TECHNOLOGICAL CHANGES AND ITS IMPACT ON RUBBER PLANTATION INDUSTRY IN KERALA - AN ECONOMETRIC STUDY

Thesis submitted to the
Cochin University of Science and Technology
for the Award of the Degree of
DOCTOR OF PHILOSOPHY

By
AJITH KUMAR N.

Under the Supervision of
Dr. P. SUDARSANAN PILLAI,

DEPARTMENT OF APPLIED ECONOMICS
COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY
COCHIN 22 KERALA

OCTOBER, 1994

SCHOOL OF MANAGEMENT STUDIES
COCHIN UNIVERSITY OF
SCIENCE AND TECHNOLOGY
COCHIN - 682 022, Kerala, India
Phone 85-5310

Dr. P. SUDARSANAN PILLAI
M. A., M. Com., LL. B., Ph. D

Dated...26.10.1994

CERTIFICATE

Certified that the thesis "Technological Changes and its Impact on Rubber Plantation Industry in Kerala - An Econometric Study" is the record of bonafide research carried out by **Mr. Ajith Kumar N.** under my guidance. The thesis is worth submitting for the degree of Doctor of Philosophy in Social Sciences.

Dr. P.Sudarsanan Pillai
(Supervising Guide)

DECLARATION

I declare that the thesis entitled "Technological Changes and its Impact on Rubber Plantation Industry in Kerala - An Econometric Study" is the record of bonafide research carried out by me under the supervision of Dr.P.Sudarsanan Pillai, Reader, School of Management Studies, Cochin University of Science and Technology. I further declare that this has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles of recognition.

Ajith Kumar

Cochin - 22
25-10-1994

Ajith Kumar N.

ACKNOWLEDGEMENTS

It is with a deep sense of gratitude, I remember my supervising guide Dr. P. Sudarsanan Pillai, Reader, School of Management Studies, Cochin University of Science and Technology and Project Director, ICSSR research project on "Management Practices in Rubber Plantation Industry in India", for his sincere guidance, valuable suggestions and constructive criticism. Further I am indebted to him for appointing me as a Junior Research Fellow in the Research Project, during the course of which I conceived and developed the topic of the present study.

In this context, I am also thankful to the Indian Council of Social Science Research, New Delhi, for permitting me to make use of the data and other relevant information collected for the research project.

I express my gratitude to Prof. (Dr) N. Unnikrishnan Nair, Head of the Division of Statistics, Cochin University of Science and Technology, for his constructive suggestions and encouragement during the course of this study.

I am very grateful for the many comments and suggestions by Prof. (Dr) P.P.Pillai, Head of the Department, Department of Economics, Calicut University, during the course of my research work.

I am thankful to Dr. K.C. Sankaranarayan, Professor and Head of the Department of Applied Economics for providing the necessary facilities during the course of my Ph.D programme

I am also indebted to Dr. M.K. Sukumaran Nair, Reader, Department of Applied Economics, Cochin University of Science and Technology for his constant encouragement

I express my sincere thanks to the staff of Rubber Board and Rubber Research Institute of India, for the help they rendered in collecting information on the subject. Special mention has to be made to the valuable discussions I had with Sri. R.G. Unni, Deputy Director, Statistics, Dr Tharian George, Deputy Director, Economics and Smt. LalithaKumari Statistician, of the Rubber Board.

I am Specially indebted to Mr. Praseethlal, Scientific Officer and other staff of the DRDO - Cochin University Computer Centre for providing me the necessary assistance in statistical analysis.

I also wish to place on record my gratitude to the librarians of

- Centre for Development Studies, Trivandrum.
- Department of Economics, University of Kerala, Trivandrum
- Rubber Research Institute of India, Kottayam
- United Planters Association, Coonoor.

My thanks are also due to Miss Elizabeth Abraham, Librarian, Department of Applied Economics, CUSAT and Mr. D. Gopi, Asst.Librarian, School of Management Studies, CUSAT for their unstinted co-operation. I am also grateful to the office staff of the Department of Applied Economics and School of Management Studies.

I also acknowledge the co-operation of all my friends and well wishers.

The successive drafts of the thesis were neatly and efficiently typed by Miss. Suja. My deepest thanks to her.

Last but not the least, I remember my parents for their patience and constant encouragement without which I could not have completed the present work.

AJITH KUMAR N.

CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

CHAPTER I

INTRODUCTION

Almost all natural rubber, which is processed into industrial raw material for use in a wide range of manufactured articles, comes from a perennial tree known as 'Hevea Brasilliensis'. India, the fourth largest producer of natural rubber accounted for about five per cent of global output in 1991-92. The area planted with rubber trees in the country increased from 86,067 hectares in 1955-56 to 466,323 hectares in 1991-92. A parallel increase in rubber production was also recorded during this period, production rising from 23,730 tonnes in 1955-56 to 3,66,745 tonnes in 1991-92. The national average yield per hectare of mature rubber trees increased from 353 kilogrammes to 1130 kilogrammes during this period.

A notable feature of rubber plantation industry in India is its concentration in a few states viz., Kerala, Tamil Nadu and Karnataka. Kerala, the southernmost state in India contributes about 92 per cent of the total natural rubber production in the country. It has about 3,97,000 hectares under rubber, which accounts for about 86 per cent of the total area under rubber cultivation in the country.

Research has led to major technological changes in rubber growing and production in India during the last four decades. The dramatic yield increases have been due to advances in agro-botanical and chemical technologies. There has been wide spread adoption, especially in the estate sector of the high yielding cultivars and the associated package of improved techniques. The potential for greater output has improved the prospects for sustained growth of the industry in the face of both fluctuating prices and increasing cost of inputs. The major challenge facing policy makers and planners is to devise policies which will both continue to encourage productivity increase in the estate sector and at the same time, enable the technologically backward producers in the small holding sector to reap the benefits of technological developments.

Statement of the problem

The present study describes in detail the major technological advances in the rubber-growing industry in the last four decades. The major technological changes experienced in the rubber plantation industry during the period are the introduction of high yielding planting materials, scientific application of fertilisers, use of pesticides, tapping during rainy season using rain guards, use of yield stimulants and improved tapping methods. Each of these advances is discussed along with an examination of the extent to which these technological developments have been adopted by the industry. A detailed analysis of the technological changes have been done for the estate sector. The estate sector rather than the small holding sector was chosen for this analysis because the former exhibits a relatively high degree of homogeneity in management and in production techniques. In addition, the more systematic organisation of the estate sector made data more readily available.

One of the apparent features of the pattern of growth of rubber plantation industry in Kerala is a significant positive trend in output growth. In 1955-56, the output of natural rubber in Kerala was 21,680 tonnes, which increased to 3,44,503 tonnes in 1991-92; an increase of 1583 per cent over a period of 36 years. This spectacular increase in output of natural rubber may be observed as the consequence of both productivity improvement through technological advancement and expansion of area.

The present study is an attempt to analyse the impact of technological changes on rubber production in Kerala. The area of the study comprises whole of Kerala state, which enjoys a predominant position in the total natural rubber production in the country in terms of both area and production.

SIGNIFICANCE OF THE STUDY

Natural rubber is one of the agricultural crops in which the recent technological developments have been significant. Natural rubber is the livelihood of more than six lakhs rubber growers and workers in Kerala. Hence any improvements in agricultural technology will be affecting a sizable section of the population in Kerala. The policy initiatives to be taken in respect of the technological changes should be preceded by an assessment of the present situation. Therefore the analysis of the technological changes of such an important crop is of particular interest. A review of the available literature on rubber reveals that no exclusive study on technological changes in the rubber plantation industry has so far been attempted in India. So the present study may fill the gap to a certain extent.

Objectives of the study

The overall objective of the study is to analyse the technological changes in the rubber plantation industry in Kerala. The specific objectives are the following.

1. To analyse the growth rates of area, production and yield per hectare of natural rubber in Kerala
2 To decompose the output growth into its components namely yield growth and area growth.
3. To examine whether instability in natural rubber production is reduced by technological change.
4. To estimate the rate of diffusion of high yielding planting materials in the estate sector and the small holding sector.
5. To fit a model for measuring embodied and disembodied technological change in the rubber plantation industry.
6. To examine the impact of high yielding varieties of planting materials on input-output relationship in the estate sector.

SOURCES OF DATA

The main source of primary data was the Research project; 'A Study of the Management Practices in Rubber Plantation Industry in India'[1] in which the researcher himself was a Junior Research Fellow. Data pertaining to 49 rubber estates in Kerala were made use of for the detailed analysis.

For the analysis of growth rates, instability, and technological changes, the main source of secondary data was the Rubber Board, Kotayam. Other sources of secondary data include publications of the Kerala State Planning Board, Department of Economics and Statistics,and the International Rubber Study Group, London.

---

[1] Dr Sudarsanan Pillai, P. A Study of the Management Practices in Rubber Plantation Industry in India, Research Project (1989-1993) sponsored by the Indian Council of Social Science Research at the School of Management Studies, Cochin University of Science and Technology, Cochin-22.

METHODOLOGY.

The analysis of technological changes has been done taking into consideration the following characteristics of rubber cultivation.

1. the rubber tree has a long gestation period-the unproductive period before tapping starts- of about seven years.
2. long productive life span of more than thirty years.
3. yield profile of the rubber tree which depicts the age-yield relationship resembles a flattened F- distribution curve
4. rubber production is non-seasonal except for inclement weather and wintering effects.
5. the impact of any change in the quality of planting materials can be felt on production only after several years.

The period of reference in the present study is from 1955-56 to 1991-92 which has been divided into two sub-periods to capture the impact of the introduction of the technology of new planting materials developed in India during the late sixties. The cut-off point was the year 1975-76. The second period i.e. from 1975-76 to 1991-92 is also considered to be a period of stagnation in the agricultural sector of Kerala. In this connection, rubber is termed as an exceptional crop. So it is worthwhile to analyse the growth patterns of rubber plantation industry during that period. Growth rates were worked out for the variables like tappable area, production and yield per hectare using log-linear trend fitting. To test whether there is any acceleration/deceleration in growth rates, a log-quadratic functional form has been applied. Separate growth rates were worked out for the two sub periods using a kinked exponential model. It is evident that the two factors viz., area and yield have been influencing production simultaneously. Decomposition analysis has been done to segregate the effects of yield. growth and area growth on production growth.

Any instability in natural rubber production is of great significance to both the government and the plantation industry. Therefore, an attempt has been made to analyse the instability patterns in the rubber plantation industry. using Mac Bean indices.

It is widely believed that large estates are faster in the adoption of innovations. In this context, the diffusion rates of improved planting materials among estates and small holdings is compared by fitting logistic curves for the data on the proportion of high yielding varieties.

Meaning and Classification of Technological Change

Technological progress has been singled out as the most dominant variable affecting agricultural productivity and development. Technology means society's pool of knowledge used by the industry regarding the physical and social phenomena, knowledge regarding the application of this principles to production and the knowledge of the day-to-day operations of production. Technological change is the advance of technology, such advance taking the form of new methods of producing existing products, new designs which enable the production of products with important characteristics and new techniques of organisation and management.

There are different ways of classifying technological change. One method is to classify them as embodied and disembodied technological change. The technological change in the rubber plantation industry can be broadly classified as embodied and disembodied technological change. Embodied technological change is one which is incorporated into the latest version of an input. Under the embodiment hypothesis improvements in technologies affect output only to the extent that they are carried into practice either by net capital formation or by the replacement of old fashioned equipment. Embodied technological changes in the rubber plantation industry includes the change in the quality of planting materials and the changes during the immature phase. Disembodied technological change is defined as technical change which does not require new inputs to introduce it into the production process. It can therefore be identified with a shift in the production function. To this category includes the organisational improvement and improved tapping methods:

An attempt is made in the present study to estimate technological change in the rubber plantation industry using the framework of vintage production function. The following vintage production function was used for the analysis

$$Y_t = \Sigma\phi(\nu).a(\nu,t)\ \zeta_{t-\nu}$$

Where $a(\nu,t)$ is the area under rubber trees planted in year 'ν' which is remaining in year 't'. $\zeta_{t-\nu}$ is the yield of a hectare of rubber trees of age '$t-\nu$' according to the average yield profile. Solving this equation, the values of the function gives an estimate of embodied technical change.Disembodied technical change can be measured from the model by including a function f(t) in to the model

$$Y_t = f(t) \sum_{\nu} \phi(\nu)\ a(\nu,t)\ \zeta_{t-\nu}$$

By estimating the parameters of $\phi(\nu)$ and f(t), we get the rate of growth of embodied and disembodied technical change. An estimate of the coefficient of f(t), gives the rate of growth of disembodied technological change and an estimate of the coefficients of $\phi(\nu)$ gives the rate of growth of embodied technological change.

Lastly, the effects of the change in the quality of planting materials on the input-output relationship in the estate sector has been analysed using the framework of production function. Detailed methodology of the various methods used for the analysis is given in the corresponding chapters.

SCHEME OF THE STUDY

The study is divided into eight chapters. The first chapter is introductory in nature. It presents the problem, objectives and a brief methodology. The second chapter brings out, an evaluation of various studies on natural rubber in India and other countries. The third chapter presents a profile of the rubber plantation industry in India. Chapter four contains the analysis of growth patterns, instability and the rates of diffusion of the technology of high yielding planting materials in the estate sector and the small holding sector. Chapter five provides a detailed discussion of the different technological changes that have been experienced in the rubber plantation industry. Chapter six is an attempt to measure the embodied and disembodied technological change in the rubber plantation industry. Chapter seven examines the impact of high yielding planting materials on input-output relationship in the estate sector. The eighth and the final chapter presents summary, conclusions and recommendations emerged from the study.

CHAPTER II

A REVIEW OF STUDIES ON RUBBER PLANTATIONS

CHAPTER II

A REVIEW OF STUDIES ON RUBBER PLANTATIONS

A large number of studies on different aspects of rubber plantation industry have been made by several expert committees and individual scholars. The literature available on rubber plantation industry deals with various aspects such as the economics of rubber cultivation, supply response to price changes, forward and backward linkages, management practices, role of government, yield performance of different types of planting material etc. Some studies on the technological changes in the rubber plantation industry have been carried out in Malaysia,one of the major rubber producing countries in the world. The present chapter presents a brief review of important studies available on rubber plantation industry.

Reports

Most of the studies on rubber plantation industry published in the fifties and sixties were conducted by various committees appointed by the government of India and Rubber Board The first systematic study on various aspects of rubber plantation was done by the Plantation Inquiry Commission[1]. The growth of the industry, area distribution of rubber holdings and the position of small holding sector in the industry were the chief areas of interest for the commission. Among other things the committee discussed the capital structure, marketing, transporting and labour relations in the industry.

The marketing problems of rubber growers were examined by Reddy[2]. The study was mainly concerned with problems of the small holding sector. It emphasised the need for an efficient marketing organisation in the small holding sector.

In 1959, the committee appointed for enquiring into the kangany system in the plantations of Kerala submitted its report[3]. The report recommended the abolition of kangany system in Kerala, which was subsequently accepted by the government.

---

[1] Madhava Menon, P. (1956), Report of the Plantation Inquiry Commission Part III, Rubber, Manager of Publications, Government of India, New Delhi.

[2] Reddy D.V. (1950), Marketing Organisation for Rubber, Indian Rubber Board, Kottayam.

In order to suggest improvements in the rubber plantation industry in India, Rubber Board sent a team to Malaya[4]. The recommendations of this delegation is largely related to the organisation of development, research and extension activities in the rubber plantation industry.

In 1968[5], Rubber Small Holdings Economics Enquiry Committee appointed by the Ministry of Commerce, Government of India conducted a study on the economics of rubber small holdings in India with a view to bringing to light the drawbacks and deficiencies of the small holding sector. The Committee observed that small growers react more quickly to price changes than large growers. The potential of the small holding sector as the source of employment and livelihood to a sizable section of the population is emphasised in the study. According to the committee, distribution of the planting materials at concessional

---

[4] Rama Varma (1963), Report of the Delegation to Malaya, Rubber Board, Kottayam.

[5] Abdullah T.M. (1968), Report of the Rubber Small Holdings Economics Enquiry Committee (1968), Rubber Board, Kottayam

rates and subsidies helped the diffusion of improved materials among the growers. It was pointed out that the lack of proper cultural practices is one of the major reasons affecting the productivity in small holdings.

Unny and George Jacob[6] conducted a sample survey of the small holdings in India in 1969-70. The main objective of the study was to estimate the yield per hectare of the small holding sector. Various factors such as area under rubber, planting materials used, cultural practices, tapping systems, method of processing and marketing adopted were also analysed.They came to the conclusion that interplanting of other trees or crops with rubber is comparatively low in area planted with budgrafts and clonal seedlings vis-a-vis area planted with unselected seedlings. Manuring and plant protection measures are regularly done only in area under high yielding varieties. Regarding tapping practices, the study found that alternate daily tapping is very common in budded area while daily tapping is followed in unselected area.

---

[6] Unny, R.G and George Jacob (1972), Rubber Small Holdings in India, Report of the Sample Survey 1969-70, Rubber Board, Kottayam

Family labour is employed for tapping small holdings. It was found by the study that majority of the small holders' rubber is sold mainly to the licensed dealers. This study was the first systematic study conducted to assess the position of the small holding sector in India.

Krishnankutty, P.N. and Haridasan,V[7]. provides some idea on the family budget of rubber plantation workers. The main objective of the study was to examine the living conditions of the plantation workers. The major conclusions are that 61.1 percent of the expenditure of the plantation workers is incurred on food articles and that the net difference between income and expenditure of families surveyed was found to be positive.

A study of the management practices in rubber plantation industry was conducted by Sudarsanan Pillai.[8] The overall objective of the study was to investigate into the various

---

[7] Krishnankutty, P.N. and Haridasan, V.(1976), Family Budget of Rubber Plantation Workers in Kozhikode District-Report of a Survey, Rubber Board, Kottayam.

[8] Sudarsanan Pillai, P.(1993), A Study of the Management Practices in Rubber Plantation Industry in India, Research Project Sponsored by Indian Council of Social Science Research, School of Management Studies, Cochin University of Science and Technology, Cochin.

management practices followed in the plantation industry in India at large and rubber plantations in particular with a view to evolving suitable tools, strategies, policies etc. and also for developing an integrated management system for rubber plantation industry in India. A comparative study of the management practices followed in India and Malaysia was also undertaken. Primary data for the study has been collected from the estates and holdings in India and Malaysia.

Books on Rubber

One of the most important books published on rubber plantation industry is that of Barlow[9]. In his book, Barlow gives historical, technological, social, political and economic aspects of the Malaysian Rubber Plantation Industry. The ultimate goal of the development of the industry is perceived, in this book, as the maximisation of social value product, this being defined in broad terms which include an equitable distribution of gains amongst all members of society.Technological aspects of production and processing and the development of the synthetic rubbers are

---

8 Barlow Colin (1978), The Natural Rubber Industry, its Development, Technology and Economy in Malaysia, Oxford University Press, Kuala Lumpur.

analysed. The economics of producing and processing rubber on estates and small holding and possible improvements in the deployment of resources are explored. The structure of marketing channel between producers and consumers and the organisational arrangements on patterns of resource allocation.are also examined. The book contains valuable information and a penetrating analysis of the rubber plantation industry in Malaysia.

National Council for Applied Economic Research[10] draw our attention to the demand and supply position of natural synthetic and reclaimed rubber in India. Demand and supply forecasts were worked out on the basis of regression analysis. The desirable stock of rubber to be held in the future and operational stocks at different stages from the producer to the consumer were estimated using statistical models. However, a comparison of the estimated and actual figures for the eighties, currently available showed that there is wide difference between the two. In the case of natural rubber, it was found that the production and tappable area were under estimated by about 25 percent while the consumption was over estimated by about 12 percent for the year 1989-90

---

[10] National Council for Applied Economic Research (1980), Ten Year Perspective Plan for Rubber 1980-81 To 1989-90, National Council for Applied Economic Research, New Delhi

Estimates for other years also showed wide variation with the actual figures. The deficit in supply was over estimated by about 300 per cent. While arriving at the estimates, the study seems to have taken a biased view of the demand and supply position of natural rubber in India.

Tan[11] examined the problems in the marketing of natural rubber. The study developed an econometric model of the world natural and synthetic rubber market. It was pointed out by the study that the secular decline in natural rubber price up to 1973 in the world market was primarily due to the substitution of natural rubber by the cheaper synthetic rubber. The econometric model developed was used for forecasting natural rubber price. The study also analysed the implication of natural rubber market stabilisation along the lines of international natural rubber agreement. It was found by the study that the natural rubber supply is influenced by prices up to fourteen year lags. The study emphasised the need for a stockpiling policy so that consumers will not be faced with unforeseen shortages.

---

[11] Tan Suan, C (1984), World Rubber market Structure and Stabilisation - An Econometric Study, World Bank Staff Commodity Paper No.10, World Bank, Washington.

