# Sources of Innovation : An Economic Analysis


Ira R. Bidkar


Himalaya Publishing House
BOMBAY • NAGPUR • DELHI

*Published by:* Mrs. Meena Pandey *for*
**HIMALAYA PUBLISHING HOUSE**
*Head Office*
"Ramdoot", Dr. Bhalerao Marg
Girgaon (Kelewadi)
Bombay-400 004.
Phones: 363863 360170

*Branch Office*
"Pooja Apartment" 4-B Murari Lal Street
Ansari Road, Daryaganj
New Delhi-110 002
Phone: 270392

Prof. Raghbendra Jha has acted as Research Consultant on behalf of ICSSR, New Delhi, for the publication of this book and suggestions made by him have been incorporated.

The Indian Council of Social Science Research gave the financial support towards the publication of this work. However, the responsibility for the contents of the book— facts, opinions, conclusions, etc.—is entirely that of the author and not of the ICSSR.

*First Edition* : *1991*

ISBN-81-7040-275-1

*Printed at* :
Sanjeev Printers
Babarpur Road, Shahdara, Delhi-110032.

# SOURCES OF INNOVATION : AN ECONOMIC ANALYSIS

# *Preface*

Seminal contributions in the midfifties established the pre-eminence of technical change as a factor in economic growth. Since then, the study of dynamics of technical change both at the aggregate and the firm level has been a major concern of economists in the developed countries. However, similar studies relating to developing countries have been relatively scanty although such an understanding is much more crucial to their economic growth. This study raises and explores some of these issues.

The research, a revised version of my doctoral dissertation, is an outgrowth of my interest in teaching the course 'Science, Technology, and Society' to the B. Tech. students at I.I.T., Bombay. But for the facilities and the infrastructure available at I.I.T., Bombay, this research would have been impossible.

The revision was completed during my tenure as Visiting Fellow at the Indira Gandhi Institute of Development Research (IGIDR). I am indebted to Prof. Kirit Parikh, Director, IGIDR, for providing me the opportunity and encouragement.

I am deeply grateful to my thesis supervisor Prof. M. J. M. Rao for providing guidance and encouragement at various stages of my work. His expertise and insights were of invaluable help in resolving many issues of econometric analysis and interpretation.

I wish to express my deep gratitude to the members of my thesis committee, Prof. D. U. Sastry and Prof. K. L. Krishna, for their valuable comments and keen interest in my work.

I owe an equal debt of gratitude to the late Dr. Narottam Shah, former Director, Centre for Monitoring Indian Economy, who generously granted me access to the relevant literature and facilities at the CMIE and was a source of support and encouragement.

I am indebted to the senior executives of the firms who provided information and spent considerable amount of time and resources helping me obtain the required data.

I thank Professor R. E. Bedford, former Deputy Director, I.I.T., Bombay, for granting financial assistance for printing the questionnaire. I also thank Prof. H. N. Pathak who took keen interest in my work and provided valuable suggestions.

I acknowledge and appreciate the assistance given by the entire staff of the Electronic Data Processing Centre, University of Bombay, and particularly, P. S. Philip, who provided prompt and efficient computer service and advice.

I gratefully acknowledge the services rendered by the library staff at I.I.T., Bombay, and IGIDR. I wish to record my gratitude to the late Dr. V. N. Misra, Librarian, I.I.T., Bombay, and Mr. Railkar, Librarian, IGIDR, for prompt an defficient service.

I thank my son, Urvish Bidkar, for assisting me in additional computer work despite the pressures of his B. Tech. programme at I.IT., Bombay.

Special thanks is due to Mr. Kunju for typing the manuscript expeditiously and neatly.

The responsibility for any errors or omissions that still remain is entirely mine.

