Historically, innovation performance in firms had been measured through input related measures such as amount of R&D expenditure, R&D intensity (expenditure as a percentage of sales) and number of scientific/technical personnel. More recently, output indicators and of late, process indicators are being increasingly used to achieve a better quantification of innovation performance. This paper identifies innovativeness, new product/service, managerial process improvement and production process improvement as the key variables of innovation performance. It aims to derive the key inter-relationships among these major variables of innovation performance in firms, using data drawn from an opinion survey among manufacturing firms in India. The importance of new product development skills in enhancing innovation performance is revealed.

Introduction

Background. Firms are well aware that innovation performance has a significant impact on overall firm performance. Historically, innovation performance in firms had been measured through input related measures such as amount of R&D

expenditure, R&D intensity (expenditure as a percentage of sales) and number of scientific/technical personnel. More recently, output indicators and of late, process indicators are being increasingly used to achieve a better quantification of innovation. This paper identifies *innovativeness, new product/service, managerial process*

improvement and *production process improvement* as the key variables of innovation performance and studies the inter-relationships among these variables.

Innovation. The broad definition of innovation has been provided by the National Knowledge Commission, Government of India (2007); as per the Commission, it is a process by which “(i) introduction of new or improved goods or services and/or (ii) implementing new or improved operational processes and/or (iii) implementing new or improved organizational/managerial processes” can be planned and achieved, resulting in value enhancement for generators and/or users. This definition has been used (in adapted form) in this paper.

The process of innovation is thus multi-faceted involving several dimensions that need be meshed in an integrated manner.

Innovation Performance Measures. There have been several studies that have examined how innovation performance in a firm can be measured *per se*. Input related measures were among those most popularly used. Prime among input related measures are amount of R&D expenditure, R&D intensity (expenditure on R&D as a percentage of sales) and number of scientific/technical personnel (OECD 2002). For instance, Harhoff (1998) has suggested use of R&D expenditure, while Adams (1990) has preferred number of R&D personnel.

Output measures then came to be introduced with the realization that new products or processes or technologies are tangible and are outcome of innovation efforts. Thus, a study on innovation and business performance in the Canadian biotechnology industry has used R&D intensity and new product introductions as the principal measures of innovation effectiveness (Hall and Bagchi-Sen 2002).

With rising awareness of the importance of intellectual property in enhancing innovation performance and driving competitive advantage, output measures related to intangible property came to be used as proxies of innovation performance. Patents and patent citations are among the most often cited measures of innovation performance (Katila 2000; Neely 2002; Archibugi 1992). Scientific or technical reports and publications are other considered measures. A survey of high-tech companies in Taiwan brought out that a higher level of sophistication in innovation and R&D management practice does lead to better innovation performance as measured by the number of new products, patents and technical reports (Huang and Lin 2006).

These traditional forms of measuring innovation performance continue to be used. Even now, investments in formal R&D and number of patent grants continue to be used to estimate innovation performance (NESTA 2007).

But these methods are not applicable to a whole range of industries, including the service sector, which are either not very technology-intensive or where the knowledge generated is not readily codifiable. In such industry sectors, number of patents or R&D personnel or even quantum of R&D expenditure are not considered to be suitable proxies.

Mainly on account of these reasons, process indicators have come to be used to achieve a better quantification of innovation in a more universal manner. For example, Bernstein and Nadiri (1991) have used process improvements that result in reduced costs of production or product innovation that lead to increase in the profit margin on sales as measures. Examples of other process measures used include percentage of profits or sales from products introduced during the last X (usually 3 or 5) years, percentage of profits or sales from patents (Griffin and Page 1993).

Kuczarski (2000) has conceived several measures related to the technical performance of new products developed; inclusive of return on innovation investment (research costs + development costs + incremental production costs + initial commercialization pre-launch costs), new product success rate, number of new products commercialized during the last 3 years, number of new products remaining in the market during a given timeframe and number of new products launched in a timely manner (time to market). Measures of project management skills and management process improvements have also been put to use in conjunction with these measures for assessing innovation performance across several kinds of industry sectors (AD Little 2005; Damanpour 1991).