Umadevi[12], studied the backward and forward linkages of the plantation sector vis-a-vis the other sectors in the Kerala economy. The study uses Ramussen's method of quantitatively estimating the backward and forward linkages which accounts for the direct requirements also. A 24x24 input-output table for Kerala for the year 1973-74 at purchase prices was constructed for the study. The main conclusion emerging from the study is that the rapid growth of the plantation sector may not be helpful in providing a growth stimulus to the economy. The linkage of agriculture and animal husbandry with the rest of the economy is better than that of the plantation sector. Hence, the present trend in Kerala of converting the land under paddy into cash crop cultivation needs to be viewed with alarm. She has observed that if rubber is processed inside Kerala the linkage of the rubber products industry is likely to be high. It is not high at present since it is not processed in Kerala on a large scale. If rubber is processed and exchanged for food, which is imported by Kerala, then it would promote a horizontal division of. labour, i.e. exchange for finished goods rather than the exchange of an unfinished good for a finished good leading to a vertical division

---

[12] Umadevi, S. (1989), Plantation Economy of the Third World, Himalaya Publishing House, Bombay.

of labour, of latter, puts the producer of raw materials at a disadvantage in the process of exchange.

Ph.D Thesis

Jose[13] studied the economics of rubber plantation industry in Kerala. After discussing the importance and growth of the industry, the impact of various development schemes are explained. Role of Rubber Board and Rubber Marketing Societies in the development of the industry are examined. The demand-supply position of natural rubber industry is also studied. Cost of production of rubber is calculated, by using secondary data. The profit shares of the estate sector and the small holding sector are found out by using the break-even chart. It is concluded that comparatively estates enjoy higher rate of profit than small holdings. Other major conclusions of the study are:

1. Wide fluctuations in the prices of natural rubber adversely affect the long term supply position, due to the difficulties

---

12. Jose Thomas (1979), The Economics of Rubber Plantation Industry in Kerala, Unpublished Ph.D. Thesis, Cochin University of Science and Technology, Cochin.

on the part of the rubber producers to make healthy. long term plan for future production

2. Further, improvement in production is comparatively higher in small holding sector than estate sector.
3. Break even analysis showed that the break even point for the estate sector has increased to 631 kgs.in 1974-75 from 410 kgs.in 1965-66. The profit share remained more or less same during the period in the estate sector.
4. For the small holding sector, the break even points are 325 kgs. and 474 kgs.respectively in 1965-66 and 1974-75. But the profit share has decreased sharply form 450 kgs. to 196 kgs.

Management practices in the rubber plantations in India was studied by Haridasan, V.[14] A comparison between the practices followed by Indian and non-Indian companies is also made. The management practices in the rubber plantations are examined in the light of management principles and techniques adopted in business and industry. Management principles of finance, marketing, materials, transporting, planning, organising, staffing directing and controlling are examined. The study is limited to the estates belonging to the limited companies in India.

---

[14] Haridasan, V (1979), An Enquiry into the Management Practices Followed in Rubber Estates in India, Ph.D. Thesis, Cochin University of Science and Technology, Cochin.

Ciciliyamma[15] studied the structural changes and profitability in the rubber plantation industry. She analysed the changes in rubber area in comparison with area under other cash crops. A major reason for the change in area under rubber cultivation, as found by the study, is the proliferation of a large number of small holdings. Supply response of natural rubber was studied using a simple distributed lag model which hardly considers the characteristics of a perennial crop like rubber. It was found that the price of competing crops had a greater influence on the changes in area and output than the lagged prices. The profitability of rubber cultivation among small holders was analysed from a single village in Meenachil Taluk. Meenachil Taluk is the region where the yield per hectare is highest in Kerala. Therefore conclusions based on the data from this taluk alone could hardly be used for explaining the general situation in Kerala.

---

[15] Ciciliyamma Thomas (1984), An Economic Analysis of Rubber Cultivation in Kerala, M.Phil Thesis, University of Kerala, Trivandrum.

Raju[16] analysed the input and output price movements, productivity trends, capacity utilisation and returns to scale in rubbed based industry in Kerala. The analysis of trends in input and output prices led the researcher to the conclusion that both had increased over the years. Rubber based industry in Kerala showed signs of declining trend in productivity and decreasing returns to scale. The capacity utilisation of the rubber manufacturing units selected for the study was low. Shortage of power and raw materials, labour problems and inadequate marketing facilities are the major hurdles in the progress of the industry identified in the study. The researcher had given much attention to the supply side of natural rubber. Analysis of supply response using the distributed lag model revealed that short-term response is mainly affected by current price rather than lagged price and long-term planting decisions are influenced by the prices of the previous eight years. The study concludes that favourable price was of the major reasons for the increase in rubber production in the state. He also examined the changes in production and productivity in the natural rubber plantation industry in Kerala.

---

[16] Raju K.V. (1990), The Economics of Rubber-Based Industry in Kerala, Unpublished Ph.D. Thesis, Cochin University of Science and Technology, Cochin.

Articles in Research Journals

Yee[17] had established that with yield stimulation, the increase in yield , particularly in the older tapping panels, offsets the increase in production cost and hence a higher level of operating profits can be derived.

Dand[18] , forecasted the prices of RSS 1 and RSS 2 sheet rubber using the Box and Jenkins technique. Starting with a generalised forecasting model, he worked out the forecasts after completing the steps involved such as identification, estimation and diagnostic checking.

Sunil Mani[19] examined the intra-year variation in the price of natural rubber in the 1970s and the role played by

---

[17] Yee Yuen Loh (1983), "Effects of Yield Stimulation or Profitability and Rubber Production Hypersurface in the Estate Sector", Journal of Rubber Research Institute of Malaysia, Vol. 31 No.1, pp. 5-26.

[18] Dand Mohd Naji Bin (1983), A Forecasting Methodology as Applied to Rubber Prices, Journal of R R I M, vol.31,part 3,pp. 188-203.

[19] Sunil Mani(1984), "Price Movements for an Agricultural Raw Material with Inventory Adjustment: case of Indian Natural Rubber Market in 1970's", Economic and Political Weekly, Vol.19, No.51-52.

the rubber stock in explaining it. He also presents a brief account of the rubber economy in Kerala, and the pattern of distribution of small holdings and estates between 1955 and 1979.

Yee, Longworth and Strong[20] studied the nature and magnitude of shift in the derived input demand and cost functions associated with different levels of rubber growing technologies. The paper analyses two different aspects of the problem.The study tried to answer questions such as whether past research has produced technology biased towards one or more input factors, the effect of past technology advances on the unit cost of producing raw rubber. The methodology is based on the assumption that the basic underlying production process may be described by a Cobb-Douglas production function. The study is based on the data collected from the estate sector pertaining to three production years, viz., 1964, 1970 and 1976.The conclusions of the study are:

1. Technological developments which occurred in the past have played an important role in the Malaysian rubber industry in increasing productivity and reducing unit cost of production.

---

[20] Yee, Y. L., Longworth, J.W. and Strong, S.M. (1984), "Impact of Technological changes on input demand and cost functions in the Malaysian Rubber Industry", Journal of Rubber Research Institute of Malaysia, Vol.31, No.2, pp. 71 -87.

2. Past research has not been biased in favour of one or more inputs.
3. The gains from research along the same lines as in the past appear to have been diminishing over time.

Chew[21] estimated the rate of technological change in Chinese rubber small holdings in Peninsular Malaysia under the frame work of a production function. A Cobb-Douglas production function was specified and fitted to two sets of cross-sectional data collected in 1963-64 and 1978. The study concluded with the observation that the technological changes in chinese rubber small holdings is the capital-augmenting type. The estimated rate of progress was about 1.2 per cent per annum.

Suleiman and Ching[22] examined the productivity of land and labour in the Malaysian rubber estate sector for the period

---

9.TA Chew (1984), "Measuring the Rate of Technological Change in Chinese Rubber Small holdings - A Micro-economic Approach, Journal of Rubber Research Institute of Malaysia Vol. 32, Part 3, pp. 191-197.

[22] Suleiman Habibah and Lim Ching (1988)," Some Economic Aspects of Productivity in the Rubber Estate Sector". Proceedings of RRIM Rubber Growers Conference 1987, RRIM, Kuuala Lumpur.

1960-84. They have established that, to a large extent, land productivity was responsible for the growth of the labour productivity. Further, they found that the continued economic viability of the rubber industry depends very much on improvements in land utilisation via re-investment policy, development and adoption of high yielding planting materials.

Tharian George, Tomy Joseph and Toms Joseph[23] evaluated the yield performance of some selected planting materials. The data was collected from one of the largest rubber planting companies in India. The main objectives of the study were to assess the yield performance of selected planting materials, to estimate the extent of individual and combined influence of selected variables on yield rate, to determine the year of tapping which gives the maximum yield for each planting material and to assess the planting policy of the Company. Fifteen popular planting materials were selected for the study. Since the data pertaining to yield for the 20 years of tapping were not available for all the varieties, trends in yield rates were analysed separately for

---

[23] Tharian George, K. Tomy Joseph and Toms Joseph (1988), "Evaluation of the Yield Performance of Selected Rubber Planting Materials in the Context of the Planting Policy", Indian Journal of Natural Rubber Research, Vol.1, No.2, pp.66-78.

three time periods, viz., ten, fifteen and twenty year periods. The influence of year of tapping and density on the trends in yield rates of individual planting materials were estimated by employing multiple regression analysis.

The analysis of yield data showed that PB 28/59,RRIM 605, PB 5/51 and GT1 are found to be superior to others in terms of yield during the ten years where data for all the 15 types of planting materials were available. RRIM 605 had the lowest coefficient of variation. An observation offered by the study was that there is a positive relationship between yield and instability. The multiple regression analysis showed that the variation in yield can be explained from 64 to 87 per cent in the 20 year period, 76 to 98 per cent in the 15 year period and 74 to 100 per cent in the ten year period depending on the planting material. Further, the study observed that the planting policy of the company in relation to the yield performance of the selected planting materials during the ten year period justifies its policy as is evident from the rank correlation. A limitation of the study is that the data had been collected from a single plantation Company, so that generalisation is hardly possible. Another point to be noted is that, RRII 105, the most popular planting material in India, has not been included in the study.

Tharian George, Haridasan and Sreekumar[24] conducted a study on the role of government and structural changes in rubber plantation industry. The study analysed the development of the industry and the implications of the policies pursued by the government from time to time. The study observes that the price factor is relatively more significant when compared to the various factors which played a positive role in the development of the rubber plantation industry in India till the 1940s. On various occasions, the prices were protected from falling below remunerative levels which, to a large extent, played a pivotal role in maintaining the tempo of growth of the industry. The study examined the various measures introduced by the government to achieve the growth of the industry since independence. The major reasons for the increase in production and productivity found by the study are:

1. Replanting subsidy scheme introduced in 1957 and the new planting subsidy scheme introduced in 1979.
2. Extension of cultivation in traditional as well as non-traditional areas. In this process, the concerned state

---

[24] Tharian George,K., Haridasan,V., and Sreekumar,B.(1988), "Role of Government and Structural Changes in Rubber Plantation Industry", Economic and Political Weekly, Vol. 23, No. 26, pp. M158-M168, November 26.

governments have also taken active interest by establishing rubber plantations under public sector corporations.

3. The land reforms introduced in Kerala State in 1965, which exempted plantation crops from land ceiling while maximum limits to individual holdings for other crops were introduced.
4. Policy of notifying minimum price for natural rubber based on the estimated cost of production.
5. The growth of indigenous rubber goods manufacturing industry.

The study concludes that both the central and state governments played an active role in the development of the industry. The policies followed by the government had certain significant consequences on the structure of the industry in terms of changes favouring the growth of a dominant small holding sector, in the geographical distribution of area under rubber and in the ownership pattern in the estate sector.

Sudarsanan Pillai[25] pointed out that modern management techniques and practices which are found most effective in industries have not found their proper use in plantations. The management practices in the large number of rubber plantations under various organisational set up widely differ from each other. It was observed by the study that the rubber plantations offer tremendous opportunities to implement modern management techniques to improve both production and productivity.

Toms Joseph, Haridasan and Joy Cyriac[26] made a study on the comparative cost advantages of two types of rain guarding of rubber trees. The study was conducted among small holdings with equal representation to the two types of rain guarding, viz., polythene sheet rain guarding and tapping shade rain guarding. The average yield per hectare at which rain guarding is profitable has been calculated by employing the discounted cash flow analysis. The cost and benefit figures were estimated using the

---

[25] Sudarsanan Pillai, P. (1989), "Management of Rubber Plantations in India : An Overview", <u>Indian Manager</u>, Vol.XIX, No.2, pp.55-63.

[26] Toms Joseph, Haridasan,V. and Joy Cyriac (1989), "Economics of Rain Guarding-A Comparative Analysis", <u>Indian Journal of Natural Rubber Research</u>, Vol.2, No.2, pp.125 - 130.

details on cost, yield per hectare and stand per hectare. The income received and the cost incurred were discounted to facilitate comparison.The average yield which makes the cost-benefit ratio equal to unity which is the minimum average yield to recommend rain guarding, was calculated on the assumption of 20 per cent yield increase from rain guarding. The estimated figure is 675 kg/ hectare. The adjusted three year average cost estimate gives results in favour of polythene sheet rain guarding.

Sudarsanan Pillai[27] in another study examined the management of rubber marketing in India. The major problems in rubber marketing, identified by the study were the fluctuations in price, fluctuations in supply and the visual grading system. It was recommended that the setting up of a central marketing agency in the model of coffee pool which would ensure justifiable price to the growers. Opening of more regional and central processing factories and the formation of more rubber producers. socites are other recommendations of the study. The need for a proper import distribution management to safeguard the interests of both rubber cultivators and manufacturers has been emphasised by the study.

---

[27] Sudarsanan Pillai, P. (1991),"Management of Rubber Marketing in India", <u>Indian Manager</u>, Vol.XX, No.2&3, pp.94-98.

It has been found from the survey of literature that though many studies have been conducted on rubber plantation industry in India and its various aspects, no study has so far focused attention exclusively on the technological changes in rubber plantation industry in Kerala. In this context, the present study would be a pioneering attempt at analysing the technological changes and performance of the rubber plantation industry in the country.

CHAPTER III

PROFILE OF RUBBER PLANTATION INDUSTRY IN INDIA

CHAPTER III

PROFILE OF RUBBER PLANTATION INDUSTRY IN INDIA

Plantations were introduced in the third world countries in the sixteenth century by foreigners who had imperialistic relationship with the natives. For example, major plantation crops tea, rubber and coffee, were brought to India by foreigners.

Natural rubber is produced from the latex of large number of trees, vines and shrubs. Over 895 species of plants belong to 311 genera of 79 families are producing rubber. Of these the most important are para rubber (Hevea Brasilliensis), Panama rubber (Castilloa elastica), Ceara rubber (Manihot Glaziorii), Ficus elastica and Funtumia elastica. The first three are the natives of South and Central America while the fourth has its natural habitation in South-East Asia. Funtumia elastica is a native of Africa. Among these, para rubber or Hevea brasiliensis, contributes the lion's share of the natural rubber produced in the world

In India, wild rubber trees were found in the forests of Assam in the beginning of nineteenth century. In fact, as early as 1810, the famous botanist Rox Bourgh assisted by M.R. Smith of Silhet found 'ficus elastica' growing wild in the forests of Assam. Between 1880 and 1890, the production of rubber from that source averaged between two hundred and four hundred tonnes annually[1].

The initiative in supplementing the supplies of wild rubber with the product of plantations was taken in India during the second half of the ninteenth century. The subject was given real importance only in 1872 when Collins, an Edinburgh botanist, was instructed by the India office to draw up a report concerning the rubber trees of America and to ascertain whether they could be grown in India[2]. In the following year, it was observed by Dietriah Brand that Kanara, Malabar and Travancore were suitable for rubber cultivation[3]. In 1875, Robert Cross and C.R. Makham

---

[1] Gosh, H.H. (1928), Realm of Rubber, J.R.Daymond, Calcutta, p.141.

[2] Huebert L. Terry (1907), India Rubber and Its Manufacture, Archibald Constable & Co. Ltd. London.

[3] Willie J.A. and Ferreira, O.G. (1907) Note on rubber cultivation, Higginbotham & Co., Madras, 1907, P.19

were sent by the British government to collect seeds and cuttings of the castilloa tree. In 1876, Robert cross was sent to para to collect information about the trees yielding the para and ceara rubber. The seedlings were brought to Kew (United Kingdom) of which only less than three per cent could be saved. In 1876, Henry, A. Wickham, an English Coffee planter residing in Brazil undertook botanical expedition to the Amazon valley on behalf of the Government of India. It was pure luck that Wickham happened to make his collection on the banks of the Tapajos river in an area where 'Hevea brasilliensis' was the only species of Hevea available. The collection of Hevea seeds by Wickham set the stage for the initiation of the rubber plantation industry[4]. Wickham is said to have collected 70000 Hevea seeds which were delivered to London. These seeds were planted in special gardens in Kew Gardens. The plants which were developed successfully at Ceylon were blessed with a more favourable climate than India for raising the young seedlings. From this nursery, plants were subsequently delivered to India, Burma, Malaya and Indonesia. This laid down the foundation of the rubber plantation industry in Far East.

---

[4] Armstrong A.A. (1966), A Probe into the Early History of Rubber, All India Rubber Planters' Conference, Mundakkayam, Souvenlr,p.40

Henry Wickham is considered as the father of the rubber plantation industry in the Far East.

It was in 1878 that the first consignment of Hevea plants were received in India from Ceylon. Some more small consignments of the original Wickham collections were received during the period 1880 to 1881. In India, the first attempt to plant rubber was made in the teak plantations of Nilambur, in erstwhile Malabar, now a part of Kerala. Many of the Hevea trees planted at Nilambur were allowed to perish[5]. The plants which came in 1880 and 1881 were planted on an experimental scale in different parts of south India and Andaman islands. In 1881, rubber was planted in the Government botanical gardens at Burliar in Nilgiris. In 1886, F.J. Ferguson obtained some more planting materials from Ceylon, which he planted in Kozhikode and Poonoor, which formed the nucleus for the expansion of rubber cultivation in India. The trials of planting rubber in the initial days were in coffee or tea plantations.

---

[5] Speer.S.G.,(Ed.) (1953), UPASI 1893 - 1953, UPASI, Coonoor, P.213

Development of Rubber Plantations in India from 1902 to 1955

Rubber cultivation in india started on a commercial scale in the year 1902. In that year . J.J.Murphy, J.A.Hunter, K.E. Nicoll and C.M.F. Ross, all European planters, formed the 'Periyar Syndicate'and started the first commercial plantation on the banks of periyar river at Thottakkad near Aluva in the erstwhile Travancore State.[6]

In 1904, J.J. Murphy, H. Drummond Deane and R.S. Imray started planting in Yendayar, Eldorado and Mundakkayam estates, all in central Travancore[7]. The next six years saw the starting of rubber cultivation by many others. This was mainly because of the encouragement given by the Government, which was mainly in the form of granting land for rubber cultivation. During the period 1904-1910, two important rubber companies, viz., The Travancore Rubber and produce Company and the Malayalam Rubber and Produce Company came into existence. By 1910, Mundakkayam had become the leading centre of rubber plantations in India, with an

---

[6] Tharian George K., Haridasan V. and Sreekumar B. (1988), Role of Government and structural changes in Rubber plantation Industry Economic and Political Weekly November 26, p.M-158.

[7] Speer.S.G (1953), Op cit p. 215.

area of 4047 hectares which was about forty per cent of the then existing area under rubber in India. Aided first by the motoring boom and later by the demands of World War I, annual production showed an average increase of 16 per cent during the period 1905-1915[8]. The price also broke all records with the highest ever level (1,400 per ton) being reached in April 1910. Encouraged by the price rise, the rubber industry expanded immensely, so that the world production of raw rubber in 1917 was 3.64 times as large as in 1910.[9]

High price of rubber attracted people for planting rubber in India. Increased price was supplemented by the encouraging attitude of the Government of Madras and Mysore. For example Government exempted all lands already planted or to be planted with rubber from the assessment of tax for three years in Wynad and for five years in the Nilgiris by an order in 1904. The Government of Mysore also passed an order in 1906, granting a maximum of 202 hectares per planter free of assessment of land tax for the first five years. Yet another factor which attracted foreign planters in India was the availability of cheap labour .

---

[8] Allen P.W (1972), Natural Rubber and the synthetics, Crosby Lockwood, London, pp.39-40.

[9] Stafford Whitely G. (1920), Plantation Rubber and the testing of Rubber, Longmans Green and Co., London p.V .

As has been seen from above, rubber was initially planted in India by Europeans in the estate sector. Indians began rubber cultivation in 1910, through the floating of a joint stock company under the name of Malankara Rubber and Produce Company. By the end of 1910, three more companies, viz., the Marthoma Rubber Company, the Kuttanad Rubber Company and the Travancore Commercial Company were floated. All these companies were started in the erstwhile princely state of Travancore. These development in rubber planting in Travancore had its impact on the neighbouring Cochin state. A planting company owned by Indians, viz., Vaniampara Rubber Company was started in 1911. High rubber prices and the remarkable financial performance of the plantation companies attracted individual investors to enter the field of rubber cultivation.

The outbreak of the First World War created some unfavourable effects on the rubber plantation industry. Restriction placed on the issue of capital by public limited companies, joining of a number of European supervisory staff in the armed force, restriction of exports to Germany, and sinking of a number of ships which were used for exporting rubber were some of the factors that adversely affected the rubber plantation industry. These developments resulted in having surplus stocks of rubber with producing countries including India. The surplus stock of rubber badly affected the price of rubber and the events in the period had a profoundly negative effect on natural rubber's economic health.