Ira R. Bidkar

## TABLE OF CONTENTS


| *Chapter* | | | *Page* |
|---|---|---|---|
| | **Preface** | ... | *v* |
| **1.** | **The Problem** | | |
| | 1.1. Introduction | ... | 1 |
| | 1.2. Definitions and Concepts | ... | 2 |
| | 1.3. Alternative Analytical Approaches | ... | 3 |
| | 1.4. Some Observations on the Data and Methodology | ... | 6 |
| | 1.5. Interpretation of Empirical Evidence—Some Caveats | ... | 9 |
| | 1.6. An Outline of the Study | ... | 10 |
| **2.** | **The Role of Research and Development in the Innovation Process** | ... | 10 |
| | 2.1. Introduction | ... | 10 |
| | 2.2. Review of Empirical Research | ... | 10 |
| | 2.3. Issues Analyzed | ... | 14 |
| | 2.3.1. How Important is R and D to Innovation? | ... | 14 |
| | 2.3.2. R and D and Technological Selfreliance | ... | 16 |
| | 2.3.3. Determinants of R and D Expenditure | ... | 17 |
| | 2.3.4. The Role of the Size Factor in R and D | ... | 17 |
| | 2.4. Hypotheses, Empirical Evidence, and Interpretation | ... | 17 |
| | 2.4.1. The Importance of R and D in Innovative Activity | ... | 18 |
| | 2.4.2. Technological Self-reliance, R and D, and Innovation | ... | 24 |
| | 2.4.3. Determinants of R and D Expenditure | ... | 29 |

| Chapter | | Page |
|---|---|---|
| | 2.4.4. The Role of the Size Factor in R and D... | 30 |
| | 2.4.5. Conclusions—Econometric Analysis ... | 31 |
| 2 5. | Descriptive Evidence on Some Aspects of R and D in the Sample of Indian Firms ... | 32 |
| | 2.5.1. R and D in Indian Firms : Concepts, Activities and Objectives ... | 32 |
| | 2.5.2. R and D in Indian Firms : Allocation of Resources and Output ... | 35 |
| | 2.5.3. R and D in Indian Firms : Determinants and Constraints ... | 38 |
| | 2 5.4. R and D in Indian Firms : Dynamic Strategies ... | 39 |
| | 2.5.5. R and D in the Sample of Indian Firms :An Assessment ... | 40 |
| 3. | **Market Structure, R and D and Innovation** | |
| 3.1. | Concepts and Definitions ... | 44 |
| 3.2. | Controversy Regarding the Direction of Causality ... | 46 |
| 3.3. | Review of Literature on Market Structure as a Causal Factor ... | 47 |
| | 3.3.1. The Debate : Competition Versus Monopoly ... | 47 |
| | 3.3.2. Empirical Evidence on the Debate ... | 48 |
| | 3.3.3. Empirical Studies Relating to Neo-Schumpeterian Hypotheses ... | 50 |
| 3.4. | Limitations of Empirical Research ... | 51 |
| | 3 4 1. The Problem of Simultaneity ... | 51 |
| | 3.4.2. Is the Debate Meaningful ? ... | 52 |
| 3.5. | Qualitative Ananlysis of Market Structure and Innovation ... | 53 |
| 3.6. | Hypotheses Tested ... | 54 |
| 3.7. | Empirical Evidence and Interpretation ... | 55 |
| 3.8. | Conclusions ... | 62 |

| Chapter | | Page |
|---|---|---|
| **4.** | **Market Demand, Relative Factor Prices and Innovation** | |
| 4.1. | Introduction ... | 63 |
| 4.2. | The Demand-pull Model ... | 63 |
| | 4.2.1. The Demand-pull Hypothesis ... | 65 |
| | 4.2.2. Empirical Evidence on the Demand-pull Hypothesis ... | 65 |
| | 4.2.3. Innovation and Market Demand—A Qualitative Assessment ... | 66 |
| 4.3. | Relative Factor Prices and Inducement Mechanism ... | 66 |
| | 4.3.1. The Theoretical Debate ... | 67 |
| | 4.3.2. Empirical Verification of the Theory of Induced Innovation ... | 71 |
| | The Induced Innovation Hypotheses ... | 74 |
| | 4.4.1. Empirical Evidence on Induced Innovation, Inducement Mechanism and Constraints ... | 75 |
| 4.5. | Conclusions ... | 77 |
| **5.** | **Risk, Incentive to Invest, Availability of Finance, and Innovation** | |
| 5.1. | Introduction ... | 79 |
| 5.2. | Major Issues in the Debate ... | 79 |
| 5.3. | An Outline of Empirical Investigation ... | 83 |
| 5.4. | Empirical Evidence on the Arrow Hypotheses ... | 84 |
| 5.5. | Availability of Finance ... | 86 |
| | 5.5.1. Evidence on Finance as a Constraint ... | 87 |
| 5.6. | Conclusions ... | 88 |
| **6.** | **Governmental Regulation, R and D and Innovation** | |
| 6.1. | Introduction ... | 89 |
| 6.2. | The Indian Scene ... | 90 |
| 6.3. | Empirical Evidence ... | 94 |
| 6.4. | Taxation Policies ... | 102 |
| 6.5. | Other Controls ... | 104 |