Thus, it is apparent that input, output as well as process related measures are in vogue, as proxies of innovation performance.

Innovation Performance Related Variables. It is evident from the above discussion that no single measure can provide a clear appreciation of innovation performance; rather an integrated measure accounting for more than one attribute would provide a better quantification. Thus, in this research, the following variables from among those discussed above have been taken up for study, in preference to the traditional measures such as R&D intensity, publications, patents or others mentioned.

(i) **Innovativeness:** The innovativeness of a firm is assumed to be a key variable impacting the innovation performance of a firm. This is a reflection of an organization's tendency to innovate, to be original and to introduce new ideas.

(ii) **New Product/Service:** This refers to the firm's capability to generate new products or services.

(iii) **Managerial Process Improvement:** Managerial process improvement refers to that attribute of innovation performance of a firm,

which reflects the capability to improve existing innovation related managerial processes in the firm.

(iv) **Production Process Improvement:** The improvements made in the production processes resulting in better products or services offered by a firm are assumed to be important attributes of its innovation performance. Improvements could result in lower costs, improved quality through better features, or improved delivery.

Purpose and Organization of Paper

Objective. The objective of this paper is to study the inter-relationships among these four identified variables that together represent an integrated measure of innovation performance in firms.

Evidence has been gathered from empirical analysis based on an opinion survey of manufacturing firms in India.

Structure of the Paper. The broad rationale used in this paper is presented in the initial section; covering the background and an introduction to the basic concepts. In the next section, the approach and methodology followed in the paper to interpret the data has been delineated, while the following section reports the major findings. Finally, the conclusions and limitations of the paper are as enumerated in the last section.

The Approach

Cross-sectional survey methodology and purposive sampling, targeting the top management (managing directors/chief executive officers or executives designated by them) of 150 Indian manufacturing firms fulfilling specific financial performance criteria, have been used. Firms covered are those with highest financial performance (basis: highest Return on Total Assets during 2006-07 and 2007-08) selected from among

top performing Indian firms during 2008 (basis for top performance: market perception measured by highest average market capitalization in 2007-2008). The sectors covered are (i) auto and auto components manufacturing (private sector); (ii) chemicals, drugs and pharmaceuticals (private sector); (iii) general engineering (private sector) and (iv) general engineering (public sector). The study has thus focused upon Indian manufacturing firms with above average, consistent financial performance in these sectors.

The questionnaire has been structured to address the relationships to be studied among the variables identified in the first section. *Face validity* of the questionnaire has been established by consulting seven experts, comprising three from academic institutions and four from industry. Next, *criterion validity* of the questionnaire has been tested to ensure its predictive validity using the same set of experts. The suggestions made by the experts has been incorporated in the questionnaire, included some changes in the language and sequencing. Principal Component Factor Analysis has also been done to validate the constructs. Next, the reliability of the questionnaire had been assessed by computing the Cronbach Alpha values to test internal consistencies.

The questionnaire has further been refined through pilot testing in four select firms. After incorporation of the emerging suggestions, the questionnaire has been administered systematically to the entire targeted sample.

Data collected from each firm covers its perceptions about its innovation performance using a 7-point Likert scale (1: strongly disagree to 7: strongly agree). Suitable statistical techniques have been opted for analysis of the data, using SPSS 11.0 version.

In order to examine whether significant differences were there between the sectors of industry in the sample, one-way Analysis of Variance (ANOVA) tests have been conducted. After eliminating scope for noteworthy differences among the four broad sectors of industry, the relationships between the innovation performance variables have been examined in depth using stepwise regression analysis.

Results and Discussion

69 complete responses have been received out of the 150 firms that had figured in the sample. Checks for outliers, normality and linearity to satisfy the underlying assumptions of the analysis techniques applied have been made. The profile of the 69 firms is indicated in Figure 1.