After the world war I, rubber plantation industry began to show signs of improvement. Highly remunerative prices were offered for rubber in the international market. The exports also started to pick up. Table 3.1 gives the export of rubber from India during 1922-33. The table shows that exports were increasing gradually till 1931.

Table 3.1

EXPORT OF NATURAL RUBBER FROM INDIA DURING 1922-1933

(in tonnes)

Year	QuantityExported
1922	4979
1923	3861
1924	4572
1925	6401
1926	6604
1927	7112
1928	7316
1929	8027
1930	6909
1931	5487
1932	1118
1933	1422

Source: Knorr K.E.(1945) World Rubber and its Regulation, Stanford University Press, California, p.248.

The price of natural rubber started to fall in the beginning of 1930's and 1932 recorded the lowest ever price of 14 per ton[10] The fall in prices dealt a severe blow to rubber economy all over the World. To stave off further deterioration, India and other important rubber producing countries like United Kingdom (on behalf of the straits settlements and the Malay States, Ceylon, British North Borneo, Sarawak), Netherlands, France and Siam reached an inter-governmental agreement on 7th May 1934. The agreement which was known as 'International Rubber Regulation Agreement'(IRRA) had the approval of governments controlling 98 per cent of the World's rubber production[11] This agreement was the first comprehensive and compulsory scheme adopted for the control of rubber supplies in the world. By the agreement, each country was allotted an export quota roughly on the basis of average exports from 1929 to 1932 • Limitations were imposed on planting and replanting. The administration of the scheme was entrusted with the International Rubber Regulation Committee (IRRC) consisting of representatives of the participating countries. The most important function of the

---

[10] Allen P.W. (1972), op.cit. p. 44.

[11] Bauer, P.T. (1947), The Rubber Industry. A study in Competition and Monopoly, Longmans Green and Co. London p. 84.

committee was fixing of the export quota for each country. After 1938, it also had powers to fix permissible percentages of new planting and replanting.[12]

The International Rubber Regulation Agreement was originally for a duration of control from 1st June 1934 to the end of 1938. The agreement was renewed in 1937 with only minor modifications of its provisions for a period of five years ending in 1943. It was further extended for a few months for establishing a non-regulatory organization covering · major producers and consumers of rubber. The Rubber Regulation Scheme was in operation in India up to 1942.

The enforcement of the regulation in India was entrusted with a local committee called Indian Rubber Licensing Committee which was constituted under Indian Rubber Control Act 1934. The committee consisted of representatives of Travancore, Cochin, Madras and Mysore Governments . The headquarters of the committee was at Kottayam . The committee resolved that no rubber could be exported without license or accompanying a certificate of origin.

---

[12] ibid., p. 86.

This was done to enforce the export quota fixed by the IRRC in India. The export quota and the actual quantity of rubber exported from India during 1934-43 is given in the table 3.2

Table 3.2

EXPORT QUOTA AND THE QUANTITY EXPORTED FROM INDIA DURING 1934-43

(in Metric tons)

Year	Export Quota	Quantity exported
1934	6960	6096
1935	8382	8230
1936	9144	8738
1937	9144	10161
1938	13209	8128
1939	17781	9856
1940	18035	13209
1941	18035	4164
1942	18035	..
1943	18035	..

Source: Knorr K.E., Op.cit.pp.133,248 and Rubber Board publications.

The table reveals that the actual export of rubber was very much below the quota permitted by the rubber regulation scheme In order to regulate the exports, quotas were fixed for individual estates on the basis of production records of the estates during the period 1929-32. In the case of small holdings, assessment was made according to some assessment rules since no reliable records were available with them. The agreement adversely affected the tempo of planting of rubber by small holders. Area newly brought under rubber cultivation each year was very low during the scheme, especially in the small holdings sector. Table 3.3 indicates the area newly planted with rubber during 1935-42.

Table 3.3

RUBBER NEW PLANTINGS DURING 1935 TO 1942

Year	Estate	Small Holdings
1935	95	3
1936	631	5
1937	1264	45
1938	1616	161
1939	2833	1185
1940	2328	1367
1941	1341	789
1942	3446	2464
TOTAL	13554	6019

Source: Madhava Menon, P., op.cit.,p.99.

Even though the Rubber Regulation Scheme adversely affected the planting tempo, the scheme was helpful in keeping the price of natural rubber roughly constant. The scheme also helped India in another way. The quota system introduced left a large portion of the rubber produced in the country, unsold, making it available for internal consumption at prices considerably below the world prices. This situation offered a very attractive climate for starting rubber manufacturing industries in India.

The outbreak of World War II changed the natural rubber situation in India . The allied nations had been cut off from the major rubber producing countries which left them to depend wholly on India and Ceylon for obtaining natural rubber. More over, a strategic commodity like rubber was indispensable in any war and its demand shot up during the war period. This resulted in a spurt in domestic demand for natural rubber in India. By the middle of 1941, India became a net importer of rubber, as the rapid growth of the rubber manufacturing industry outstripped the capacity of the plantation industry. In spite of severe restrictions on rubber consumption and of the high price offered for the product, only comparatively small quantities were exported after 1941.[13]

---

[13] Bauer, P.T. (1947) op. cit. p.303.

During the war period , the Government of India and various state governments issued orders to face the war-time difficulties. In 1942, the Government of India issued the Rubber Stocks (control) Order under which the estates, dealers and manufacturers were required to submit returns of stocks to the Rubber Controller or the Supply Department of Government of India. In that year itself, the Indian Rubber Licensing Committee recommended the Government to fix prices for various grades of rubber. The state governments of Travancore, Cochin and Mysore also passed orders converting the maximum prices of rubber into fixed prices and made the violation of prices an offence. On 23 November, 1942, the Indian Rubber Control and Production order was passed and the Indian Rubber production Board was constituted with the object of encouraging production of rubber by all possible means. Under the order, all restrictions on planting and production were removed and rubber growers in India were induced to produce more by exploiting trees to the maximum. War-time necessities increased the demand for natural rubber and the trees were subjected to indiscriminate tapping. Increase in the demand for natural rubber helped in increasing the area under cultivation during 1942-47. The production which showed an increasing trend during the first three years from 1942, changed to a declining trend afterwards. The table 3.4 gives area, production, consumption,import and export of rubber during 1942-47.

Table 3.4

AREA, PRODUCTION, IMPORT AND EXPORT OF NATURAL RUBBER (ALL INDIA) DURING 1942 TO 1947

Year	Area (hectares)	production (tonnes)	consumption (tonnes)	Import (tonnes)	Export (tonnes)
1942	56027	16218	14628	548	567
1943	57955	16671	10801	847	1231
1944	59681	17629	12304	32	3048
1945	61612	16690	15477	62	2298
1946	62521	15967	14262	172	304
1947	52987	14681	17272	1745	

Source: Indian Rubber Statistics (1987-88), Vol.18, Rubber Board p.87.

The indiscriminate tapping methods adopted during the war time adversely resulted in reduced production. The Rubber plantation in India was in a very bad shape as the tress in most of the areas were over exploited and worn out. The fall in prices after the end of the war also worsened the situation. Various proposals were considered by the Government for large scale rehabilitation of the industry. Early in 1947, the Rubber(production and Marketing) Act was passed to replace the Indian Rubber Control and Production Order of 1942 and a statutory organisation, the Indian Rubber Board, was constituted to promote the organised development of the rubber plantation Industry.

Rubber Plantation Industry Since 1955-56

The production of natural rubber has been increasing rapidly since mid fifties. Table 3.5 presents the production of natural rubber and the index of production of natural rubber in India. Natural rubber production increased from 23730 metric tonnes in 1955-56 to 366745 metric tonnes in 1991-92 with the index number (base year 1955-56) rising to 1545. A decrease in production was experienced during the years 1959-60,1977-78,1978-79, 1981-82. Except for the years 1977-78 and 1978-79, the decline in production was marginal. Production of natural rubber which had touched 149632 tonnes in 1976-77 fell to 146987 tonnes during 1977-78 again to 135297 tonnes in 1978-79. However the industry improved its production to 148470 tonnes in 1979-80. The fall in production in 1977-78 and 1978-79 was mainly

Table 3.5

NATURAL RUBBER PRODUCTION IN INDIA 1955-56 TO 1991-92

Year	Production (in tonnes)	Index
1955-56	23730	100
1956-57	24060	101
1957-58	24534	103
1958-59	24169	102
1959-60	24173	102
1960-61	25697	108
1961-62	27446	116
1962-63	32239	136
1963-64	37487	158
1964-65	45616	192
1965-66	50530	213
1966-67	54818	231
1967-68	64468	272
1968-69	71054	299
1969-70	81953	345
1970-71	92171	388
1971-72	101210	427
1972-73	112364	474
1973-74	125153	527
1974-75	130143	548
1975-76	137750	580
1976-77	149632	631
1977-78	146987	619
1978-79	135297	570
1979-80	148470	626
1980-81	153100	645
1981-82	152870	644
1982-83	165850	699
1983-84	175280	739
1984-85	186450	786
1985-86	200465	845
1986-87	219520	925
1987-88	235197	991
1988-89p	259172	1092
1989-90p	297300	1253
1990-91p	329615	1389
1991-92p	366746	1545

P: Provisional

Source : Indian Rubber Statistics Vol.19 and Rubber Statistical News-Various Issues because of the adverse climatic conditions prevalent during these years and the widespread industrial disputes in 1977-78 and 1978-79

Growth in the production of natural rubber is the result of both the increases in area under rubber cultivation and the average yield per hectare. Area under rubber cultivation increased from 86067 hectares in 1955-56 to 466323 hectares in 1991-92. While the tappable area increased from 67181 hectares to 324540 hectares during this period. Table 3.6 gives the area and tappable area under rubber and their indices since mid fifties It is observed from the table that as in the case of production, area and tappable area have been increasing. The index numbers for 1991-92 for area and tappable area were 542 and 483 respectively.

The second factor which accounts for the increase in production is the increase in productivity measured in terms of yield per hectare which has gone up from an extremely low level of 353 kilogrammes in 1955-56 to 1130 kilogramme in 1991-92 with the index rising to 320. Table 3.7 gives the yield per hectare from 1955-56 to 1991-92 and the corresponding index numbers with 1955-56 as the base year.

Table 3.6

AREA AND TAPPABLE AREA UNDER RUBBER CULTIVATION

(1955-56 to 1991-92)

Year	Area	Index	Tappable Area	Index
1955-56	86067	100	67181	100
1956-57	97339	113	72236	108
1957-58	111027	129	71022	106
1958-59	122970	143	70253	105
1959-60	132412	154	69808	104
1960-61	143905	167	70253	105
1961-62	157880	183	74301	111
1962-63	170749	198	84054	125
1963-64	176846	205	95506	142
1964-65	182324	212	108381	161
1965-66	186713	217	112709	168
1966-67	192260	223	113500	169
1967-68	198592	231	117727	175
1968-69	204414	238	123282	184
1969-70	210803	245	133107	198
1970-71	217198	252	141176	210
1971-72	219981	256	149307	222
1972-73	223465	260	154962	231
1973-74	227317	264	165604	247
1974-75	231452	269	170879	254
1975-76	235876	274	178482	266
1976-77	240593	280	185594	276
1977-78	245200	285	191006	284
1978-79	249250	290	190330	283
1979-80	261390	304	192554	287
1980-81	278057	323	194245	289
1981-82	295503	343	196211	292
1982-83	313161	364	199712	297
1983-84	331674	385	204520	304
1984-85	350957	408	210519	313
1985-86	369348	429	223347	332
1986-87	388550	451	237064	353
1987-88	406443	472	249100	371
1988-89p	423722	492	266103	396
1989-90p	440684	512	289060	430
1990-91p	455252	529	306413	456
1991-92p	466323	542	324540	483

P: Provisional
Source : Indian Rubber Statistics Vol.19 and
Rubber Statistical News-Various Issues

Table 3.7

AVERAGE YIELD PER HECTARE IN INDIA
(1955-56 to 1991-92)

Year	Yield	Index
1955-56	353	100
1956-57	333	94
1957-58	345	98
1958-59	344	97
1959-60	346	98
1960-61	365	103
1961-62	370	105
1962-63	384	109
1963-64	393	111
1964-65	420	119
1965-66	448	127
1966-67	483	137
1967-68	548	155
1968-69	576	163
1969-70	616	175
1970-71	653	185
1971-72	678	192
1972-73	725	205
1973-74	756	214
1974-75	762	216
1975-76	772	219
1976-77	806	228
1977-78	770	218
1978-79	711	201
1979-80	771	218
1980-81	788	223
1981-82	779	221
1982-83	830	235
1983-84	857	243
1984-85	886	251
1985-86	898	254
1986-87	926	262
1987-88	944	267
1988-89p	974	276
1989-90p	1029	292
1990-91p	1076	305
1991-92p	1130	320

p: Provisional
Source: Indian Rubber statistics Vol-19
and Rubber Board, Kottayam.

Table 3.7 reveals that the rubber plantation industry has done fairly well in increasing the average yield per hectare during the study period.

The share of the major rubber producing states in the area under rubber cultivation and production of natural rubber is given in Table 3.8, Table 3.9 respectively.

From Table 3.8 and Table 3.9, it is evident that Kerala accounts for more than 85 percent of the area under rubber cultivation and more than 92 percent of the total output of natural rubber in the country.

The dominance of Kerala in the production and area under rubber cultivation can not be seen in the average yield per hectare. The average yield of Kerala was second to Tamil Nadu till 1990-91 which enjoved the most favourable conditions for rubber cultivation. Also, the Kanyakumari district of Tamil Nadu from where most of the rubber produced in Tamil Nadu comes from is free of abnormal leaf fall disease which is common in Kerala.

Table 3.8

STATE-WISE AREA UNDER RUBBER CULTIVATION
(Area in hectares)

Year	Kerala	Tamilnadu	Karnataka	Others	Total
1955-56	80537	3917	1503	110	86067
1956-57	91301	4289	1578	171	97339
1957-58	104621	4646	1589	171	111027
1958-59	116113	5092	1594	171	122970
1959-60	124907	5715	1619	171	132412
1960-61	135809	6256	1659	181	143905
1961-62	149015	6923	1747	195	157880
1962-63	161110	7509	1935	195	170749
1963-64	166542	7988	2121	195	176846
1964-65	171209	8599	2321	195	182324
1965-66	174561	9283	2633	236	186713
1966-67	179194	9873	2916	277	192260
1967-68	184647	10366	3289	290	198592
1968-69	189125	10852	4069	368	204414
1969-70	193763	11287	5285	468	210803
1970-71	198424	11712	6525	537	217198
1971-72	200474	12077	6767	663	219981
1972-73	202761	12677	7059	968	223465
1973-74	205595	13108	7470	1144	227317
1974-75	208430	13439	8090	1493	231452
1975-76	211808	13776	8585	1707	235876
1976-77	215797	14049	8736	2011	240593
1977-78	219506	14345	8790	2559	245200
1978-79	222210	14585	8815	3640	249250
1979-80	232503	15260	8861	4766	261390
1980-81	247675	15513	9004	5865	278057
1981-82	263200	15740	9227	7336	295503
1982-83	279000	16020	9502	8639	313161
1983-84	295600	16240	9973	9861	331674
1984-85	312300	16450	10710	11497	350957
1985-86	328023	16567	11392	13366	369348
1986-87	342642	16765	11913	17230	388550
1987-88	355010	16917	12353	22163	406443
1988-89	366700	17037	12809	27176	423722
1989-90	376810	17100	13200	33574	440684
1990-91	388000	17150	13500	36602	455252
1991-92p	397000	17200	14100	38023	466323

p - Provisional

Source : Indian Rubber Statistics, Vol.19 and Rubber Board, Kottayam.

Table 3.9

STATE-WISE PRODUCTION OF NATURAL RUBBER(IN TONNES) 1955-56 TO 1991-92

Year	Kerala	Tamil Nadu	Karnataka	Others	All India
1955-56	21680	1606	406	38	23730
1956-57	21853	1806	365	36	24060
1957-58	22196	1890	425	23	24534
1958-59	22062	1665	425	17	24169
1959-60	21890	1814	437	32	24173
1960-61	23175	2040	452	30	25697
1961-62	24954	2060	402	30	27446
1962-63	29057	2695	447	40	32239
1963-64	33792	3176	468	51	37487
1964-65	41391	3724	481	20	45616
1965-66	46953	3195	382	0	50530
1966-67	50495	3927	396	0	54818
1967-68	59978	4048	434	8	64468
1968-69	66473	4100	470	11	71054
1969-70	76897	4526	516	14	81953
1970-71	86773	4859	519	20	92171
1971-72	95499	5140	550	21	101210
1972-73	105934	5739	659	32	112364
1973-74	117221	7036	856	40	125153
1974-75	121558	7523	1012	50	130143
1975-76	128769	7631	1282	68	137750
1976-77	139349	8535	1667	81	149632
1977-78	135907	9015	1959	106	146987
1978-79	123677	9367	2100	153	135297
1979-80	136609	9108	2537	216	148470
1980-81	140320	10446	2128	206	153100
1981-82	139435	10510	2606	319	152870
1982-83	152662	9700	3070	418	165850
1983-84	162212	9736	2785	547	175280
1984-85	172092	10603	3095	660	186450
1985-86	184563	11025	4090	787	200465
1986-87	202129	11755	4855	781	219520
1987-88	216562	12470	5253	912	235197
1988-89p	238414	13370	6222	1166	259172
1989-90p	275397	14065	6475	1363	297300
1990-91p	307521	13645	6665	1784	329615
1991-92p	344503	13145	7260	2337	366745

p-Provisional

Source-Indian Rubber Statistics Vol-19 and Rubber Board,Kottayam

Table 3.10

AVERAGE YIELD PER HECTARE IN MAJOR RUBBER PRODUCING STATES IN INDIA DURING 1955-56 to 1991-92

Year	Kerala	Tamil Nadu	Karnataka	Others	All India
1955-56	347	501	281	284	353
1956-57	324	554	252	269	333
1957-58	335	578	293	209	345
1958-59	337	517	282	154	344
1959-60	336	570	290	291	346
1960-61	354	617	305	272	365
1961-62	360	602	268	272	370
1962-63	370	691	293	363	384
1963-64	377	735	315	298	393
1964-65	405	796	342	-	420
1965-66	440	677	280	-	448
1966-67	471	816	285	-	483
1967-68	538	825	310	-	548
1968-69	568	827	344	-	576
1969-70	609	848	372	-	616
1970-71	647	857	378	-	653
1971-72	673	865	412	-	678
1972-73	721	884	450	-	725
1973-74	750	943	501	-	756
1974-75	755	942	544	-	762
1975-76	768	924	536	-	772
1976-77	802	953	614	-	806
1977-78	764	1003	501	-	770
1978-79	698	1046	539	-	711
1979-80	764	990	632	-	771
1980-81	780	1077	531	-	788
1981-82	770	1060	600	-	779
1982-83	828	967	704	428	830
1983-84	864	918	536	547	857
1984-85	890	991	577	567	986
1985-86	897	1044	729	563	898
1986-87	924	1071	818	554	926
1987-88	942	1080	858	612	944
1988-89p	967	1153	991	746	974
1989-90p	1025	1188	996	678	1029
1990-91p	1080	1149	958	611	1076
1991-92p	1143	1079	985	627	1130

p: Provisional
Source: Indian Rubber statistics Vol.19 and
Rubber Board,Kottayam

However, the gap in the yield levels of Tamil Nadu and Kerala has narrowed during the study period as is evident from table 3.10.

The above discussion reveals that natural rubber brought to India in the latter part of the 19th century had a slow but upward trend in area and production in the first half of the twentieth century. Initially rubber plantations were owned by Europeans, in the estate sector. Gradually Indians also started rubber cultivation both in the estate sector and the small holding sector. Until rubber manufacturing industries were started in the thirties, natural rubber was fully exported. It seems worthwhile to note that a favourable government policy was the main reason for the development of the rubber plantation industry in India till independence. British Government's interest in natural rubber was mainly because of its importance as a raw material for their rubber manufacturing industries. After 1955-56, the growth of the industry was more impressive than in the pre-independence period. A detailed analysis of the performance of the rubber plantation industry since 1955-56 is given in Chapter IV.

CHAPTER IV

GROWTH AND INSTABILITY IN RUBBER PLANTATION INDUSTRY

CHAPTER IV

GROWTH AND INSTABILITY IN RUBBER PLANTATION INDUSTRY

In this chapter, the growth performance of the rubber plantation industry in Kerala is analysed using summary measures with a view to identify the changes, if any, that have taken place during the period 1955-56 to 1991-92. The conclusions are mainly drawn on the basis of growth rates with reference to the area under cultivation, output and yield per hectare of rubber plantations. The difference in these estimates over different periods of time and different regions will enable us to draw useful inferences regarding the possible reasons for such changes, which will turn out to be vital to the interests of the development of the rubber plantation industry in the state. The growth rates for Kerala are estimated and are compared with those of two other major rubber producing states, viz., Tamil Nadu and Karnataka as well as with the figures pertaining to India as a whole. This is followed up with a study of the effect of area and yield on output growth using the decomposition method. The fluctuations or instability in natural rubber production has been affecting the price of natural rubber and has been causing difficulties to the government in planning imports. Therefore, the instability in the production of natural rubber has also been analysed in this chapter. Finally, the rates of diffusion of high yielding varieties in the small holding sector and the estate sectors are estimated and are compared.