*Chapter* *Page*

**7. The Determinants of R and D and Innovation : An Overview**

7.1. Introduction ... 108
7.2. The Determinants of R and D Expenditure ... 108
7.2.1. R and D Expenditure: Demand Factors ... 108
7.2.2. R and D Expenditure : Supply Factors ... 110
7.2.3. R and D Supply—Deflated ... 110
7.3. The Determinants of Innovations ... 113
7.3.1. Factors Affecting Innovation Demand ... 113
7.3.2. Innovation Supply—Determinants ... 116
7.4. Multiple Regression Models ... 120
7.5. Major Findings ... 120

**8. Epilogue : Some Rethinking on Innovation and Development Policy**

8.1. Introduction ... 123
8.2. The Conventional Thinking on Economic Development and its Paradoxes ... 123
8.3. Unscrambling the Savings—Investment Puzzle : the Role of Technical Change ... 126
8.4. Some Policy Implications ... 131
8.5. Facts Versus Value Judgements on Technology Policy ... 132
8.5.1. The Stylized Facts of Technical Progress... 132
8.5.2. The Policy Implications of Stylized Facts ... 134
8.5.3. A Shift in Emphasis—From Choice of Techniques to Competitive Innovation ... 136
8.6. Policies to Promote Competitiue Innovation ... 137
8.6.1. Regulation of Science and Technology... 138
8.6.2. The Social Framework ... 140

**Appendix**

A. Measurement of Innovation ... 142
B. Index of Technological Proficiency ... 147
C. Glossary of Variables ... 149
Select Bibliography ... 151

# 1

# *The Problem*

## 1.1 Introduction

Allocating existing resources efficiently has been the prime concern of economic analysis for a long time. The problems related to expanding the existing resource base through developing new technology—the problems concerning the outward shift of the production possibility frontier—were treated as exogenous to economic analysis. The pioneering studies of Schmookler (1966) and Denison (1962, 1967) and numerous researches thereafter[1] suggested that technological progress is an important endogenous economic variable explaining economic growth. Once technological progress is regarded as an important economic variable, it is pertinent to inquire what factors stimulate or hinder it and to what extent are these factors amenable to management and control.

The view that technological progress is an endogenous variable which can be explained in economic terms had far-reaching ramifications. It spurred re-examination of development policies and rethinking on the role of investment in tangible capital vis-a-vis human capital in promoting growth in developed countries. In the developing countries, along with the 'savings gap' and the 'foreign exchange gap', there emerged an acute awareness of the 'technology gap'. The important question asked recurringly by all concerned is—how can the developing countries generate indigenous technological capability ?

---

[1]These researches are well documented in the references of the following survey articles : R. Nelson (1959), R.E. Johnston (1966), C. Kennedy and A.P. Thirlwall (1972), M. Kamien and N. Schwartz (1975).

The present study is inspired by the conviction that the major source of stimulating investment may not be variations in the rate of interest a la Keynes, but rather changes in an economy's propensity to innovate a la Schumpeter. The study explores the micro and macro level factors that stimulate innovations and generate investment and growth. A self-sustaining process of economic growth can thrive only on the basis of continuous increases in productivity and a study of the sources of innovations takes us to the roots of the phenomenon of increasing productivity and economic growth.

An improvement in productivity is initiated at the micro-level when a firm decides to introduce a new product or a new process.[2] This phenomenon of change resulting from implementation of new discoveries by firms raises several issues. What are the preconditions of successful technological innovation ? Are innovations stimulated by perceived market demand ('demand-pull') or are innovations stimulated by new technological discoveries ('technology-push')? What is the role of research and development in the process of technological innovation? Is a competitive market structure more conducive to innovations than a monopolistic one? What role can the government play in generating technological innovations? The study raises and attempts to analyse these issues.