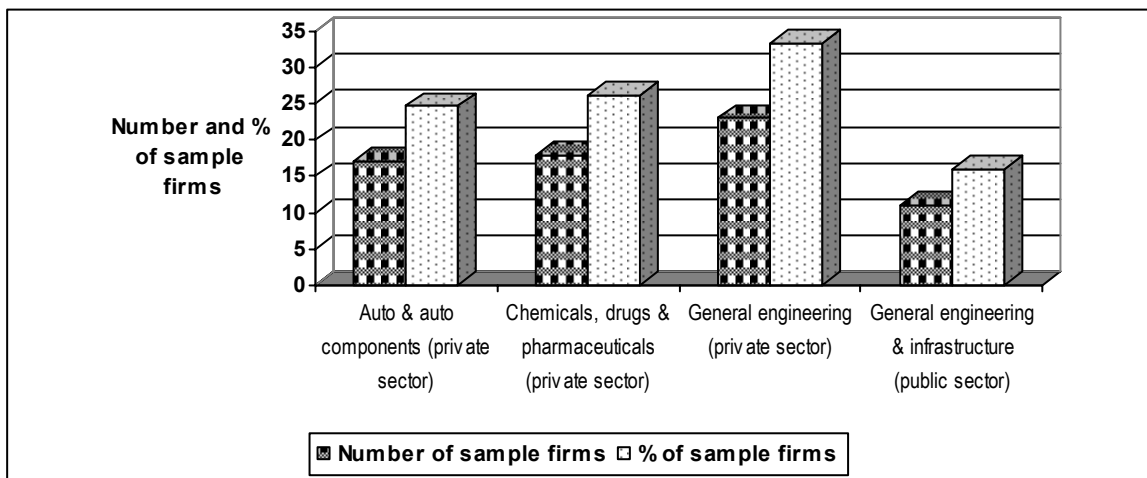


Figure 1: Profile of Sample Companies.

It has been observed that there is a comparable as well as adequate representation from all the groups; there are seventeen from the auto and auto components (private) sector, eighteen firms from the chemicals, drugs and pharmaceuticals (private) sector, twenty-three firms from the general engineering (private) sector and eleven firms from the general engineering and infrastructure (public) sector.

From the *construct validity tests* conducted to test the internal validity of the constructs, it was observed that the cumulative percentage values of the factor loadings were ranging between 63.491 and 89.829; both well above the recommended cut off of 50 per cent. Thus, no construct was excluded and the questionnaire, as a whole, stood validated.

From the reliability tests, it was observed that the Cronbach Alpha values ranged from 0.7911 to 0.9603. Both these values being well above the accepted criterion for internal consistence of 0.701, the reliability of the constructs was established.

Hypotheses of difference between the four sectors have been tested using one-way

ANOVA. The significance level of all the variables was observed to be greater than 0.01 (99 per cent significance) and the F value (observed) was lower than the F value (critical) for all the variables studied, thus establishing that there is no significant difference between the various sectors and the sample can be treated as a single homogenous whole for the variables being studied.

Inter-Dependencies amongst Innovation Performance Variables. To determine the interdependencies between the Innovation Performance variables and understand the inter-relationships amongst them; stepwise regression analysis has been carried out in respect of each of the four variables.

Analysis Results. Table 1 is a summary of the analysis results taking each of the Innovation Performance variables to be the dependent variable, and the remaining three variables as independent variables.

Table 1: Regression Model Summary for Inter-Relations amongst Variables

Dependent Variable	R	R Square	Std. Error of the Estimate	Predictors: (Constant)	Unstandardized Coefficient		Standardized Coefficients	t	Sig.
					B	Std. Error			
Innovative-ness	.742	.551	.63626	New Product/Service	.454	.135	.420	3.365	.001
				Managerial Process Improvement	.347	.116	.373	2.991	.004
New Product/Service	.834	.695	.48803	Production Process Improvement	.402	.105	.399	3.820	.000
				Managerial Process Improvement	.267	.093	.311	2.879	.005
				Innovativeness	.205	.092	.222	2.218	.030
Managerial Process Improvement	.802	.643	.61573	New Product/Service	.424	.147	.364	2.879	.005
				Innovativeness	.274	.116	.254	2.356	.021
				Production Process Improvement	.317	.141	.271	2.245	.028
Production Process Improvement	.799	.638	.52458	New Product/Service	.522	.111	.526	4.692	.000
				Managerial Process Improvement	.277	.096	.325	2.898	.005

New Product/Service followed by Managerial Process Improvement have been identified as the vital predictors of Innovativeness. R square value of .551 indicates that these variables influence Innovativeness to the extent of 55.1 per cent. The beta values of these variables have been observed to be .420 and .373 respectively. The B values at .454 and .347 indicate a more significant influence by the former and a moderate impact by the latter variable. New Product development (NPD) and better managerial processes are expected to enhance the innovative capabilities of the firm.