The exercise of finding growth rates and instability was carried out for the period 1955-56 to 1991-92. This period was divided into two sub-periods for the purpose of analysis. The first period corresponds to the period 1955-56 to 1976-77 and the second period corresponds to 1976-77.The major reason for taking the cut-off point at 1976-77 is the introduction of high-yielding varieties developed in India. New high-yielding varieties developed in India were put to commercial use in the late sixties. Considering a lag of seven to eight years of immaturity period, the production in the second period is expected to reflect the impact of the new high-yielding varieties developed in India Growth rates and instability measures were worked out for the entire period and for sub-periods.

The years 1977-78 and 1978-79 are considered to be years of abnormal rubber cultivation in the sense that production declined sharply during these years. Therefore, in order to verify whether the exclusion of these outliers is necessary, two separate sets of regressions were run for output, yield and area with and without these outliers for the second sub-period. The results, showed clearly that the effect of these outliers is marginal and negligible.

Growth Rates of Area, Production and Yield per Hectare

A study of the growth rates of area, yield and production is useful in assessing the spatial and temporal differences in the development of the industry. These measures would be helpful in making policy decision in the future. In this section it is tried to analyse the growth rates of area, production and yield from mid fifties.

Several statistical/econometric methods are available for the computation of growth rates. However, statistically estimated growth rates are generally accepted. For finding out growth rates, a function is fitted to represent the relationship between the variable under consideration and time. Growth rates are estimated statistically by employing ordinary least squares method.

One of the assumptions that is made in the regression analysis using ordinary least squares method is that the residuals(errors) are normally distributed.Although small departures from the normality assumption do not affect the model greatly,gross nonnormality is potentially serious as the t or F-statistics depends on the normality assumption[1]. One method of checking the normality assumption is to plot the residuals on normal probability paper. This plot is designed in such a way that the cumulative normal distribution will plot as a straight line. In the present analysis the residuals are converted to standardised residuals and is plotted on a normal probability paper.

$$\text{Standardised residual} = e_i/\sqrt{(SSE/n-2)}$$

where e_i is the residual and SSE is the error sum of squares and n is the number of observations. The normal probability plots of the standardised residuals were constructed for the residuals obtained in the estimation of growth rates of all the variables.The plots indicated that the residuals are approximately normally distributed (See Appendix)

---

[1] For a detailed discussion of the analysis of residuals,see Montgomery Douglas,C.and Peck Elizabeth,A.(1982), Introduction to Linear Regression Analysis, John Wiley & Sons, New York, p.59.

Linear Growth Rate

In the case of a linear model, we take time (year) as the independent variable and the area, tappable area, production or yield as the dependent variable. The equation of a linear trend is specified by

$$Y_t = \alpha + \beta.t + u_t \qquad (1)$$

where u_t is a purely random disturbance term which satisfies the assumptions of the general linear model. Equation (1) is fitted to the data using Ordinary Least Squares method The growth rate corresponding to this model is given by

$$G_Y = (1/y).(dy/dt) = \beta/y \qquad (2)$$

A characteristic feature of the linear growth rate is that it varies over the years. The usual practice is, however, after estimating the parameter β , the linear growth rate is postulated to be constant over time and is converted into an equivalent constant compound rate of growth. This is because the linear growth rate is found to be not very convenient for any comparison of growth between two periods or between two regions. In order to convert the linear rate of growth into compound rate of growth, the former is divided by the mean value of the entire period. Logically, if we need to estimate the compound rate of growth over a period, the proper procedure is to choose the exponential growth rates.[2]

Exponential Growth Rates

In the present study, exponential growth rates are chosen as a starting point, rather than the simpler linear growth rates. One of the important variables under study is the output of natural rubber. Exponential growth rates are used for studying the rubber output because of the *a priori* expectation that the change in output in a given year is more likely to be a constant percentage of output in the previous year than a constantly diminishing percentage of it. Since the decomposition analysis is also based on the trend estimation, it is necessary that a common method of estimation is required for all the variables Moreover, it seems reasonable to assume that larger errors, deviations of

---

[2] Dandekar, V M (1980), Introductory Speech in the Seminar on Data Base Methodology for the Study of Growth Rates in Agriculture organised by the Indian Society of Agricultural Economics, Lonavala, February 9-11.

actual values from fitted values, are associated with larger output,a multiplicative error term is more appropriate than an additive one.

The semi logarithmic function which provides the exponential growth rates is given by

$$\ln Y_t = \alpha + \beta t + u_t \qquad (3)$$

where Y_t is the value of the variable for which the growth rate is to be estimated in year t.

α is a constant.

β is the exponential growth rate

and u_t is a purely random disturbance term.

As noted above, the assumption of semi logarithmic functional form puts the restriction of constant percentage growth rate. Table 4.1 presents the national level and state level exponential growth rates for the period 1955-56 to 1991-92. The table also reports the t-values which are used to test whether the estimated coefficients are significantlly different from zero. The growth rate of area under rubber in India was 3.8 per cent. The growth in area was highest in Karnataka, which experienced a growth of 7.0 per cent per.annum. Kerala experienced a growth rate of 3.5 per cent which is below national figures.

Table 4.1

GROWTH RATE OF AREA OUTPUT AND YIELD OF RUBBER IN MAJOR PRODUCING STATES DURING 1955-56 TO 1991-92

(1955-56 to 1991-92)

State	Area	Tappable Area	Output	Yield
Kerala	3.63 (24.64)	4.26 (29.26)	7.83 (27.85)	3.58 (22.91)
Tamil Nadu	3.84 (15.84)	0.49 (29.57)	6.43 (27.66)	2.12 (15.93)
Karnataka	7.04 (20.68)	5.39 (13.55)	9.26 (19.26)	3.87 (21.08)
All India	3.80 (29.80)	4.30 (32.16)	7.78 (29.36)	3.48 (23.34)

Note: 1. Growth Rates are worked out using an exponential function of time which is transformed into $\ln Y_t = a+bt+u_t$
Growth rate = bx100

2. Values in the parantheses are the corresponding t- values which are used to test whether the coeffcients are significantly different from zero.

3. All growth rates are significantly different from zero.

The production of rubber in the country increased at the rate of 7.8 per cent per annum over the 37 year period, from 1955-56 to 1991-92.The estimated figure for Kerala for this period was 7.9 per cent. Karnataka showed the highest growth in output also. This impressive growth in production is mainly because of the increase in area and improvement in yield. Yield improvement is presumed to be the result of change in agricultural technology.

In general, yield per hectare has been showing an upward trend. The growth rates of yield per hectare were 3.7 per cent for Kerala, 3.1 per cent for Tamil Nadu, 4.0 per cent for Karnataka and for 3.5 per cent for India. Thus growth rate of yield per hectare in Kerala is slightly higher than that at the national level. The only state which had a higher growth rate in yield was Karnataka. Table 4.1 clearly indicates that the rubber plantation industry has revealed continuous spectacular improvement during the study period in terms of area, production and yield per hectare.

Test for Acceleration / Deceleration

One of the assumptions that has been made in estimating exponential growth rates is that the growth rates are constant over time. But it is possible that the growth rates have, in fact, accelerated or decelerated . If it happens the exponential trend fitting fails to explain this phenomena. Therefore a different method is employed to test whether there is any acceleration or deceleration in growth rates. Consider the function

$$\ln y_{t.} = \alpha + \beta .t + u_t \qquad (4)$$

If the growth rate is changing over time, β can be expressed as a function of time. It is assumed that the function is linear in time in order to keep the analysis simple.

i.e. $\beta = \beta_1 + \beta_2.t$ (5)

Substituting in (4)

$$\ln y_t = \alpha + \beta_1.t + \beta_2.t^2 + u_t \quad (6)$$

The coefficients are estimated using Ordinary Least Squares method. Hypothesis of constant growth rate is rejected if 'β_2' is significantly different from zero. The growth rate is accelerating if $\beta_2 > 0$ and decelerating if $\beta_2 < 0$. The t-statistic of the estimate of the coefficient β_2 is used for testing the significance of acceleration/deceleration. The value of '$2\beta_2$' determines the magnitude of acceleration/deceleration.

In order to avoid the problem of multicollinearity arising as a result of the introduction of the time squared term, the following transformation is made for ' t '

$$t' = t - \frac{(n + 1)}{2} \quad (7)$$

where n is the number of years for which analysis is undertaken. In the present study n = 37. In the test for acceleration/deceleration, t' is used to mean t. Correlation between t and $(t)^2$ is not significant.

Test for acceleration/deceleration was undertaken in the present study by estimating the coefficients of the log-quadratic function with the logarithms of area,production and yield per hectare as the dependent variable using the method described in the previous paragraphs. The results of the analysis are presented in table 4.2.

Table 4.2

LOG QUADRATIC TREND ESTIMATES OF TAPPABLE AREA, PRODUCTION AND YIELD
UNDER RUBBER IN MAJOR RUBBER PRODUCING STATES IN INDIA
FROM 1955-56 to 1991-92.

	Tappable Area		production		Yield	
	c	d	c	d	c	d
Kerala	0.042 (34.24)	0.0005 (3.73)	0.078 (34.07)	-0.001 (4.29)	0.036 (27.43)	-.001 (4.02)
Tamil Nadu	0.043 (38.44)	-005 (4.33)	0.064 (44.35)	0.0011 (7.48)	0.021 (24.21	-.0006 (6.85)
Karnataka	0.053 (18.94)	0.0017 (5.86)	0.093 (29.10)	0.0022 (6.77)	0.039 (23.25)	0.0005 (2.92)
All India	0.043 (37.20)	-.0004 (3.58)	0.08 (36.08)	-.0010 (4.34)	0.035 (28.57)	-.0005 (4.20)

Note: 1. The coefficients c and d are estimated by using the equation $Yt = a+ct^2+dt+ut$.

2. Figures in brackets indicate t-values.

3. All the t-values are significant at 1% by two-tailed test

From the table, we find that the states of Kerala and Tamil Nadu and the national level data for tappable area, production and yield showed significant deceleration. The annual growth rate of rubber production, then estimated by log-quadratic curve for the period 1955-56 to 1991-92, falls annually by small amounts of 0.2 per cent in Kerala, 0.22 per cent in Tamil Nadu and by 0.12 per cent for the country. For Karnataka, the growth rate rises by small increments of 0.44 per cent annually. For tappable area and yield also, deceleration was experienced for the states of Kerala and Tamil Nadu and also for the country as a whole. Here also, the exception was Karnataka, which experienced an acceleration.

Inter-temporal Comparison of Growth Rates

The test for acceleration/deceleration, showed that there exists, significant acceleration/deceleration in growth rates. Therefore, it is presumed that the growth rates are varying over time and that there may be difference between the first and second period. In view of the above considerations, separate growth rates were calculated. To compare the growth rates for two time periods, the usual method is to fit two separate regressions for the two time periods. A defect of this method is that it assumes discontinuity between the two periods. Another defect is that each of the sub period growth rate may be both greater than or less than the growth rate for the period as a whole, which is unrealistic. In the present study,the growth rates are estimated without discontinuity. The model is called a kinked exponential model[3] The following single equation is used to estimate the growth rates for the two time periods.

$$\ln Y_t = \alpha_1 D_1 + \alpha_2 D_2 + (\beta_1 D_1 + \beta_2 D_2).t + u_t \quad (7.)$$

where D_1 = 1 for the first sub-period

= 0 for the second sub-period

D_2 = 1 for the second sub-period

= 0 for the first sub-period

Discontinuity is eliminated by a linear restriction at the break point ' k '

$$\alpha_1 + \beta_1 . k = \alpha_2 + \beta_2 . k \quad (8)$$

From (8) , we get

$$\alpha_2 = \alpha_1 + \beta_1 . k - \beta_2 . k \quad (9)$$

$$D_2 = 1 - D_1 \quad (10)$$

Substituting in (7)

$$\ln Y_t = \alpha_1 + \beta_1 (D_1 t + D_2 k) + \beta_2 (D_2 t - D_2 k) + u_t \quad (11)$$

---

[3] For a discussion on kinked exponential models, see Boyce James op. cit., p.267-271.

The ordinary least square estimates of β_1 and β_2 give the exponential growth rates for the first and second sub-period respectively. Where as the log-quadratic form discussed earlier assumes a smooth and continuous growth, the kinked exponential form assumes a sharp break in the growth curve. Table 4.3 presents the kinked exponential growth rates for the two sub-periods.

Table 4.3

GROWTH RATES OF AREA, OUTPUT AND YIELD OF RUBBER IN MAJOR PRODUCING STATES USING KINKED EXPONENTIAL MODEL (1955-56 to 1976-77 and 1977-78 to 1991-92)

State	Period I				PeriodII			
	Area	Tap.Area	Output	Yield	Area	Tap.Area	Output	Yield
Kerala	3.63	5.01	9.49	4.48	3.63	2.92	4.89	1.97
	(13.11)	(22.90)	(24.47)	(20.57)	(8.66)	(8.94)	(8.47)	(6.08)
Tamil Nadu	5.75	5.26	8.23	2.97	0.44	2.63	3.23	0.60
	(27.30)	(30.77)	(36.58)	(17.17)	(1.77)	(10.72)	(10.08)	(2.54)
Karnataka	9.50	3.34	6.72	3.38	2.65	9.04	3.78	4.75
	(25.69)	(5.24)	(9.04)	(10.14)	(5.06)	(10.18)	(12.84)	(9.48)
All India	3.88	4.99	9.36	4.37	3.97	3.07	4.96	1.89
	(14.80)	(24.73)	(25.92)	(21.60)	(10.01)	(10.22)	(9.24)	(6.29)

Note: 1 Period I - 1955-56 to 1976-77
Period II - 1977-78 to 1991-92

2. Values in theparantheses are the corresponding t- values which are used to test whether the coeffcients are significantly different from zero.

3. All growth rates are significantly different from zero.

The second period is the period after high yielding varieties developed in India where put to commercial use. A glance at table 4.3 reveals that the rubber plantation industry showed improvements in terms of area, yield and production during both the sub-periods under study. The most striking observation is that in the states of Kerala and Tamil Nadu as well as at the national level, yield grew faster in the first sub-period. During the first period, the yield grew annually by 4.37 per cent in India, 4.48 per cent in Kerala and 2.97 per cent in Tamil Nadu. The corresponding growth rates for the second period were 1.89 per cent, 1.97 per cent and just 0.60 per cent respectively.

The conclusion emerging from the foregoing analysis is that the rate of growth during the second sub-period failed to keep pace with the earlier period. It is surprising that despite an increase in the percentage of area under high-yielding varieties, yield growth has slackened in the second period. Lower growth rate in the second period can be partially attributed to the high mean yield levels in the first period, which precluded the possibilities of spectacular growth in the second period. This is strongly supported by the fact that Karnataka having the distinction of being the state with lowest productivity levels among the three states showed an improvement in the second period

Yet another reason for the slower growth in the second sub-period was that most of the fertile and suitable land for cultivation of rubber have been used in the first period itself. Therefore, most of the land newly brought under cultivation in the second period was marginal or comparatively less fertile land. Owing to this bottleneck, in order to keep up the average yield per hectare, the industry required additional utilisation of technology. Even though, the growth rate was low in the second period, the industry was able to improve the average yield per hectare. As revealed from the discussion in chapter III, the gap between the average yields of natural rubber in Tamil Nadu and Kerala has declined during the study period. It is significant to note that the only region in India where the soil and climatic condition suitable for rubber cultivation is the Kanyakumari district of Tamil Nadu. About 97 per cent of the area under rubber cultivation in Tamil Nadu is in this region. Kerala,which does not have such favourable soil and climatic conditions was able to improve the yield to almost level with the yield of Tamil Nadu.

Decomposition of Growth in Rubber Production

The production of natural rubber registered an increase during the period from 1955-56 to 1991-92. More and more area have been brought under rubber cultivation and the yield of rubber also has been showing significant growth. It should be noted that these two factors, area and yield have been influencing production simultaneously. Therefore, it is important to study the relative contribution of these two components in the growth of natural rubber production.

Several methods of decomposing agricultural output growth are available. A drawback of majority of these methods is that they are based on data for the base year and current year only and as such do not necessarily reflect the actual trends for all the years in the series. Decomposition of output growth using some methods attribute a major part of production growth to interaction effect. This results in the failure of the technique in making any definite conclusions about the area effect and yield effect. In the present analysis, a technique for the decomposition of growth in rubber production into area effect and yield effect which uses the data for all the years in the study period is employed. An advantage of this technique is that it does not have any interaction term. The analytical framework depends on the identity which expresses output as the product of tappable area and yield.

Thus $$P_t = A_t . Y_t \qquad (12)$$

where P_t = Rubber production in year t

A_t =Tappable area in year t

Y_t =Yield per hectare in year t

Given a multiplicative identity such as (12), the exponential growth rates of the components on the right hand side sum to the growth rate of the left hand side.

ie.Growth rate of production = Growth rate of tappable area + Growth rate of yield

Area effect = (Growth rate of tappable area ÷ Growth rate of production)×100

Yield effect = (Growth rate of yield ÷ Growth rate of production)×100.

This method is used to get a broad picture of relative contribution of the component elements on output growth.The exponential growth rates obtained earlier have been used for finding out the yield effect and area effect. The result of the decomposition analysis are given in Table 4.4.

Table 4.4

DECOMPOSITION OF OUTPUT GROWTH INTO AREA EFFECT AND YIELD USING EXPONENTIAL AND KINKED EXPONENTIAL ESTIMATES

State	Period I			Period II			Full Perio		
	Output Growth (%)	Area effect (%)	Yield effect (%)	Output growth (%)	Area effect (%)	Yield effect (%)	Output growth (%)	Area effect (%)	Yiel effe (%)
Kerala	9.49	52.84	47.16	4.89	59.66	40.34	7.9	53.16	46.8
Tamil Nadu	8.23	63.88	36.12	3.23	81.32	18.68	6.4	67.19	32.8
Karnataka	6.72	49.62	50.32	13.78	65.57	34.43	9.5	57.89	42.1
All India	9.36	53.37	46.66	4.96	61.88	38.12	7.8	55.13	44.8

Note: 1. Period I - 1955-56 to 1976-77

2. Period II - 1977-78 to 1991-92

3. Growth rates for the two periods are estimated using the kinked exponential model and growth rates for the full period was estimated using exponential model.

4. Tappable area is taken for area

Table 4.4 clearly indicates the spatial and temporal variation in the growth process. It is found that of the 7.9 per cent rate of growth in aggregate production in Kerala during the study period, approximately 53.16 per cent (4.2 percentage points) be attributed to growth in area and 46.84 per cent (3.7 percentage

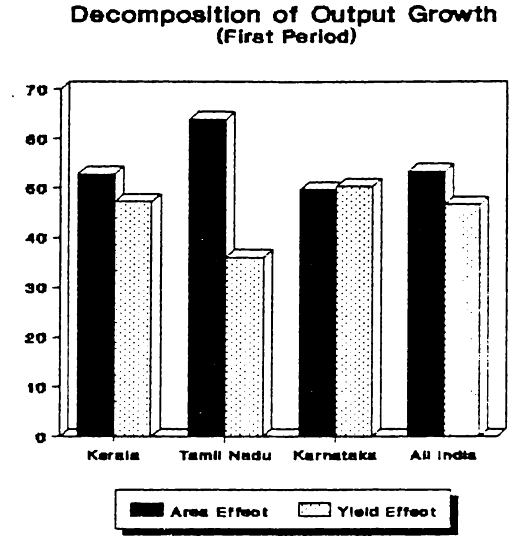

Decomposition of Output Growth
(First Period)

FIGURE-1

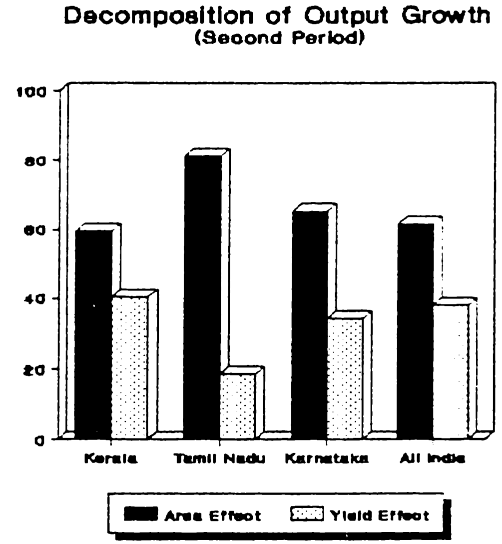

Decomposition of Output Growth
(Second Period)

FIGURE-2

points) could be attributed to yield growth. At the national level, the corresponding percentages were 55.13 and 44.87 respectively. As most of the area suitable for rubber cultivation have been brought under cultivation, the scope for the extension of the area under rubber cultivation in the state of Kerala is limited in the future. Therefore, further developments depends on increases in productivity. Area effect was the major component in output growth for all the states for both the sub-periods.The only exception was the state of Karnataka during the first period when the yield effect was greater than the area effect.