### 1.2 Definitions and Concepts

An introduction of a new method of production or a new good is the final culmination of the process of utilizing science for production. This process can be divided into five stages for analytical convenience though often the boundaries separating them are not clear, and empirical reality, which appears as a continual stream of technological improvements, often defies any such compartmentalization.

---

[2]A new product or a new process necessarily improves overall productivity for the reason that generally a firm is interested not merely in the novelty of the process or the product for its own sake but in its cost-reducing or market-expanding potential. In fact, it is this characteristic of the new product or process that distinguishes it from several other inventions which lie unused because they lack economic viability.

The literature on technological progress refers to the following stages of the process : research (pure and applied), inventions, development, innovation, and diffusion. The National Science Foundation (1959), Kuznets (1962), Schmookler (1966), amongst others attempt to define and demarcate these stages. However, considerable terminological confusion prevails due to the fact that the criteria for splitting a basically continuous stream of technological progress into various stages are subjective and determined by the needs and constraints of the study. It is not clear, for example, whether invention is a new idea, or the first conception of the way of using a new idea, or a combination of the two. A broader definition of inventive activity would include all efforts from the initial exploratory phase concerning the nature of phenomenon to the final phase of the formulation of the central properties of a new product or a process. Whether inventions belong to the stage of applied research or to the later stage of development is not easily discernible. Inventions in patentable form generally come from the development phase whereas central idea about the invention comes from applied research, and, therefore, the distinction between research and invention is artificial, though analytically useful.

Similarly the connotation of the term 'development' differs from author to author. The National Science Foundation (1959) uses the term in its wider sense, signifying a process beginning from the conception of the idea and ending with a new product or a process, which is ready for production. Others restrict the term to improvement of an idea after it has been shown to be basically sound. But even if we accept either of the definitions of development, the lines of demarcation become hazy again, for in the process of development which often consists of producing the same good on a larger scale, the physical form of the product sometimes changes, resulting in a new product.

## 1.3 Alternative Analytical Approaches

Controversies regarding the definition of each stage are unavoidable when the researcher chooses a single phase—research, or invention, or diffusion—for study. The literature on sources of technological progress is characterised by two important analytical approaches :

(a) To focus on a specific stage of the phenomenon—research and development, or inventions, or diffusion, and to attempt an intensive study of a single stage of the process.

(b) To view the process of technical change in its entirety, continuity, and complexity, and to identify and assess the role of factors that influence the process as a whole. The factors influencing technical change have been grouped into the following categories :

(i) Advances in technological and scientific knowledge ('technology-push'),

(ii) Structure of the market—competitive or monopolistic,

(iii) Prevailing conditions in the market—prospective demand, profits, and changes in the relative prices of inputs,

(iv) Flow of credit and finance and incentive to invest in innovative activities,

(v) Non-market factors—promotional and regulatory governmental policies such as anti-trust policies, trade liberalization, patent system, encouraging science-based entrepreneurship; and fiscal incentives for innovation.

Both these approaches have their strengths and weaknesses. Whereas (a) permits gathering detailed and meticulous data on a specific stage thereby enabling one to arrive at generalisations which are methodologically superior, the limited range of inquiry which is a characteristic of all such stage specific studies imposes severe restrictions on the relevance of this category of research for the policy makers. The approach also encounters the conceptual problem of demarcating a certain phase for study when accretion to the stream of technical change occurs unevenly yet steadily and continuously. The act of demarcation, even when its objectives are clear, poses certain practical problems (see Jewkes *et al* 1961, pp. 12-14).

Moreover, this stage-specific approach misses the core of the dilemma of the vicious circle of technological backwardness.

in developing countries. In these countries, technological backwardness perpetuates itself in a circular way. Low rates of capital formation perpetuate low capital/labour ratios and, therefore, low levels of labour productivity. Low levels of labour productivity are associated with low per capita income and low rate of capital accumulation. The low rate of capital accumulation acts as a major hindrance to the development of the capital goods sector. Such a stagnant and backward capital goods sector is unable to generate technological progress on the scale it did in the industrial western countries during the nineteenth century. As a developed capital goods sector acts as a major source of generating skills and aptitudes conducive to technological progress, and as such a sector does not exist in developing countries, they are caught in a vicious circle of technological backwardness (see Rosenberg 1976, pp. 148-150). The objective of comprehensive science and technology policy in developing countries is not just to promote a specific stage of the process but to initiate the process of technical progress at its roots : and also to generate forces which will help it survive through all its stages until the final culmination in the form of a new product or a new process. Research focused on a specific stage would, therefore, be of limited relevance to the requirements of policy makers.