Production Process Improvement followed by Managerial Process Improvement and Innovativeness are the vital predictors of New Product/Service, as identified by this analysis. These variables have been observed to influence New Product/Service to the extent of 69.5 per cent. The first variable impacts to the extent of .402 whereas the influence of the

The impact if New Product/Service is indicated to be much higher as compared to that of the second variable as brought out by the B values of .522 and .277 respectively. When new products are developed, it seems to result in improved production processes.

remaining variables are .267 and .205 respectively, as brought out by the B values. Improvements in the firm's production processes seem to enable NPD.

New Product/Service followed by Innovativeness and Production Process Improvement are indicated as the vital predictors of Managerial Process Improvement. The impact of these variables on Managerial Process Improvement is seen to be fairly significant to the extent of 64.3 per cent. The beta values are seen to be .364, .254 and .271. All the three variables are having a comparable impact as evident from the B values that are .424, .274 and 317 respectively. Innovation related activities seem to enhance managerial processes.

New Product/Service followed by Managerial Process Improvement are observed to be the vital predictors of Production Process Improvement impacting to the extent of 63.8 per cent.

Model for Inter-relations among Innovation Performance Variables. Figure 2 depicts the inter-relations amongst the Innovation Performance variables as derived from the above discussion.

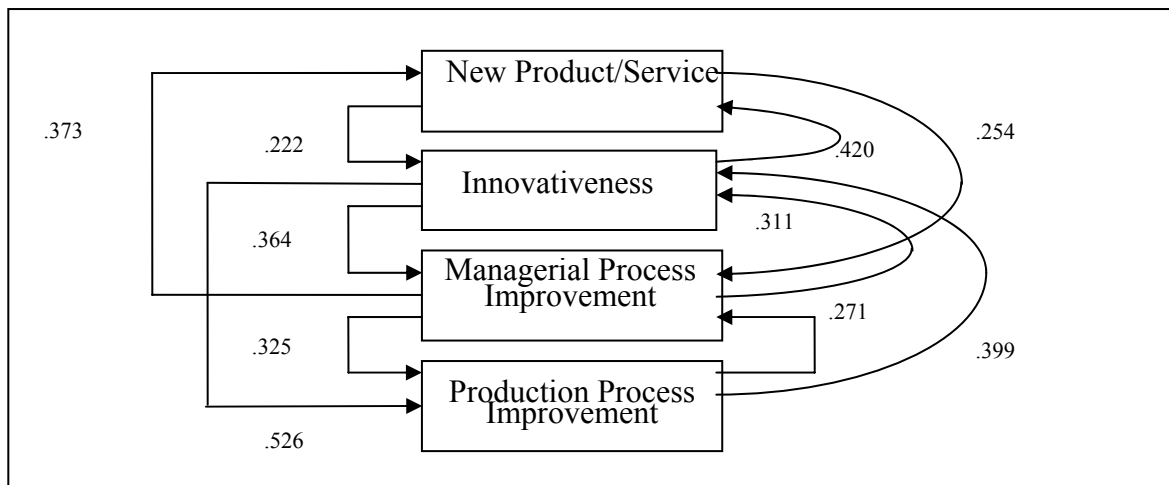


Figure 2: Inter-relations amongst Innovation Performance Variables

It is evident that each of the Innovation Performance variables is linked to two or more of the other remaining three variables. The degree of influence is also indicated in the Figure. Thus, innovation performance is to be interpreted in totality rather than in a piecemeal manner. It further emerges that among the four variables, New Product/Service is predicted to wield the maximum influence. Its impact is highest on Production Process Improvements, although it also influences the remaining variables. Thus, development of new products results in improvement in managerial processes as well as production processes, apart from the innovative capabilities of the firm.