The major conclusion emerging from the foregoing analysis is that ,judging from the dimension of output growth rates in both the sub-periods as well as in the full period,it is the area effect that is the major component of output growth. Slower growth in yield in the second period resulted in a reduction in the yield effect.

Instability in Natural Rubber Production

Instability in agricultural production can have important implications on the economy. Sustained growth is very important in agriculture where input-output relations are subject to uncertainty dependent on the vagaries of nature. Besides, fluctuations in output also can have far-reaching consequences on the farm incomes.

As revealed by the analysis of the growth patterns, the rubber plantation industry showed an improvement in terms of growth. The other points which need further analysis include instability in the two sub-periods and the contribution of yield instability and area instability on production instability. These are issues that warrant consideration, if the objective of planned development is growth with stability. Growth and stability drew the attention of economists and planners by the advent of technological revolution. The study of one without the other will put the exercise out of perspective. This put forth the need for a proper assessment of the nature and dimension of the problem of instability. Therefore, this section is devoted for the analysis of instability in the output of rubber plantation industry.

Instability is defined as the fluctuations around the trend curve. There are different methods to measure the instability depending on the method of trend elimination. One method of measuring instability over time is suggested by Boyce[4]. The method is as follows; initially a trend curve is fitted. Then the difference between the actual and estimated values of the variables are calculated and is expressed as a percentage of the estimated value.The absolute value of this percentage is regressed against time. If the estimated coefficient on time is positive, instability has increased, and if negative, instability has decreased. The t-statistic provides an indication of the significance of the trend. A limitation of this method is that the measure is sensitive to the specification of the growth trend. The estimated residuals will include specification errors as well as instability. The results of the analysis of instability is presented in table 4.5.

The table reveals that the trend test analysis gives an indication that there was no significant instability during the period of study. This persuades us to think of the futility of applying this method to the two sub-periods separately. In order to make a comparison between the two sub-periods, we switched over to a more simpler measure which is known as Mac Bean Index.

---

[4] Boyce James K. (1987), op cit., p.273.

Table 4.5

TREND TEST FOR INSTABILITY USING EXPONENTIAL TREND FITTING METHOD (1955-56 to 1991-92)

	Tappable Area		Production		Yield	
State	b	t Value	b	t Value	b	t Value
Kerala	0.009	0.06	0.026	0.09	0.003	0.05
Tamil Nadu	0.008	0.06	0.010	0.04	0.0004	0.00
Karnataka	0.130	0.34	0.250	0.53	0.007	0.05
All India	0.008	0.06	0.023	0.08	0.007	0.04

In the present study, the instability in natural rubber production is worked out using an index called MacBean index[5] This index is based on moving averages.Mac bean index is defined as

$$\text{MBI} \quad \frac{100}{n-4} \sum_{t=3}^{n-2} (|X_t - MA_t|/MA_t)$$

where MA_t is a five year moving average of the `X_t'

---

[5] MacBean, Alasdair I. (1966), Export Instability and Economic Development, George Allen & Unwin, London, p.34.

values centered on year t. It is attempted to test the hypothesis that instability, particularly in yields and production is increasing in recent times, through an intertemporal analysis of instability patterns. MacBean indices for tappable area, production and yield per hectare are calculated for the two sub-periods and a comparison is made. The magnitude of the indices gives an indication of the magnitude of instability during the period under consideration.

Table 4.6

MAC BEAN INDICES OF INSTABILITY OF TAPPABLE AREA, PRODUCTION AND YIELD OF RUBBER

State	Period I			Period II			Full Period		
	Tappable area	Production	Yield	Tappable area	Production	Yield	Tappable 'area	Production	Yield
Kerala	20.30	35.35	16.87	46.57	68.43	35.83	29.34	46.76	24.49
Tamil Nadu	17.90	32.50	15.82	44.75	56.14	25.4	28.06	43.07	20.26
Karnataka	3.87	15.79	13.45	56.4	70.42	39.35	2.87	40.32	23.56
All India	19.86	34.90	16.77	44.36	63.2	35.21	29.2	46.48	24.2

Notes: Period-I - 1955-56 to 1976-77

Period II - 1977-78 to 1991-92.

Full Period - 1956-57 to 1991-92

The estimates of instability and changes in their magnitude are presented in table 4.6. These estimates showed that instability in tappable area, production and yield per hectare of natural rubber in the country was greater in the second period than in the first period. In all the three states also, the index of instability increased in the second period. This agrees with the opinion put forward by Sen[6]. He opined that instability increased as farming was extended to marginal lands. However, this conclusion should be viewed along with the fact that the growth rates of production was lesser in the second period. This brings us to the conclusion that apparently there is no positive relationship between growth rate and instability in the case of a perennial crop like rubber.

Decomposition of Production Instability

Here, the output variability is decomposed into its components viz., variability in tappable area, yield variability and the covariance between the two.

---

[6] Sen, Samar R. (1967), Growth and Instability in Indian Agriculture: Address to the Twentieth Conference of the Indian Society of Agricultural Statistics, January 10-12.

Consider the equation,

$$\begin{aligned} \text{Production} &= \text{Tappable Area} \times \text{yield} \\ \text{ie. } P &= A \times Y \\ \ln P &= \ln A + \ln Y. \qquad (1) \\ \text{Var}(\ln P) &= \text{Var}(\ln A) + \text{Var}(\ln Y) + \\ & \quad 2\,\text{Cov}(\ln A, \ln Y) \qquad (2) \end{aligned}$$

Where variances and covariances are around trend lines. The variance of area and yield are divided by Var (ln P) and are expressed as percentages. The covariance term, positive or negative, reflects the extent to which area and yield movements are mutually reinforcing or offsetting. The exercise has been carried out for the whole period as well as for each sub period.

Table 4.7

DECOMPOSITION OF PRODUCTION INSTABILITY

State	Period I			Period II			Full Period		
	Area effect %	Yield effect %	Interaction effect %	Area effect %	Yield effect %	Interaction effect %	Area effect %	Yield effect %	Interaction effect %
Kerala	31.45	40.50	28.05	59.65	15.77	24.58	27.00	31.08	41.92
Tamil Nadu	62.68	46.05	8.73	9.67	108.01	17.68	35.42	33.08	31.50
Karnataka	39.60	22.20	38.20	15.04	114.37	29.41	68.73	14.67	16.60
All India	32.68	38.27	29.05	57.03	13.87	29.01	25.77	31.99	42.24

Note: Area effect means Tappable Area effect.

Table 4.7 gives the contribution of each component to output variance. The analysis reveals that for the whole period, the effect of yield variability is higher than the effect of area variability. In Kerala, the yield variance and acreage variance effects were 31.08 per cent and 27.00 per cent respectively and the rest is made up of covariance between yield and area. The positive sign of the covariance term suggests that both area and yield are moving together in the same direction and their interaction effect is quite pronounced, and mutually reinforcing. While Kerala and national figure showed an almost similar ratio of contributions, Tamil Nadu and Karnataka had the positions of area effect and yield effect reversed.

Intertemporal patterns in the decomposition of output variance are interesting. In the case of India and Kerala State it was the yield variance that contributed largely to the output variance in the first period. This is not so in the case of Tamil Nadu and Karnataka. In period II, a reversal of positions was experienced for all the three States and for all India figures. Rao C.H.H.[7] argues that since variability in yield per hectare

---

[7] Rao C.H.H (1975), Technological Change and Distribution of Gains in Indian Agriculture, MacMillan & Company, Delhi

tends to be far greater than that of area, productivity oriented growth has contributed to greater variability in output. However, our analysis fails to substantiate the above conclusion for rubber.

The larger contribution of interaction term for both periods indicates that simultaneous change in area and yield further accentuated production instability. As noted earlier, individually, yield variability was an important source of production instability. The cultivation in less endowed areas and extension of cultivation to marginal and submarginal levels might have contributed to higher production instability in the second period. However, as the area instability is the dominating factor on the production instability in the second period, we could expect that the instability in the production of natural rubber in Kerala may be further reduced as the scope for growth in production due to area expansion is limited. The yield instability was significantly reduced in the second period. It could be further reduced by investing on research towards evolving of cultivars which are suitable for the existing agro-climatic conditions. These policies coupled with better cultural practices would lead to growth with stability. An interesting thing that may be noted in our analysis is the closeness of the estimates for the Kerala state and for the whole country. This is true for growth rates, acceleration/deceleration, instability or the decomposition measures. The main reason for this phenomenon is that other states really contribute very little to the national figures. So we can be justified in analysing national level data whenever the state-wise data for Kerala is not available.

Rates of Diffusion of High Yielding Planting Materials

One of the apparent features of the rubber cultivation in India has been a positive growth trend in rubber production. The commendable increase in the production of natural rubber was the result of increases in area and productivity. Productivity increases were mainly the result of technological changes. The diffusion and adoption of new technology is one of the most important stages of the process of technological change.

A major determinant of technological change in rubber plantation industry in India has been the introduction and adoption of high yielding varieties. The estate sector and the small holding sector experienced differential rates of adoption of this technology. Since the rate of diffusion is the rate at which a new technique is actually put into use, it is a critical determinant of the rate of growth of productivity[1]. If certain groups are quicker to diffuse a new, more efficient technique, they are quicker to attain the resulting increases in productivity. A measurement of the rate of diffusion is helpful in planning for future innovations.

There can be differences in the qualities of high yielding varieties. But data on area planted to specific cultivars are not available. We have access only to the data classified according to area planted to seedlings, clonal and budgrafts. Therefore, we cannot distinguish between the adoption profiles of different cultivars. What we can get is the diffusion path of an aggregate of a group of technologies Viz. HYVS which appear unique but are developed and introduced serially. Table 4.8 presents the percentage of high yielding varieties in estates and small holdings in India.

---

[1] Romeo Anthony A. (1975), "Interindustry and interfirm differences in the rate of diffusion of an innovation", Review of Economics & Statistica, Vol 57 No. 3 p.311

Table 4.8

Area under Ordinary and High-Yielding Varieties of planting materials (Percentages in Parenthesis)

Holding/Estate	1955-56	1965-66	1975-76	1985-86	1989-90
SMALL HOLDINGS					
High Yielding	2844 (7.39)	53048 (43.12)	107326 (63.62)	262745 (88.55)	342373 (94.16)
Ordinary	35644 (92.61)	69962 (56.88)	61361 (36.88)	33981 (11.45)	21252 (5.84)
Total	38488 (100.00)	123010 (100.00)	168687 (100.00)	296726 (100.00)	363625
ESTATES					
High Yielding	14874 (31.26)	39534 (62.06)	64978 (96.71)	72072 (92.24)	76945 (99.85)
Ordinary	32705 (68.74)	24169 (37.94)	2211 (3.29)	550 (0.76)	114 (0.15)
Total	47579	63703 (100.00)	67189 (100.00)	72622 (100.00)	7705 (100.00)

TOTAL FOR THE INDUSTRY

The diffusion path of aggregate adoption of a new technology often resembles a sigmoid or S-shaped curve, largely reflecting the spread of information. The reason behind such a behaviour of the diffusion process is given below. Initially only a few farmers adopt the innovation and that too on an experimental basis. The diffusion rate at this point is low. It is from these small number of most progressive and less risk averse farmers, the information is generated and the idea spreads. As the number of adopting producers increase, the information base widens and since there is large number of farmers who have not adopted the innovation, the diffusion rate increases. As the number of users becomes large, the number of potential users becomes small. The remaining group will be most resistant to adoption. Therefore the increase in the cumulative number of farmers that have adopted the innovation will slow down. The above process can be approximated by an S-shaped curve.

An S-shaped curve very much resembles the cumulative distribution function of a random variable. The cumulative normal and the logistic are the cumulative distribution functions most widely used in trend fitting. The logistic curve has been used for our purpose as there is almost no difference between the cumulative normal and logistic[2] and that the logistic is easier for interpretation.

According to the logistic model, the proportion of holdings/estates not using an innovation at time 't' that begin using it by time t+1 is a function of the proportion of farms that are already using the innovation at time t. The growth over time in the proportion of farms using an innovation is given by

$$P(t) = \frac{\gamma_2}{1 + e^{-(\gamma_0 + \gamma_1 t)}} \qquad (1)$$

where P (t) is the percentage planted with high yielding varieties at time t.

γ_0 is the constant of integration which positions the curve on the time scale.

γ_1 is the rate of diffusion.

---

[2] Cumulative distribution function of a random variable X is the probability that it takes a value less than or equal to x_0, where x_0 is a specified numerical value. If F (x) is the cumulative distribution function, then $F_X(x_0) = P[x \leq x_0]$

γ_2 is the ceiling of the curve.

t is the time variable.

The curve is asymptotic to 0 and γ_2. In the present case, $\gamma_2 = 1$ as the maximum value that can be attained by the proportion of HYVS is 1.

One method of estimating the parameters of equation (1) is to regress the natural logarithms of the ratio of the percentage of adopters to 100 minus that percent on time But Oliver[3], while making a comparison between different methods of fitting the logistic curve concludes that there "is no substitute for full least squares in estimating the logistic growth function. Other methods of fitting are inefficient and can give diverse estimates of the parameters...". Therefore, the above function was estimated using the iterative non-linear least squares method applied direct to the time series data with a ceiling 1.00 ($\gamma_2=1$) for both estates and small holdings. The results of the regression analysis are given in Table 4.9.

---

[3] Oliver, F.R. (1964), "Methods of Estimating the Logistic Growth Function", Applied Statistics, Vol.13, p.65.

Table 4.9

Diffusion of High Yielding Varieties Measured Over Time

	Constant γ_0	Coefficient of time γ_1	DW	$\bar{R}^2$	F
Standard Logistic Form					
Estates	-1.328	0.168	1.26	0.98	395.45
	(-7.64)	(11.00)			
Small Holdings	-1.927	0.123	1.69	0.97	278.22
	(-9.04)	(10.681)			
Linearised Form					
Estates	1.704	0.220	1.97	0.97	232.93
	(-4.78)	(15.262)			
Small Holdings	-2.256	0.137	1.72	0.96	168.63
	(-9.27)	(12.98)			

The logistic function given in equation (1) has the property

$$\ln \frac{P(t)}{1-P(t)} = \gamma_0 + \gamma_1 t \qquad (2)$$

This relationship can be used for giving more intuitive notions of the rate of diffusion γ_1. The logistic function can be used for estimating the length of time between, say P percent of firms adopted the innovation and when say P_2 percent were adopters.

From (2), this time is given by.

$$\frac{1}{\gamma} \cdot \{(100-P_1)\ P_2/P_1\ (100-P_2)\}$$

such length of time depends only on γ_1 and not on the constant term γ_0. Thus the estimate of γ_1 is used for estimating the number of years between the time when P_1 percent of all planting materials is high-yielding to when P_2 percent is high yielding.

From the estimated values[4] of the parameters γ_0 and γ_1, we can find out the date of origin, which is taken as the date of ten per cent adoption.[5]

Date of origin = $(2.2 - \gamma_1)/\gamma_2$

Year = 0 in 1955-56

Rate of acceptance = γ_2

Table 4.10 presents the dates of origin and the rates of acceptance of high yielding varieties in the estates and small holdings.

---

[4] The values obtained from the non-linear least squares method have been used for this purpose.

[5] The logistic is a distribution which is assymptotic to zero and it does not have a beginning. The ten per cent date was chosen as the date of origin in other works also. For example, see, Grilliches Zvi (1987), op.cit.p.220

Table 4.10

Dates of Origin and Rates of acceptance of High Yielding Varieties

	Date of Origin	Rate of Acceptance
Estates	1950-51	16.8
Small Holdings	1953-54	12.3

It may be inferred from the table that the estate sector realised the advantage of planting with high yielding varieties much faster than the small holding sector. The values of the dates of origin indicate that the diffusion of HYVs started in the estate sector and spread to the small holding sector with a lag of about three years. Though technologies to increase the production of rubber were available, the country has not been able to diffuse it quickly to the small farmers. It was found from the analysis that estates generally have a higher rate of adoption of technology. While the rate of diffusion was 16.8 per cent in the estate sector, small holding sector could achieve only a rate of 12.3 per cent. The value of $\gamma_2 = 0.168$ in the estate sector and ${}_2 = 0.123$ in the small holding sector implies that the latter took additional ten years to reach the 90 percent adoption level.

It is found from the analysis that the small holding sector is lagging behind the estate sector in the adoption of innovations. Rubber Board should allocate more resources to the problems of the small holders. Technologies should be developed in such a way that it is easily adoptable and profitable to the small holding sector which contributes the lion's share of the production of natural rubber in the country. The Rubber Board should take steps to effectively diffuse such technologies with the help of the recently started Rubber Producers societies.

CHAPTER V

TECHNOLOGICAL CHANGES IN NATURAL RUBBER PRODUCTION

CHAPTER V

TECHNOLOGICAL CHANGES IN NATURAL RUBBER PRODUCTION

Technology has been singled out as the most dominant variable affecting agricultural productivity and development. The productivity gains, provide a combination of increased profit to land owners, increased demand for labour and consumer benefit from lower prices. Like any other agricultural crop, natural rubber also witnessed changes in the technology of production. The present chapter examines the technological changes experienced in the rubber plantation industry in India.

It is widely accepted that one of the major reasons for the improvement in agricultural productivity was technological change. The technological changes experienced in agriculture include improved varieties of seeds, mechanisation of agricultural operations, use of chemical fertilisers, insecticides etc. Mechanisation of agricultural operations was a major development in many annual crops. However, in the case of plantation crops, the scope for mechanisation was limited and was rarely found. New improved inputs like HYVs, fertilisers and pesticides have also been increasing the yield of cultivated areas. The high yielding varieties of seeds have a higher rate of yield compared to the traditional ones for a given level of complementary inputs. Higher resistance to certain crop diseases and marginal reduction in the duration of the crop are some other advantages of the high yielding varieties. Many crops were affected by various pests which could be eliminated by using chemical pesticides. The application of plant-protective pesticides indirectly contribute to increased output by preventing crop losses at various stages.

India experienced considerable improvement in agricultural technology since independence. Of particular importance, has been the introduction of high yielding varieties. The use of high yielding varieties was supplemented by improved cultivation practices and there has been wide acceptance of chemical fertilisers, pesticides and herbicides, often specially developed for particular crops for particular environmental conditions. The wheat and rice and coarse grains have been capable of high yields with the aid of fertilisers, pesticides and adequately controlled water supplies. 'They were produced by means of genetic and agronomic "engineering" carried out in international and national research centres'[1]

---

[1] World Bank (1972), Agriculture, Working Paper, World Bank, Washington, p.7.

The use of new varieties, has been accompanied by an increasing degree of mechanization. Some examples are the use of tractors for rapid land preparation, of permitting increased double-cropping, of mechanical threshers to handle the greatly increased harvest, and of motor pumps to lift irrigation water. Productivity improvement takes place in agricultural crops by a combination of breeding better varieties, extension and improvement of irrigation, more intensive fertiliser use and mechanisation.

Higher crop yields from improved technology has been a major source of growth in rubber production, the other factor being growth in area under rubber cultivation. In Kerala, the homeland of rubber cultivation in India, any sizable improvement in output cannot be achieved by bringing more and more new area under cultivation because of the limited availability of cultivable land. Therefore the main source of growth in production in the future is, of course, growth in productivity.

The Indian natural rubber industry, has over the years, evolved a system of research capabilities that has generated a stream of indigenous technology. At times, the industry has adopted better technologies developed elsewhere, which were found to be suitable to our conditions. The productivity in rubber plantation industry depends not only on the advancement of technology, but also on the proper diffusion of new technology among the growers. Adoption of new high yielding cultivars and associated package of improved techniques has been wide spread. The associated package of improved techniques include discriminatory fertiliser application, scientific cultural practices, introduction of rain guards, application of yield stimulants and scientific tapping. It is interesting to note that majority of these factors were not considered to have any significant impact on productivity during the early years of plantation production. For example, Ashplant[2] states that the yield of rubber tree, is influenced by a variety of factors such as the tapping system, frequency of tapping, efficiency of tapping and by the age of the trees as well as the soil and the climatic conditions of the district. Thus it is clear that the knowledge of the productivity determining factors was entirely different in the initial years of rubber cultivation in India.

---

[2] Ashplant Herbert (1921), <u>Para</u> <u>Rubber</u>, Department of Agriculture, Kampala, p.7.

Planting Materials

The selection of the material to be planted is important in the cultivation of any crop. This is all the more significant in the case of a perennial crop like rubber, as the decision of the type of planting material has an effect for about thirty years. Information on the relative performance of various planting materials helps the planters in arriving at the correct decision about planting.

All the old rubber plantations in the Far-east have originated from one source viz. seeds brought by Sir Henry Vickham in the latter part of the nineteenth century from the Amazon valley in Brazil. Practically, all trees originated from this seeds which were low yielding. Research on breeding and selection was started by the various rubber research institutes in Java, Sumatra, Malaya, Ceylon and India.

Increase in yield was largely brought about by the development of several high-yielding clones or budgrafts. In the early days of the plantation industry, only unselected seedlings were available.for planting. These unselected seedlings were capable of giving yield of no more than 200 to 300 pounds per acre per year under the most favourable conditions[3]. As years passed, the unselected seedlings slowly gave way to selected seedlings of higher yield. These selected seedlings were mostly mono-clonal seedlings of which a fine example is Tjir seedlings. These selected seedlings were capable of producing on estate scale, up to 1000 or even 1500 pounds of dry rubber per acre per year under favourable environmental conditions[4].