The other approach, which is more holistic and focuses on factors generating technical change, has to contend with the problem of keeping the data requirements within manageable limits. But it has a wider perspective and offers prospects of an inquiry into the essential interdependence between the factors, as well as an analysis of external effects associated with such interdependence.

We felt it necessary to view the process of technological progress in a comprehensive manner. The empirical manifestation of the process is the introduction of a new good or a new process by a firm. We have identified individual firms who have been first to introduce new products/processes in the Indian economy and have attempted to analyze the factors underlying these decisions. In other words, we are looking at technological progress in a reverse way, starting from the penultimate stage and working our way backwards. This procedure leaves out the final stage of diffusion

unexplored. This omission does not detract from the significance of the study because we are interested in sources of innovations and not in the ex-post productivity impact of these innovations. A study of the final stage of diffusion assumes significance if the objective is to analyse the productivity impact of new goods and processes; for it has been found that improvement of a process (which often occurs with diffusion) leads to larger cost reductions than its initial introduction (see Enos 1962). Moreover, we feel that the problem requiring urgent attention in developing countries is the initiation of technological progress rather than its diffusion. This is because we can place greater confidence in the working of the market forces to ensure diffusion than to initiate technological progress.

### 1.4 Some Observations on the Data and Methodology

When we take a wider canvas, we at once encounter the problem of collecting data on a selective basis. Gathering data about even a single stage like development is an extremely expensive and time consuming research, and gathering extensive data on all stages would make the project unmanageable. We have, therefore, gathered data on a very selective basis.

As published data on the various aspects of the problem were not available, it was decided to collect the data by questionnaire. We collected the relevant data from the records of the firms whenever available, and relied on the decision maker's subjective perception of the relevant factors if there were gaps in information.

The crucial question pertaining to data collection was : what is innovation in the Indian context and who is an innovator ? Taking the clue from the Annual Reports (1969-79) of the Directorate General of Technical Development (DGTD) on new products and processes introduced in India, innovation in the Indian context can be defined as a new product or a new process introduced in the Indian market for the first time either through entirely indigenous R and D efforts or through adaptive R and D. The firm who performs this task is an innovator.

Having derived an operational definition of innovation, the next problem was to identify innovating firms and derive a measure of innovations in each firm. The innovating firms were

identified using the DGTD data. However, deriving an accurate measure of innovations in each firm posed several formidable problems besides the basic one of defining the very concept of novelty. These problems are discussed in Appendix A. The number of new products/processes introduced by a firm and considered to be 'significant breakthroughs' was taken as a measure of innovation for each firm. The reasons for adopting this procedure are also discussed in Appendix A.

Barring exceptionally innovative firms, each firm is able to make only a few major breakthroughs during its entire life. The timing of major breakthroughs varies considerably among firms. Hence if we limit the observation to a few recent years, we might get a distorted picture of the innovative strength of a firm. We have, therefore, taken the total number of major breakthroughs (INLO) achieved during a firm's lifetime as a measure of innovation.

The data regarding explanatory variables concerning behavioural responses such as attitude towards risk and dynamic responses to changing market conditions is measured using dummy variables. These are derived from the responses to the questionnaire. These variables, listed in Appendix C, indicate the presence or absence of a certain attribute.

We would also like to stress the fact that whenever we had to choose between two variables—one which is conceptually closer to the problem analyzed but not easily measurable and another, which is more accurately measurable, but not as much relevant conceptually—we have preferred the former alternative. For example, appendix A discusses the rationale and problems in taking such an approach to measure the dependent variable innovation. Another important variable which illustrates our approach is the measure of market structure. For the reasons discussed in Chapter 3, we have rejected a precise measure of the market structure, namely, concentration ratio, in favour of other alternative measures (all dummies) which in our view are more relevant conceptually. This is quite contrary to the established convention amongst economists to prefer a variable more amenable to measurement even though conceptually less accurate.