Conclusions

Innovation performance in firms can be quantified as a single integrated measure of the firm's innovativeness, its capabilities to develop new products and services, improve existing innovation related managerial processes and production processes resulting in lower costs, improved quality through better features, or improved delivery. Development of new products and services has the most significant impact on innovation performance.

These conclusions have been deduced based on the perceptions of the top management of a select group of Indian manufacturing firms that have been performing exceedingly well financially during successive years 2006-07 and 2007-08. Any bias seen to emanate on account of this may be construed to be a limitation of this paper.

References

AD Little, *Innovation Excellence: How Companies use Innovation to Improve Profitability and Growth*. Arthur D Little, www.adlittle.com, 2005 [Accessed 8-December-2009].

- Adams, J.D., "Fundamental Stocks of Knowledge and Productivity Growth." *Journal of Political Economy*, 1990, 98/4, pp. 673-703.
- Archibugi, D., "Patenting as an Indicator of Technological Innovation: A Review." *Science and Public Policy*, 1992, 6, pp. 357-358.
- Bernstein, J.I. and Nadiri, M.I., "Product Demand, Cost of Production, Spillovers, and the Social Rate of Return to R&D." *NBER Working Paper 3625* (February 1991).
- Damanpour, F., "Organizational Innovation: A Meta-analysis of Effects of Determinants and Moderators." *Academy of Management Journal*, 1991, 34/3, pp. 555-590.
- Griffin, A. and Page, AL., "An Interim Report on Measuring Product Development Success and Failure." *Journal of Product Innovation Management*, 1993, 10, pp. 291-308.
- Hall, L.A. and Bagchi-Sen, S., "A Study of R&D, Innovation, and Business Performance in the Canadian Biotechnology Industry." *Technovation*, 22/4, 231-244, 2002.
- Harhoff, D., "Vertical Organization, Technology Flows and R&D Incentives: An Exploratory Analysis." *CIG Working Papers FS IV 98-02*, Research Unit: Competition and Innovation (CIG), Wissenschaftszentrum Berlin (WZB), 1998.
- Huang, E.Y. and Lin, S., "How R&D Management Practice Affects Innovation Performance: An Investigation of the High-tech Industry in Taiwan." *Industrial Management and Data Systems*, 2006, 106/7, pp. 966 - 996.
- Katila, R., "Using Patent Data to Measure Innovation Performance." *International Journal of Business Performance Management*, 2000, 2/1-2-3, pp. 180-193.

Kuczmariski, T.D., "Measuring your Return on Innovation." *Marketing Management*, 2000, 9/q, 24-32.

National Knowledge Commission, *Innovation in India*. <http://knowledgecommission.gov.in/downloads/documents/NKC_Innovation.pdf>, 2000 [Accessed 15-September-2008].

Neely, A., *Business Performance Measurement: Theory and Practice*. Cambridge University Press, New York, USA, 2002.

NESTA, *Hidden Innovation*. Report no. June 2007, National Endowment for Science, Technology and the Arts, London, UK, 2007.

OECD Economics Department (Ahn, S.), *Competition, Innovation and Productivity Growth: A Review of Theory and Evidence*. OECD No. 317, 17/01/2002.

authored several text and research books and has published around 100 research papers in national and international journals.

Biographies

J.S.A. Bhat is a Scientist in the Ministry of Science & Technology, Government of India. In her professional work spanning research, industry and Government experience, she has dealt with different facets of innovation management and technology transfer at the micro and macro levels.

Prof. Sushil, currently Professor of Strategic Management in the Department of Management Studies, IIT Delhi, has several publications and a number of books to his credit. He specializes in flexible systems management, strategic change and flexibility, technology management. He is the founder president of Global Institute of Flexible Systems Management and life member of several other national and international bodies.

Prof. P.K. Jain, currently Professor of Finance and Modi Foundation Chair Professor at Department of Management Studies, IIT, Delhi, has a long teaching experience in finance and accounting related subjects. He has been associated with many research and consultancy projects in these fields. He has authored/co-