One of the main characteristics of the unselected planting material was its yield variability. The yield of the trees varied considerably. As the planters shifted to selected seedlings, the output from their progeny was higher than that of the completely unselected seedlings. Still the variability was significant. The extra yield was also not much higher in majority of the cases because the selected mother tree has often cross pollinated with poor fathers adjacent to them.

---

[3] Nair C.K.N. (1974), "Recent developments in Rubber, Research Paper presented at the rubber planters' conference, Kottayam.

[4] ibid

A major breakthrough in the production of high-yielding clones was the development of the technique of budgrafting. As early as in 1916, a Dutch Scientist, Van Ehlten, successfully grafted buds from selected high-yielding trees on to the seedling stocks. The trees thus obtained are known as clones, or plants whose scion - that part above the root stocks - is obtained by negative propagation. Their main characteristic is similarity in all important features such as yield and habit of growth and in other aspects such as the shape of the seed and markings on its coat[5]. The planters were over-enthusiastic about the possibilities of yield enhancement. It was readily believed that by budding from the existing best yielders would straight away, in the first generation, provide plants capable of yielding 2000 to 3000 pounds per acre per year[6].

Significant advances in the breeding of high-yielding clones were made in the fifties. Notable contributions in the

---

[5] Barlow C., op.cit., p.116.

[6] Ashplant Herbert (1924), "Recent Developments in the Rubber Planting Industry with Special Reference to Budding, Brownbast treatment Manuring of Rubber etc.", Rubber Growers Association Incorporated), London, p.9.

development of high-yielding clones were from the Rubber Research Institute of Malaysia (RRIM) and Rubber Research Organisation of Indonesia. The high-yielding clones developed in the above research institutes were subsequently adopted by the farmers in India. Breeding of high clones started in India in 1954 when the Rubber Research Institute of India was started. The institute has been able to evolve some high-yielding planting materials like RRII-105 and RRII-208. These clones have been evolved by hand pollination and selection which were developed in the small scale trials during 1956-1961. The plants in these trials came into bearing from 1963 onwards. The promising performance of these plants in the initial years of production encouraged the Rubber Research Institute of India in releasing it to planters for experimental planting in the late sixties and subsequently for commercial planting by the middle of seventies. Unlike in the case of other plantation crops, the various countries engaged in the production of natural rubber was able to work out an international clone exchange programme. The co-ordination of the clone exchange programme was done by the International Rubber Research and Development Board. This enabled the natural rubber producing countries to exchange high yielding planting material for multiplication, trials and planting. This approach has helped in eliminating the repetition of efforts and saved much time which have been used for further useful research This unity among the rubber producing countries have greatly contributed to the advancement of the plantation industry.

In the fifties and sixties, the only objective of Hevea breeding was improvement in yield per tree. During these days, the scientists were not interested in other factors affecting rubber production like disease resistance, drought tolerance, wind resistance etc.. But by the seventies the research work started in this direction too.

Reduction of Immaturity period

Development of planting materials with reduced immaturity period was given an important place in the research programmes of the Rubber Research Institute of India in the eighties. The immaturity period denote the unproductive phase extending from the time of field planting to the commencement of tapping. Therefore, reducing the immaturity period has got great significance in the economics of rubber cultivation. Reduction in immaturity period has at least two benefits viz. early income and the replacement of old less productive trees by new high yielders, there by providing more earnings from each hectare.

In the early fifties, the gestation period for rubber in India was about ten years. At present, a great majority of small holdings as well as estates take about seven years for attaining the criteria of tappability. However, the current expectation of the immaturity period among Malaysian growers is only five and half years[7]. It was reported by some estates during the survey that the immaturity period was reduced to about four and half years on an experimental scale.

Apart from the type of planting materials, other cultural operations are equally important in reducing the immaturity period. Experiments done in the Rubber research Institute of India have shown that reduction of immaturity period in rubber can be attained by improved nursery techniques, using advanced planting materials, timely manuring coupled with irrigation, establishing good cover crops, adopting better plant protection and other cultural operations.

---

[7] Wood B.J.. and Edward N.C. (1987), "The Role of Research and Development in Plantation Profitabilities"; The Planter, Vol.63, pp.236-248.

A much higher yield could be achieved if the environmax' concept is put into effect. The environmax concept envisages use of planting materials suitable to a particular environment.It is interesting to note that one particular clone, RRII 105 - has been extensively planted throughout the country without regard to the environment in which it is planted. Farmers usually turned to this clone because of its high yield potential. The high yield potential makes the planters to over look other factors to be considered before taking a decision on the planting material. The difficulty in putting into practice the environmax concept in India is that the number of clones available for major planting is insufficient. It is important that the environmax concept be closely followed by the farmers, both small and large, so that the appropriate clone is planted in the right environment to ensure adaptability and high yield. It is in this line that the research and extension work of the Rubber Board have been. directed in the recent years.

Manuring

In the earlier days of rubber cultivation, manuring was seldom done in rubber plantations, as it was not considered necessary. But the need for proper and regular manuring in the immature and mature rubber areas is now well recognised by the growers. Fertilizer application to the young rubber tree during the pre-tapping stage is for accelerating growth, there by reducing the non-productive immature period. Fertilizer treatment to mature rubber trees under tapping is designed to increase productivity of the trees. Healthy and rapid renewal of the bark is a vital problem in rubber plantations and this depends greatly on the nutrient supply. Manuring in the broad sense aims at making available all the essential nutrients deficient in soil at optimum levels.

The Rubber Board has been helpful in spreading the concept of fertilizer usage among the rubber growers. Even though their extension activities were helpful in this movement, a financial subsidy scheme launched by it has not found much favour with growers. As per the scheme, a 50 per cent subsidy was given on cost of fertilisers purchased from co-operative societies and applied in immature areas planted with high yielding materials. The main reason that made the scheme unattractive was that most of the small holdings were interplanted or inter cropped and as per the scheme, such holdings were not eligible for the subsidy.

Table 5.1

ESTIMATED AREA UNER THE USAGE OF FERTILIZERS IN THE RUBBER PLANTATION INDUSTRY IN INDIA, 1986 -87.

Category	Total Area (hec.)	Estimated Area Manured (hec.)	Percentage of Area Manured (%)
SMALL HOLDINGS			
1. Mature area HYV	179500	107700	60
2. Mature area non HYV	35000	8750	25
Total Mature Area	214500	116450	54
IMMATURE			
3. Upto 4 Years	40000	32000	80
4. 5 - 7 years with cover crop	10250	8200	80
5. 5 - 7 years with cover crop	16750	13400	80
Total Immature Area	67000	53600	80
Total area under small holdings	281500	170050	60
ESTATES			
Mature HYV	50000	40000	80
Upto 4 years	8000	8000	100
5 - 7 years	10000	10000	100
Total for Estates	68000	58000	85
NURSERIES	750	750	100
Total	350250	222700	64

Source : Rubber Board, Kottayam.

It was estimated that around 51000 tonnes of artificial fertilizers worth Rs.114.75 million was consumed by the industry in 1987-88[8] The major artificial fertilizers consumed by the industry are Urea, Phosphate, Potash, Magnesium sulphate, Ammonium sulphate and Factomphos. Average dosage per hectare for India in 1988-89 was 25.15 kgs of Nitrogen, 23.90 kgs of Phosphorus,19.08 kgs of potassium and 0.62 kgs of magnesium. For this, it was estimated that 9571 tonnes of Nitrogen, 9094 tonnes of phosphorus, 7759 tonnes of potassium and 236 tonnes of Magnesium were required for the industry.

Table 5.1 shows that fertilizer application was not as widely practiced in the small holding sector as in the estate sector. While only 60 per cent of the area in the small holding sector was subject to any kind of fertilizer application, the corresponding figures for the estate sector was 85 per cent. The gap between estates and small holdings in the use of fertilizers was found for both the mature and immature areas. The table also shows that the area under high yielding varieties were largely

---

[8] Tharian George K and Toms Joseph (1992), "Rubber based Industrialisation in Kerala -An Assessment of Mixed Linkage", Economic and Political Weekly, Jan 4-11, pp.47-56.

subjected to fertilizer application. This is in contrast to the area under non high yielding varieties where only a small percentage was using fertilizers. From the forgoing analysis, it is clear that in the usage of fertilizers, the small holding sector was far behind the estate sector.

The yield response to fertilizer application varies from place to place depending upon factors such as clonal variety, climate, soil types, soil nutrient status, leaf nutrient content, manuring history and existing ground condition. However, scientifically no sound and systematic fertilizer policy was followed by the industry till 1957, probably due to non-availability of proper manurial recommendation suited to local conditions to be followed by rubber growers[9]. In 1957, Rubber Board issued the first general fertilizer recommendation taking into consideration the agro-climatic condition in the rubber growing regions in India. Improvements were made in the manurial recommendations in the later years.

---

[9] George C.M. (1974), "A New Approach for the Economic Usage of Fertilizers for Rubber in India", Paper presented at the Rubber Planters' conference, Kottayam.

Fertilizer application, one of the most important items of expenditure in the rubber plantation, has the specific objective of obtaining maximum economic benefits, through minimum investment. To attain this objective, the fertilizer usage should ensure maximum enhanced early growth which will in turn reduce the unproductive immature period with subsequent economic benefit of getting early returns for the huge investment. In addition to this, achieving maximum economic yield increase throughout the life span of the plants should be an objective. A distinction can be seen between the growth of the immature plants and mature trees. Enhanced early growth of the immature plants can be achieved by adopting the general fertilizer recommendations and the second objective can be fulfilled by adopting a discriminatory fertilizer application. It was observed by Pushparajah[10] that in addition to giving better growth and yield, major nutrients also affected the quality of the latex produced.

---

[10] Pushparajah E., (1977), Nutrition and Fertilizer Use in Hevea and Associated Covers in Peninsular Malaysia - A Review", Journal of Rubber Research Institute of Srilanka, Vol.54, pp.270-283.

Discriminatory Fertiliser Application

It is now well recognised that the possibility of getting responses in yield to fertiliser application for mature rubber depends on the factors such as present yield and yielding capacity of the planting material, the age and condition of the trees, tapping history, the nutrient supply capacity of the soil, the nutrient status of the trees and manuring and soil management history. Therefore it is necessary to consider all these factors before applying fertilisers. For the efficient and economic use of fertilisers, discriminatory fertiliser application based on the the results of fertiliser trails and soil and leaf analysis is essential in order to obtain maximum economic benefits from the fertiliser applications. Such a practice could result in use of lower amount of fertilisers or increased returns from the same investment in fertilisers. It was estimated that 10 to 20 per cent increase in yield is obtained merely by adopting discriminatory fertiliser application[11] But the studies conducted showed that while about 59 percent of the estates practiced it, only 11.25 per cent of the small holders adopted such a practice.

---

[11] Mukundan Menon P. (1989), "Short Term Techniques for Boosting Rubber Productivity", Rubber Board Bulletin, Vol.24, No.4, p.29.

Table 5.2

PERCENTAGE OF ESTATES AND HOLDINGS, WHERE SOIL AND LEAF ANALYSIS IS IN PRACTICE

Type of Ownership	Percentage of estates in which S/L. analysis is practised (%)
ESTATES	
Government Estates	86
Public Limited Companied	83
Private Limited Companies	33
Partnership firms	63
Proprietorship firms	42
Religions Estates	63
SMALL HOLDINGS *	11.25

Source: For estates, Sudarsanan Pillai P. op. cit.

Note:* The Data refers to Smallholdings in Meenachil Taluk, a prominent rubber growing area. Source: Michael, T.T.,op.cit.

It should be noted that a large majority of the small holders did not go in for discriminatory fertiliser application even in one of the prominent rubber growing regions in Kerala, were the study was conducted[12]. Table 5.2 reveals the failure on the part of the

---

[12] The data for small holdings refers to Meenachil Taluk in Kerala, which is one of the prominent rubber growing regions in the country.

extension wing of the Rubber Board in spreading the technology of discriminatory fertiliser application which is economically advantageous to the growers.

Plant protection

Effective protection of rubber trees against the ravaging diseases which cause considerable economic loss, engaged the serious attention of the scientists. For their spread, if unbridled, leads to decline in yield and loss of many trees. The major fungal diseases in India are abnormal leaf fall disease, the shoot root disease and powdery mildew. The abnormal leaf fall disease, caused by the fungus phytophthora is a disease annually recurring during the months of June, July and August. The fungus infects the leaves, fruits and small twigs of the plants. It was observed that while all high yielding clones and clonal seedlings are highly susceptible to this disease, the effects on the unselected seedlings were not so severe[13] Presently all rubber growing regions in India, except the Kanyakumari district of Tamil

---

[13] Radhakrishna Pillai P.M. (1976) "Aerial Spraying Against Abnormal Leaf-fall Disease", Rubber BOard Bulletin, Vol.13, NO.3, pp.116-118

Nadu is ravaged by the abnormal leaf fall disease. It is estimated that the yield loss due to this disease in high-yielding trees is about 30 - 50 per cent. The incidence of abnormal leaf fall was first noticed in the year 1910, within a few years of the commencement of rubber cultivation in India. In the early days of rubber cultivation, high volume spraying using Bordeaux mixture was recommended for the control of this disease. This is a laborious, time consuming and costly operation. An alternative method of spraying is using micron 420, Mini Micron 77 or saw duster/sprayer. For estates, this too is a slow operation since it could cover only 4 to 5 hectares per day. A faster method is aerial spraying. The first field trial on aerial spraying was carried out in the year 1960. Commercial aerial spraying started in the year 1963. Small helicopters with a capacity of 120 to 170 litres of spray mixture are now being replaced by helicopters capable of carrying 300 to 350 litres. Estates usually carry out aerial spraying to check the disease. Small holdings cannot go in for aerial spraying and they require sprayers. Manual spraying involves large quantities of water, which is often impracticable during the dry-spraying season and climbing up of individual trees necessitating the deployment of large labour force. The cost of power sprayers is very high and can be ill-afforded by individual small holders. In 1987-88, the rubber plantation industry consumed about 1000 tonnes of fungicides worth Rs.38 million. One of the measures that can be taken to improve the plant protection practices among small growers is to help groups of small growers in purchasing power sprayers. The rubber producers' societies started recently can do a lot in this regard.

Another major disease affecting the rubber plantations is the powdery mildew disease. This disease can be checked by dusting using sulphur dust. Apart from the above diseases, the rubber trees are also subjected to a number of diseases which affect stem and bark. Panel protectants and other fungicides are used to control these diseases.

An important point to be noted in this regard is that even though the scientists were successful in evolving some disease control measures and the farmers were progressively adopting it, little progress has been made in breeding clones resistant to diseases. The emphasis on higher yields seems to have encouraged some diseases and stimulated some previously unknown diseases. The emphasis of research in this area needs to be in evolving clones capable of resisting the diseases commonly found in India. The environmax concept of using planting materials suitable to particular environment will be helpful in this aspect also.

Tapping System.

Rubber Trees have an economic life of about thirty years and the cost of establishment of these trees are very high. Therefore the selection of the exploitation technique is very important. The industry emerged into its modern form when systems of tapping based on excision of the outer bark were developed by H.N. Ridley in the last decade of the nineteenth century

In India, tapping of rubber trees generally starts seven years after planting. After commencement of tapping, the virgin bark is invariably used for twelve years and the first renewed bark for another twelve years and intensive tapping and slaughter tapping for another 4 to 6 years. Tapping is a skilled job. Correct timing, maintenance of proper angle of incision and deep yet damage-free tapping are important for full exploitation of yield potential. Attempts to replace the skill of the tapper with machine is not advisable for a country where labour is cheap and abundant Mechanisation of tapping should be given only low priority.

The ideal tapping system is the one that combines maximum yield and minimum cost with best growth and bark development. No clone evolved so far has the capability to stand daily tapping. Daily tapping results in drastic retardation of growth and high incidence of brownbast. But a number of small holdings, practice daily tapping. The widely adopted system of tapping is half spiral, once in two days 1/2 . s/2 d/2 with or without sunday rest. A section of growers have now switched over to tapping once in three days. Earlier the criterion of tappability was the age of the trees. Now, importance is given to size of the trees rather than its age.In order to improve the system of tapping in rubber plantations, Rubber Board has started giving training to tappers and small growers. Tappers' training schools were started in different parts of the country for providing training to tappers and small growers. These tappers' training schools are run by the Rubber Board.

Weeding

The problems due to weed growth are serious in rubber plantations. Weed growth is particularly harmful in rubber nurseries and in immature areas. Weed control is an important and costly cultural practice in rubber plantations. It is essential to keep the plantation completely devoid of weeds both in the nurseries and immature areas to facilitate good growth and also for establishing leguminous ground covers. Timely sowing of cover crops and bimonthly weeding of interrows for the first two years would facilitate the establishment of good cover crop. This could limit the weeding to planting strips and selective slashing of weeds in interrows.

From 1970s chemical weed killers or weedicides are being used by large estates to a limited extent. It was observed by Mathew et al[14] that the use of weedicides is helpful in controlling weeds in the planting strips in the seedling nursery. Rubber plantations are affected by several types of weeds and till now no single weedicide have been evolved in controlling all the weeds in rubber plantations. But a suitable combination of two or three weedicides can effectively control the weed growth. The combination being determined by the dominant type of weed population.

---

[14] Mathew M., Punnose K.I. and Potty S.N (1977), "Report of the Results of Chemical Weed Control Experiments in the Rubber Plantations in South India". Journal of Rubber Research Institute of Srilanka, Vol.54, No.2, pp.478-488.

Chemical Stimulation of Yield in older plantations

Stimulating rubber trees with the chemical ethephons (2-chloro ethyl phosphoric acid) is one of the most important and comparatively recent agricultural technologies developed to increase the efficiency of production in the natural rubber industry. The application of this chemical is capable of boosting rubber yields by 20 to 50 per cent of well-kept trees in tapping for more than fifteen years[15]. The yield response on stimulation depends on many factors such as type of clone, age, nutrient status of the tree, tapping system, method frequency of application of stimulant etc.

The earliest attempt to stimulate rubber trees was by periodic scraping of the bark below the tapping groove. In 1929-30, experiments for evolving yield stimulants were conducted by the Rubber Research Institute of Malaysia using a mixture of cattle manure, wood ash, sulphate of iron and permanganate of potash. By the 1950s chemicals were used by the estates for the stimulation of trees. They used phenoxy acetic acids 2,4-D and

---

[15] Mukundan Menon P., op.cit., p.29.

2,4,5-T. It was in the late sixties that ethylene was used for this purpose The stimulant now widely used, ethephon, is an ethylene inducer. It was commercially introduced in the seventies and is now widely adopted by estates as an effective means of increasing productivity. Although production cost increases with yield stimulation, the increase in yield, particularly in the older tapping panels, often offsets the increase in production cost and hence a higher level of operating profits can be obtained.

Rain Guarding

If tapping is not done during rainy season, the number of tapping days will be reduced to about 100 to 120 days in holdings where the alternate daily tapping system is followed. Tapping can be carried out during rainy season by fixing rain. guards to the trunk above the tapping panel. Rain guarding makes it possible to tap each tree for an extra 30 to 40 days per year under once in two days system and it is expected to increase the yield by about 10 to 15 per cent[16]. A study conducted by the Rubber

---

[16] Mukundan Menon p., op cit.,p.29.

Board has shown that the yield per hectare, justifying the adoption of rain guarding is 675 kg/hectare[17]

Cover crops

Rubber is the only plantation crop which makes use of leguminous ground covers. This cover crops can mobilise large quantities of plant nutrients, particularly nitrogen during the first two or three years after their establishment in newly planted areas, thereby promoting the performance of the trees in respect of growth and yield . Cover crops will also control soil erosion. Controlling soil erosion is all the more important as most of our rubber is grown on hilly or sloping land exposed to wind and heavy rains resulting in severe erosion of the rich top soil. The covers will also help in reduction or elimination of root disease as found in Malaysia, the greater use of legume covers becomes essential.

---

[17] Toms Joseph, Haridasan;V. and Joy Cyriac (1989), "Economics of Rainguarding - A Comparative Analysis", Indian Journal of Natural Rubber Research, Vol. 2, No.2, pp.125-130.

Apart from the changes in the above mentioned factors, changes were experienced in other aspects such as preparation of land for planting, clearing the land for planting, lining, pitting, planting, density of planting etc.

It has been found from the foregoing discussion that the rubber plantation industry in India witnessed significant changes in the technology of production. The most important change being the change in the quality of the planting materials. High yielding planting materials developed in the research centres inside and outside the country were widely used by the farmers. High yielding planting materials with a reduced immaturity period were also developed. The use of high-yielding planting materials were supplemented by improved cultural practices, scientific application of fertilisers and pesticides, rainguarding and use of yield Stimulants. All these factors are said to have helped in improving the production of natural rubber in the country.

CHAPTER VI

MEASUREMENT OF TECHNOLOGICAL CHANGE IN RUBBER PLANTATION INDUSTRY

CHAPTER VI

MEASUREMENT OF TECHNOLOGICAL CHANGE IN RUBBER PLANTATION INDUSTRY

Literally, the term 'technology' means the sum of knowledge of the means and methods of producing goods and services. Technological progress implies the growth in this knowledge. For decades, the progress in the technology of production has been singled out as the most dominant variable affecting agricultural productivity. Improvement in agricultural technology provides the proper stimulus to agricultural production. This will result in increasing factor productivity. The productivity gains provide a combination of increased profits to land owners and consumer benefits from lower prices. The increased profits will result in an increase in the incomes of land owning farmers. Lower prices will help in maintaining or improving the demand for the commodity instead of searching for alternatives.

As revealed from the analysis of growth rates, productivity in the rubber plantation industry showed a significant growth during the last three and a half decades. The major contributor to this growth in productivity is perceived to be technological change. The objective of the present chapter is to examine the changes in technology on the basis of aggregate time-series data But, before making an attempt to measure the technological changes in the rubber plantation industry, we propose to take some of the theoretical aspects in the economic analysis of technological change.

Definitions of Technological change

A number of definitions of technological change have been used in the economic literature. Solow employed an indirect definition of technological change. He uses the phrase technical change' as a short hand expression for any kind of shift in the production function. Thus, slowdowns, speedups, improvements in the education of labour force and all sorts of things will appear as technological change[1]. There are several factors that might give rise to an apparent shift in the relationship between output per labour and capital per labour. Domar[2] used the word

---

[1] Solow R.M. (1957), "Technological change and the Aggregate Production Function", Review of Economics and Statistics, August, p..312.

[2] Domar E.D (1961), On the Measurement of Technological Change, Economic Journal, Vol.71, No.284, p.709.

residual , i.e., that part of the increased output per man which is left over after increases in capital per man are accounted for Mansfield[3] defines 'technology' as the society's pool of knowledge regarding the industrial arts. Technological change is the advance of technology, such advance often taking the form of new methods of producing existing products with important new characteristics and new techniques of organisation, marketing and management.

Classification of Technological Change

There are different ways of classifying technological change. One important distinction has been drawn between embodied and disembodied technological change. Technological change is disembodied if an increase in technology causes the same type of factor inputs to produce more output even if total inputs do not increase. This implies that independent of any changes in the factor inputs, the isoquant contours of the production function

---

[3] Mansfield E. (1968), The Economics of Technical Change, W.Norton, New York, p.11.

shift towards the origin as time passes[4] This type of technological change is often referred to as of manna from heaven type. By the assumption that the change is disembodied, we expect to increase the output without any change in the quantity of inputs used as time passes. It. means that the technical progress is organizational and that the existing inputs are used more effectively. Its effect is measured from the production function.

$$Y(t) = A\ (t)\ F(K(t),\ L(t)) \qquad (1)$$

where Y(t) is the output in year t, K(t) is the capital employed in year t and L(t) is the labour input in year t. A(t) is the term reflecting technological change.

Consider the Cobb-Douglas production function

$$Y(t) = A(t)\ (K(t))(L(t))^{1-\alpha} \qquad (2)$$

---

[4] Burmeister E. and Dobell R. (1970), Mathematical Theories of Economic Growth, Macmillan, London. p.66.

Assuming A(t) as an exponential function of time, the above function becomes

$$Y(t) = A e^{\mu t} (K(t))^{\alpha} (L(t))^{1-\alpha} \qquad (3)$$

μ is the rate of technological change

Modern economists dispute the view of technological progress as completely disembodied saying that technological progress must be embodied in some inputs. Although Domar[5] referred to technological progress embodied in capital goods, Solow's[6] work can be regarded as the first model of embodied technological progress. Solow criticised the view of seeing technological progress as of manna from heaven type. In Solow's[7] words.

> It is as if all technical progress were something like a time and motion study, a way of improving the

---

[5] Domar E.D. (1957), Essays in the Theory of Economic Growth, Oxford University Press, New York, p.72.

[6] Solow R.M.(1960),"Investment and Technical Progress", in Arrow K, Karlin. S, and Suppes, P. (eds.) Mathematical Methods in the Social Sciences, Stanford University Press, pp. 89-104.

[7] Solow R.M., ibid., p.90-91.

organization and operation of inputs without reference to the nature of inputs themselves. The striking assumption is that old and new capital equipment participate equally in technical change. This conflicts with the casual observation that many if not most innovations need to be embodied in new kinds of durable equipment before they can be made effective.

Thus it is found that technological change is completely disembodied is some what unrealistic since it does not consider the changes in the quality of inputs. The disembodiment hypothesis makes no distinction between capital of newer vintages and older vintages. Under the embodiment hypothesis, technological change is one which is incorporated in to the latest version of an input: for example, design improvements in capital equipment. Solow assumed that technological progress affects new capital goods especially new machines. In Phelps'[8] words:

> Solow postulates an index of technology, which advances neutrally and exponentially at the rate The nature of the technology is so indexed such that at every point of

---

[8] Phelps, Edmund S. (1962), "The New View of Investment-A Neoclassical Analysis", Quarterly Journal of Economics, Vol.76, No.1, pp.549.

time, it affects the efficiency only of new capital goods. Every capital good embodies the latest technology at the moment of its construction, but it does not participate in subsequent technical progress. Thus Capital" becomes a continuum of heterogeneous vintages of capital goods.

The assumption that technological progress is embodied in new machines, that the machines of different vintages (different dates of manufacture) are qualitatively dissimilar and that they cannot in general be aggregated into a single measure of capital is the basis of estimating embodied technological progress. Thus this approach shows a departure from the orthodox assumption of complete homogeneity of the capital stock.

Turning to the models with embodied technological change where the technological progress is regarded as consisting of a progressive improvement of the quality of machines Solow[9] introduced an approach for measuring embodied technological change

---

[9] Solow R.M. (1969), op. cit.

by developing a capital vintage model with the following assumptions

1. Machines of the same vintage are identical
2. Machines of the latest vintage are more productive than those of the preceding vintage by a constant exponential factor.

For each vintage υ of capital, there is assumed a Cobb-Douglas constant returns to scale production function showing the relationship at time t between output produced by capital of vintage υ, $Y(\upsilon,t)$; the surviving capital of vintage υ, $K(\upsilon,t)$;and labour working with capital of vintage υ, $L(\upsilon,t)$.

$$Y(\upsilon,t) = A^1 e^{\tau\upsilon} [K(\upsilon,t)] [L(\upsilon,t)]^{1-\alpha} \qquad (4)$$

where τ is capital embodied technological change. In equation (3), where the technological progress was assumed to be disembodied, the multiplicative factor that was incorporated in the aggregate production function was written as $e^{\mu t}$, i.e., factor representing technical progress grew at a constant rate μ as time proceeded. The analogous expression in (4), $e^{\tau\upsilon}$ means that the factor representing technological progress grows at a constant rate, τ, as the successive vintages, υ, follow one another. α and $1-\alpha$ are the elasticities of output with respect to capital and labour respectively. Since technological progress is assumed to be neutral, the elasticity parameter α is the same for all vintages.

Labour is assumed homogeneous and distributed optimally. Then an aggregate production function is obtained by summing outputs $y(\upsilon,t)$ of the various vintages:

$$Y(t) = A^1 \, [J_\tau(t)]^{\alpha} \, [L(t)]^{1-\alpha} \qquad (5)$$

Where

$$Y(t) = \int_{-\infty}^{t} Y(\upsilon,t)\, d\upsilon \qquad (6)$$

$$J(t) = \int_{-\infty}^{t} e^{\tau\nu} \, K(\upsilon,t)\, d\upsilon \qquad (7)$$

$$L(t) = \int_{-\infty}^{t} L(\nu,t)\, d\upsilon \qquad (8)$$

The variable 'J' is called effective capital stock which is obtained by weighting surviving capital for embodied technological change τ. and summing over all vintages. Since the modern machines being more efficient than the older, less weight was given to older machines. A^1 has to be differentiated from A of equation (3) as A includes things that are incorporated in J_t as well as in A^1

Solow[10] measured the embodied and disembodied technological change separately. Solow measured disembodied technological change using a production function in which cyclical factors were considered by introducing in to the estimation the unemployment rate, u. The disembodied technological progress function used was

$$Y(t) = a\,10^{b+cu+du^2}(1+\mu)^t\,K(t)^{\alpha}(L(t)^{1-\alpha} \qquad (9)$$

The capital embodied technological progress production function used was

$$Y(t) = a\,10^{b+cu+du^2}\,[J_{\tau}(t)]^{\alpha}\,[L\,(t)]^{1-\alpha} \qquad (10)$$

The parameters of this function were estimated indirectly. Alternative J_{τ} series were computed based on alternative assumptions on capital. Then the parameters were estimated for different values of τ and R^2 and standard errors for

---

[10] Solow measured disembodied technological change in Solow R.M. (1957), op. cit He measured embodied technological change in his 1960 paper.

various regressions were compared for alternate J_τ series. Then the capital embodied technological change, τ, was determined by the regression which gave high R^2 and low standard error.

The disembodied technological progress and embodied technological progress were synthesized by Phelps[11] using the production function.

$$Y(t) = A e^{\mu t} [J_\tau(t)]^{\alpha} [L(t)]^{1-\alpha} \qquad (11)$$

where

$$J(t) = \int_0^t e^{\frac{\tau}{\alpha}v} K(v,t)dv \qquad (12)$$

τ is the rate of embodied technological change and μ is the rate of disembodied technological change. If μ is zero, all technological progress is embodied in capital; otherwise it is a combination of embodied and disembodied technological progress.

---

[11] Phelps, Edmund S. (1962), op cit.

A Framework for Measuring Technological Change in the Rubber Plantation Industry

A perennial crop like rubber poses additional challenges for economic analysis compared to annual crops. There are at least three properties distinguishing it from annual crops Firstly, the rubber tree has a long productive life span with a relatively long gestation period. Secondly, the annual yields vary over the life of the tree. The yield profile which depicts the age-yield relationship resembles a flattened F-distribution curve. Thirdly, the impact of any agronomic technological change is felt after several years. These characteristics of natural rubber warrants special treatment in the analysis. The problems of the analysis are both more difficult and more complex than the widely discussed and analysed situations of annual crop technologies.

The most important determinant of technological change in the rubber plantation industry in India was the introduction of high-yielding planting materials. Other changes in the technology of production were the improvement in cultivation methods, use of new agro-chemicals in the control of pests, diseases, weeds etc., judicious application of fertilisers, tapping during rainy season using rain guards, application of yield stimulants etc. The objective of the study is to examine the changes in technology on the basis of aggregate time-series data.

Technological changes in rubber plantation industry can be broadly classified into disembodied technological changes and embodied technological changes. As noted earlier, disembodied technological change consists of better methods and organisation which changes the efficiency and production of both old and new capital, i.e., it is assumed that capital of older vintages and newer vintages are equally affected by this type of technological change. In the rubber plantation industry, disembodied technological change indicates the changes in technology during the productive phase. Under the dis-embodiment hypothesis efficiency of technology changes even if there is no change in the quality of planting materials. Disembodied technological change, i.e., change in technology during the productive phase, experienced in the rubber plantation industry include better tapping methods, application of fertilisers according to the results of soil and leaf analysis, disease and weed control measures, rain guarding, application of yield stimulants and better cultural practices.

The production of natural rubber depends on the technology embodied in the trees at planting and during the immature phase also. Embodied technology will depend on factors like the type of the planting material, planting density, propagating and planting techniques, land quality and soil type, which are all factors determined at the planting time. These are changes embodied in different vintages together with disease and weed control measures, fertiliser application, use of cover crops and general maintenance during the long immature phase.

In the following section it is tried to develop a model for measuring embodied and disembodied technological change in rubber plantation industry.

For measuring embodied and disembodied technological change, a vintage production function approach is used. Vintage production function relates the potential output in any year to planting of trees in the previous periods. A major difference in the approach of this type of production function is that it permits the violation of the assumption of homogeneity in capital. The homogeneity assumption leads to useful simplifications but do so at the expense of plausibility and accuracy. In a perennial crop like rubber, where the quality of planting material and the upbringinng of the plants during the immature phase are major determinants of technological change, the homogeneity assumption is unrealistic. Therefore, a vintage model is used in the present study. The basic feature of vintage model lies in the notion that the quality of new capital changes over time, reflecting changes in technical knowledge. In this sense capital is heterogeneous[12] and therefore different vintages cannot be simply combined to get an aggregate production function. Thus, vintage production function shows a departure from the usual approach in the sense that it assumes that the technical progress is embodied in new trees also and that the trees planted at different years (plantings of different vintages) are qualitatively different. The plantings of different vintages cannot in general case be aggregated into a single measure of capital. Under this assumption, there exists a separate production function for each vintage and the total production (output) can be treated as the sum of outputs of all vintages.

---

[12] There is another source of heterogeneity which is still ignored in vintage models. Vintages consists of smaller units of capital by means of which output can be produced. At this microstructure level, vintages are themselves heterogeneous. An additional source of heterogeneity arises from the non-instantaneous diffusion of new technologies. Both types of heterogeneity are ignored in the present analysis for reasons of simplicity.

The cultivation of rubber requires a high initial capital investment for planting and for the expenses during the immature period. The initial capital stock are transformed into a stock of trees which produce rubber after about seven years. This stock of trees is represented by the area under cultivation. Therefore, the area under rubber cultivation, which was used in several studies,[13] has been regarded as the capital input.

In the present analysis, a Cobb-Douglas vintage production function is used for the analysis of technological change. For each vintage v, a Cobb-Douglas constant returns to scale production function showing the relationship at time t between output produced by area of vintage v, $Y(\nu,t)$; the surviving area in year t of vintage v, $a(\nu,t)$ multiplied by the corresponding yield factor $\xi_{t-\nu}$ and labour $L(\nu,t)$. Then

$$Y(\nu,t) = A e^{\tau v} (K(\nu,t))^{\alpha} (L(\nu,t))^{1-\alpha}$$

$$\text{where } K(\nu,t) = a(\nu,t).\xi_{t-\nu}$$

---

[13] For example see, Smith H.P. (1982), The World Rubber Economy to the year 2000: Its Prospects and the Implications of Production Policies on Market Conditions for Natural Rubber, Vrije Universiteitte, Amsterdam and Yousuff Mohammad (1977) An Econometric Analysis of the World Natural Rubber Industry, Ph.D. Thesis, Iowa State University.

and τ is the embodied technological change and α and $1-\alpha$ are the elasticities of output with respect to capital and labour respectively. Assuming that labour is homogeneous and distributed optimally, the production functions can be arrived at by summing output $Y_{\nu}(t)$ over all vintages

$$Y(t) = A\,(J_{\tau}(t))^{\tau}\,(L(t))^{1-\alpha} \qquad (14)$$

where $J_{\tau}(t)$ is obtained by weighting the surviving capital (surviving area multiplied by yield factor) for embodied technological change and summing for all vintages. Thus

$$J_{\tau}(t) = \sum_{\nu=0}^{t} e^{\frac{\tau\nu}{\alpha}}\,K(\nu,t) \qquad (15)$$

where $K(\nu,t) = a(\nu,t)\,\xi_{t-\nu}$ (16)

$\xi_{t-\nu}$ is the yield of a hectare of trees of age $t-\nu$

The disembodied technological progress and capital embodied technological progress can be synthesized by fitting the above function with a time trend. The production function is

$$\begin{aligned} Y_t &= A\,e^{\mu t}\,[\textstyle\sum_{\nu=0}^{t} e^{\tau\nu}\,a(\nu,t)\,\xi_{t-\nu}]^{\alpha}\,[L(t)]^{1-\alpha}. \qquad (17) \\ &= A\,e^{\mu t}\,(J_{\tau}(t))^{\alpha}\,(L(t))^{1-\alpha} \end{aligned}$$

where $Y(t)$ is the output in year t

$L(t)$ is the labour input in year t

$K(t) = \sum_{\tau=0}^{t} a(\nu,t)\, \xi_{t-\nu}$ is the capital input

μ is the disembodied technological progress

τ is the rate of embodied technical change

α is the elasticity output with respect to capital and

$1-\alpha$ is the elasticity of output with respect to labour

The multiplier $\xi_{t-\nu}$,the yield factor, was included in the model to avoid distortions in the results as a result of the changes in yield due to age difference.

Estimating the above function, we get estimates of the embodied and disembodied technological change. Estimate of μ is the rate of disembodied technological change and estimate of τ is the rate of embodied technological change. For the estimation of the above production function, the age distribution of the rubber trees and the average yield profile of a hectare of rubber according to its age are required, which are derived in the following paragraphs.

Vintage Distribution of Rubber Trees.

The vintage distribution of the area under rubber cultivation was required for fitting the vintage production function. As published time-series data on area under rubber according to year of planting was not available, this distribution has been arrived at by using the data on area under rubber cultivation, new planted area and replanted area. A mathematical discarding procedure was adopted for arriving at the vintage distribution of the area under rubber cultivation.

For the data before 1938, the Indian Rubber Statistics published by the Government of India was the main source while for the period after 1938, publications of the Rubber Board was the major source. Continuous time-series data on new plantings replantings and total plantings were available from these sources. except for few years in the initial stages of plantation industry in India. However, a problem faced during the collection of secondary data was that the data for the same year from the publications of Rubber Board varied from one issue to another issue. Therefore, the criterion used was to employ the data available in the latest issue. For figures for some years in the initial period, which were not available, linear interpolation was done to obtain the missing figures. Since this was needed only for a four years in the initial days, it does not severely affect the data quality.

Natural rubber has a productive life span of about thirty years with a relatively long gestation period of seven years. However, even after the end of thirty years, rubber trees in some areas will not be cut down because of various reasons like non-availability of resources for replanting, loss of income for the first seven years of replanting, etc. In the present model, we have used a discarding system - after consultation with knowledgeable - in which trees older than 45 years does not exist. The procedure adopted is described below.

Using data on new plantings, replantings and total plantings, we find the age-distribution of trees existing in each year after 1955 is found out. We have selected a mathematical discarding procedure by which a fixed percentage of existing trees of a particular age is discarded in the subsequent year. The percentage discarded varies according to the age of the trees. Following points were considered while selecting the discarding procedure. During the first several years after planting, farmers discard trees mainly because of natural calamities, diseases etc.

The decision of discarding in this phase is based on external factors and the farmer does not have much control over it. This is a phase of slow discarding rate. After this period, in addition to these external factors, discarding is done due to old age. The rate of discarding during the second phase of the life of the tree is higher as both the age and other external factors are influencing the decision of the farmer. Therefore, two different rates of discarding were employed for the two phases of the life of the tree instead of the constant exponential rate of depreciation employed in studies on industries.

Let $a(\nu,t)$ be the area planted[14] in year 'ν' or of vintage 'ν' and still existing in the year 't'. The objective is to find $a(\nu,t)$ for $t = 1955,1956...1990$ since we have taken that the trees planted in a particular year is completely cut down by the end of 45 years, we take ν to range from 1910 to 1990

As we know, the percentage of discarded rubber area increase as the trees grow older. This means that the percentage of area planted in year ν and still remaining in year t is related

---

[14] Area planted is the sum of new planted area and replanted area.

to the age of the trees $x = t-\nu$. In order to account for the two phases of the life of the trees in an area, one of slow discarding rate and another of high rate of discarding, two separate curves are required. This will cause a discontinuity at the break point. Therefore, in order to eliminate the discontinuity and at the same time account for the differential rates of discarding we have used a kinked exponential model.

Though the replanting decisions of individual farmers vary according to the financial position, price effects, type of planting materials, etc., on the aggregate, it is reasonable to assume that the cutting of trees will increase in proportion after the trees reach a particular age, say m ,and eventually all the trees are cut down by the end of a particular year,say 'n'.'m'is the age at which the discarding function has to be changed. Consider an exponential function to explain the discarding of trees in the first age group - age less than or equal to m - and another exponential function for the tree of age above 'm'. Let

d_x^1 and d_x^2 be the discarding functions for the first and second age group respectively.

$$d_x^1 = \alpha_1 e^{\beta_1 x} \qquad \text{for } x \leq m \qquad (18)$$

and $$d_x^2 = \alpha_2 e^{\beta_2 x} \qquad \text{for } x > m \qquad (19)$$

where $x = t-\nu$ is the age of the trees.

Taking logarithms,

$$\ln d_x^1 = \log\alpha_1 + \beta_1 x \qquad (20)$$

$$\ln d_x^2 = \log \alpha_2 + \beta_2 x \qquad (21)$$

The present model imposes linear restrictions to eliminate the discontinuity. Instead of the two equations mentioned above. We use the following single equation for both the periods.

$$\ln d_x = \alpha_1^* D_1 + \alpha_2^* D_2 + (\beta_1 D_1 + \beta_2 D_2)x \qquad (22)$$

where $D_1 = 1$ for $x \leq m$

$= 0$ for $x > m$

and $D_2 = 1$ for $x > m$

$= 0$ elsewhere

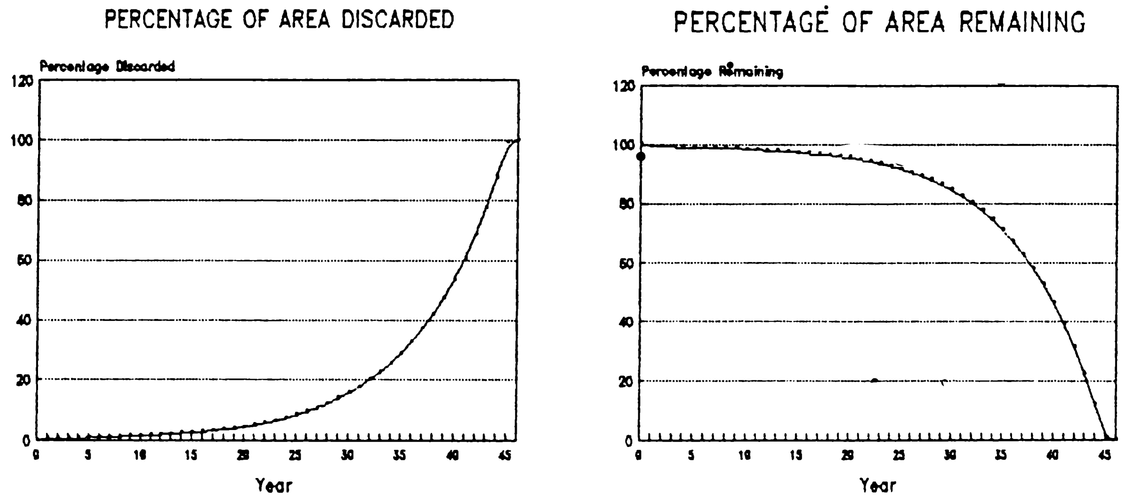
and $\alpha_1^* = \ln \alpha_1$ and $\alpha_2^* = \ln \alpha_2$

As ln d_x is linear, the discontinuity can be eliminated by using a linear restriction such that the two curves intersect at the point m. At this stage, the discarding rate is fixed by the values of m, β_1 and β_2 . Our field experience and discussions with the experts helped us in fixing the value of m. It was fixed at 20. This means that the discarding of trees up to 20 years of age is only because of natural calamities and diseases and hence at a low percentage. The percentage of area discarded at the end of the twentieth year was taken to be 5 per cent.In order to decide upon the best curve which could represent the actual discarding, different values were given for α_1,β_1,β_2 and arrived at the discarding system which best approximated the actual data on area under rubber cultivation each year. The difference between the actual and estimated figures of area under rubber cultivation in every year is found out and this difference is distributed among the different vintages by multiplying by a correction factor to get the final vintage distribution of the trees. The percentage of the discarded area and the percentage of area in cultivation remaining according to the discarding system developed are given in Table 6.1 (See figures 3&4 also)

Table 6.1
Percentages of Area Discarded and Area Remaining

Year	Percentage Discarded	Percentage of Trees remaining
0	0.00	100.00
1	0.67	99.33
2	0.74	99.26
3	0.81	99.19
4	0.90	99.10
5	1.00	99.00
6	1.11	98.89
7	1.22	98.78
8	1.35	98.65
9	1.49	98.51
10	1.65	98.35
11	1.82	98.18
12	2.01	97.99
13	2.23	97.77
14	2.46	97.54
15	2.72	97.28
16	3.00	97.00
17	3.32	96.68
18	3.66	96.34
19	4.06	95.94
20	4.48	95.52
21	5.07	94.93
22	5.74	94.26
23	6.50	93.50
24	7.36	92.64
25	8.33	91.67
26	9.43	90.57
27	10.68	89.32
28	12.09	87.91
29	13.68	86.32
30	15.49	84.51
31	17.53	82.47
32	19.85	80.15
33	22.47	77.53
34	25.43	74.57
35	28.79	71.21
36	32.59	67.41
37	36.89	63.11
38	41.76	58.24
39	47.28	52.72
40	53.52	46.48
41	60.58	39.42
42	68.59	31.41
43	77.63	22.37
44	87.88	12.12
45	99.48	0.52
46	100.00	0.00

FIGURE 6.1



PERCENTAGE OF AREA DISCARDED

PERCENTAGE OF AREA REMAINING

The results of the splitting up of the rubber area into vintages for the selected discarding system is shown in Table 6.2. The figures have been rounded to thousand hectares. In each row, one sees the decrease of a certain vintage over time. For each column the last figure greater than zero indicates newly planted and replanted area in that year.

TABLE 6.2

VINTAGE DISTRIBUTION OF TREES IN '000 HECTARES

t v	1955	56	57	58	59	60	6	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
1910	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1911	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1912	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1913	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1914	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1915	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1916	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1917	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1918	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1919	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1920	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1921	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1922	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1923	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1924	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1925	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
1926	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
1927	2	2	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
1928	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1929	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1930	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1931	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1932	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
1933	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1934	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
1935	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
1936	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1937	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
1938	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1939	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1940	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
1941	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1
1942	5	5	5	5	5	5	5	5	5	5	4	4	4	4	4	4	4	4	4	3	4	3
1943	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3	3
1944	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	3
1945	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	2
1946	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
1947	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	1	1	1	1
1948	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1949	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1950	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1951	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1952	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
1953	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

TABLE CONTINUED

VINTAGE DISTRIBUTION OF TREES IN '000 HECTARES

t v	77	78	79	80	81	82	83	84	85	86	87	88	89	90
1910	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1911	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1912	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1913	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1914	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1915	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1916	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1917	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1918	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1919	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1920	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1921	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1922	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1923	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1924	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1925	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1926	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1927	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1928	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1929	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1930	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1931	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1932	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1933	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1934	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1935	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1936	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1937	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1938	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1939	1	1	1	0	0	0	0	0	0	0	0	0	0	0
1940	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1941	1	1	1	1	1	1	0	0	0	0	0	0	0	0
1942	3	3	3	2	2	2	1	1	1	0	0	0	0	0
1943	3	2	2	2	2	2	1	1	1	0	0	0	0	0
1944	3	3	2	2	2	2	2	1	1	1	0	0	0	0
1945	2	2	1	1	1	1	1	1	1	1	0	0	0	0
1946	2	2	2	2	1	1	1	1	1	1	1	0	0	0
1947	1	1	1	1	1	1	1	1	1	1	1	0	0	0
1948	1	1	1	1	1	1	1	1	1	1	0	0	0	0
1949	1	1	1	1	1	1	1	1	1	1	1	0	0	0
1950	1	1	1	1	1	1	1	0	0	0	0	0	0	0
1951	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1952	2	2	2	2	2	2	2	1	1	1	1	1	1	1
1953	4	4	4	4	4	4	3	3	3	3	3	3	3	2

TABLE CONTINUED

VINTAGE DISTRIBUTION OF TREES IN '000 HECTARES

t v	1955	56	57	58	59	60	6	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
1954	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
1955	13	12	11	12	12	12	11	12	12	12	12	12	11	12	12	11	12	12	12	12	11	11
1956	0	16	14	14	15	14	14	14	15	15	14	14	14	14	14	14	14	14	14	14	14	14
1957	0	0	14	13	13	13	13	13	14	14	13	13	13	13	13	13	13	13	13	13	13	13
1958	0	0	0	12	11	11	10	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
1959	0	0	0	0	13	12	11	12	13	13	12	12	12	12	12	12	13	13	13	13	12	12
1960	0	0	0	0	0	17	15	15	16	16	16	15	15	16	16	16	16	16	16	16	16	16
1961	0	0	0	0	0	0	16	14	15	15	15	14	14	14	14	14	15	15	15	15	15	15
1962	0	0	0	0	0	0	0	9	8	8	8	8	8	8	8	8	8	8	8	8	8	8
1963	0	0	0	0	0	0	0	0	8	8	8	8	8	8	8	8	8	8	8	8	8	8
1964	0	0	0	0	0	0	0	0	0	9	8	8	8	8	8	8	8	8	8	8	8	8
1965	0	0	0	0	0	0	0	0	0	0	10	9	9	9	9	9	9	9	9	9	9	9
1966	0	0	0	0	0	0	0	0	0	0	0	10	9	9	9	9	9	9	9	9	9	9
1967	0	0	0	0	0	0	0	0	0	0	0	0	8	7	7	7	8	8	8	8	8	8
1968	0	0	0	0	0	0	0	0	0	0	0	0	0	9	8	8	8	8	8	8	8	8
1969	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	8	8	8	8	8	8	8
1970	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	4	4	4	4	4	4
1971	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5	5	5	5	5
1972	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	5	5	5	5
1973	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	6	6	6
1974	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	7	7
1975	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	8
1976	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE CONTINUED

VINTAGE DISTRIBUTION OF TREES IN '000 HECTARES

t v	77	78	79	80	81	82	83	84	85	86	87	88	89	90
1954	.9	9	8	8	8	8	8	7	7	7	7	6	6	6
1955	11	11	11	10	10	10	10	10	9	9	9	8	8	8
1956	14	14	13	13	13	12	12	12	12	12	11	11	10	10
1957	13	13	12	12	12	12	12	11	11	11	11	10	10	10
1958	10	10	10	10	10	10	9	9	9	9	9	9	8	8
1959	12	12	12	11	11	11	11	1	11	11	11	10	10	10
1960	15	15	15	14	14	14	14	14	14	14	13	13	13	13
1961	14	14	14	14	13	13	13	13	13	13	13	13	12	12
1962	8	8	8	8	8	8	8	7	7	7	7	7	7	7
1963	8	8	8	7	7	7	7	7	7	7	7	7	7	7
1964	8	8	8	8	8	8	8	8	8	8	8	7	7	7
1965	9	9	9	9	9	9	9	9	9	9	9	8	8	8
1966	9	9	9	8	8	8	8	8	6	8	8	8	8	8
1967	8	7	7	7	7	7	7	7	7	7	7	7	7	7
1968	8	8	8	8	8	8	8	8	8	8	8	8	8	7
1969	8	8	8	8	8	8	8	8	8	8	8	8	8	8
1970	4	4	4	4	4	4	4	4	4	4	4	4	4	4
1971	5	5	5	5	5	5	5	5	5	5	5	5	5	5
1972	5	5	5	5	5	5	5	5	5	5	5	5	5	5
1973	6	6	6	6	6	6	6	6	6	6	6	6	6	6
1974	7	7	7	7	7	7	7	7	7	7	7	7	7	7
1975	8	8	7	7	7	7	7	7	7	7	7	7	7	7
1976	8	8	8	8	8	8	8	8	8	8	8	8	8	8
1977	8	8	8	8	8	8	8	8	8	8	8	8	8	8
1978	0	16	15	15	15	15	15	15	15	15	15	15	15	15
1979	0	0	21	19	19	19	19	19	19	19	19	19	19	19
1980	0	0	0	22	20	20	20	20	20	20	20	20	20	20
1981	0	0	0	0	22	20	20	20	2	20	20	20	20	20
1982	0	0	0	0	0	23	21	21	21	21	21	21	21	21
1983	0	0	0	0	0	0	24	22	22	22	22	22	22	22
1984	0	0	0	0	0	0	0	23	21	21	21	21	21	21
1985	0	0	0	0	0	0	0	0	24	22	22	22	22	22
1986	0	0	0	0	0	0	0	0	0	23	21	22	22	22
1987	0	0	0	0	0	0	0	0	0	0	23	21	21	21
1988	0	0	0	0	0	0	0	0	0	0	0	23	21	21
1989	0	0	0	0	0	0	0	0	0	0	0	0	23	19
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	21

Yield Profile

As noted earlier, the annual yields of a rubber tree vary over the life of the tree. The production starts about seven years after planting. The unproductive life span is followed by a long productive life pan, duration of which depends on the types of clones, cultural practices followed, climatic conditions etc. The yield profile, depicting the age-yield relationship of a hectare of rubber area usually increases gradually for a few years from the first year of tapping and then it remains more or less steady for about 10 to 15 years and thereafter it starts declining.

Even though actual yields may vary from plantation to plantation, the shape of the yield profile will remain more or less the same. This is true in the case of trees of older vintage as well as newer vintages. Newer clones will have a higher yield profile and older planting materials will have a lower yield profile. The average yield profile for the industry will be somewhat different according to its location from the yield profile given below, however, the shape of the curve is almost same Therefore, we have to multiply the yield profile given below by a certain factor to get the yield profile for the industry. The multiplying factor will change according to the vintage. This multiplying factor or weightage given to trees of each vintage will provide a measure of embodied technological change.

The ideal yield profile which is used for the study is based on the data from Tharian George et.al. (1988) and the data collected for the project on management practices in Rubber Plantation Industry in India[15]. The yield profile used for the study is given in the table 6.3.

Now that the vintage distribution of area under rubber and an average yield profile are obtained vintage production function can be formulated. $a_{t,\nu}$ is the area under rubber existing in year t which was planted in year ν $(t \geq n)$ and $\xi_{t-\nu}$ be the yield from a hectare of rubber trees of age $t-\nu$ according to the average yield profile. Multiplication of the area $a_{t,\nu}$ by

---

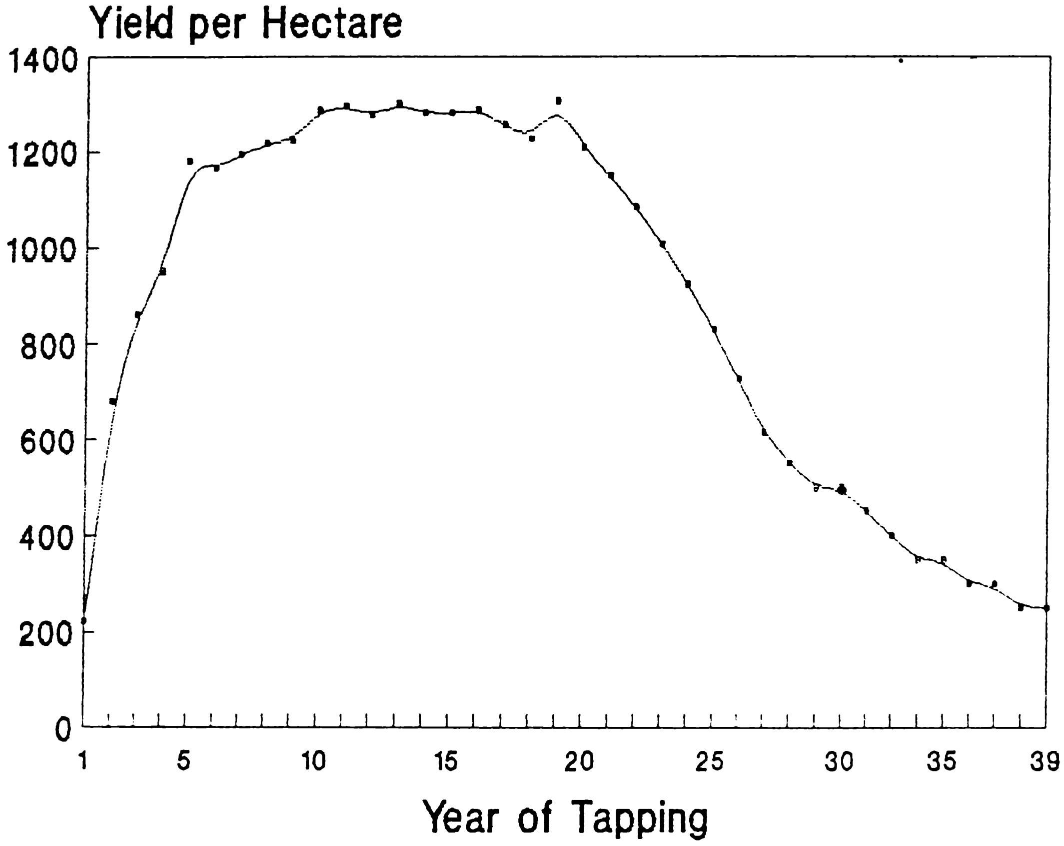
[15] Data in Tharian George et al. (1988) was collected from the estates of a large plantation company in Kerala. This data was only for the first 20 years of tapping. Yield after this period was fixed on the basis of data collected for the researc project on Management Practices in Rubber Plantation Industry in India

Table 6.3

Average Yield Profile Used for the Study

Year of Tapping	Yield per Hectare (in Kilogrammes)
1	221
2	679
3	859
4	948
5	1179
6	1165
7	1193
8	1215
9	1224
10	1287
11	1295
12	1176
13	1300
14	1282
15	1262
16	1332
17	1257
18	1226
19	1307
20	1208
21	1151
22	1085
23	1009
24	924
25	830
26	727
27	615
28	550
29	500
30	500
31	450
32	400
33	350
34	350
35	300
36	300
37	250
38	250

FIGURE 6.2
Average Yield Profile Used for the Study



$_{t-\upsilon}$ will provide the adjustments required for changes in the yield of the trees according to the differences in their ages. Changes in production due to the changes in the age-composition of the trees can not be attributed to technological change.

The surviving area or stock of capital in year t of vintage υ will be worked by a certain quantity of labour $L_{\upsilon}(t)$. The total labour supplied in year t is the sum of the labour employed for all vintages of capital. Therefore

$$L(t) = \int_{-\infty}^{t} L_{\upsilon}(t)\,d\upsilon \qquad (23)$$

Estimation of the parameters.

The estimation of the parameters of the usual Cobb-Douglas type production function is easy as the estimates can be obtained by the linear regression of the time series of the logarithms of Y(t), K(t) and L(t). No such simple method will work in the present case because time series of J_t are not available. J_t is defined in terms of unknown parameters.

For the estimation of the parameters of the vintage production function given in equation (16), some indirect method is required. Equation (16) can be transformed into

$$\ln \{ \frac{Y(t)}{L(t)} \} = \alpha + \mu t + \alpha \{ \frac{J_{\tau}(t)}{L(t)} \} \qquad (24)$$

The method used here is to estimate μ and α for alternate values of τ and then compare the R^2 and standard errors of the regressions to finally arrive at the value of τ which provides the high R^2 and low standard errors. The equation (24) and its variants were estimated to measure. embodied and disembodied technological change.

The hypothesis of embodied technology does not require that all new technological change be embodied in trees. Different models under different assumptions have therefore been explored

1. Technology is fully disembodied
2. All technology is fully embodied
3. Only apart of the new technology is embodied

Estimation was done with and without time trend. Regression without time trend implies that technological change is fully embodied. Similarly, estimation was done with $\tau = 0$ and $\tau >$

For estimating disembodied technological change, the period 1955-56 to 1990-91 was divided into two periods with cut off point at 1976-77. For measuring embodied technological change, the technology embodied in trees planted since 1910 has been considered. The period 1910 to 1990-91 was subdivided with the first period (τ_1) from 1910 to 1954-55, the second period (τ_2) from 1955-56 to 1966-67 and the third period (τ_3) from 1967-68 to 1983-84. The period after 1983-84 could not be considered for measuring embodied technological change because the trees planted since then does not come into tapping by 1990-91. The results of the regression analysis under various assumptions are given in Table 6.4. The values are given for regressions which provided the best fit.

From the results of the regression analysis, it is evident that neither embodied technological change nor disembodied technological change can be considered alone. The regression for disembodied technological change, those for $J_{o,o,o}$, with time trend, all have lower correlation coefficients and higher standard errors than for positive embodied technological change. Similarly the regressions for embodied technological change alone, those without time trend, also have lower correlation coefficients and higher standard errors than regressions including time trend. Thus it is clear that embodied and disembodied technological change should be treated simultaneously.

Table 6.4

Results of the Regression Analysis

J_{τ_1,τ_2,τ_3}	υ	α	e	R^2	S.E	F
$J_{o,o,o}$	0.29 (20.50)	0.89 (16.38)	--	98.51	0.0617	1089.78
$J_{.02,.02,03}$	--	0.925 (14.39)	--	98.79	0.0548	2764.90
$J_{.01,0,.01}$	0.19 (12.97)	1.411 (16.50)	--	99.07	0.0487	1760.00
$J_{0,0,0}$	0.13 (15.66)	0.880 (14.23)	-0.09 (-2.40)	98.74	0.0577	833.29
$J_{.01,0,.01}$	0.02 (9.70)	1.399 (18.85)	-0.03 (-0.98	99.10	0.0487	1172.76

Note :1. The values given in parentheses are respective t- values

2. e is the coefficient of the dummy variable.

3. Coefficient of the dummy variable was not significant when embodied technological change was included in the model.

The results of the regression analysis has shown that a better fit was obtained when both embodied and disembodied technological progress were included in the model. The coefficient measuring the rate of disembodied technological change, the time trend variable, is positive and significant when estimated with a break at 1975-76 to capture the changes in the disembodied technological change using the dummy variable approach. The dummy variable E was included with

E = 1 for years after 1975-76.
= 0 for years from 1955-56 to 1975-76

The coefficient of the dummy variable was found to be negative, but not significant indicating that there was no improvement in the rate of disembodied technological change in the second period.

The rate of disembodied technological change was estimated to be 2 per cent per annum during the period 1955-56 to 1990-91. The rates of embodied technological change were approximately 0.01, 0, 0.01 for the period 1910 to 1954-55, 1955-56 to 1966-67 and 1967-68 to 1983-84 respectively.

The results presented here suggested that the rate of embodied technological change have accelerated after 1967-68 This by itself, however, does not imply that the productivity have increased in that period as a result of the more rapid advances in embodied technology. The average age of the trees have changed during that period, offsetting the impact of accelerated rate of technological change. Our examination of the average age of the trees showed that it has increased by about three years • during the period after 1967-68 compared to the period 1955-56 to 1967-68. Given the increased rate of technological change after 1967-68, the results suggests that the productivity might have grown further had it not been for the decrease in the tempo of replanting of old trees in the late sixties and seventies. Therefore, along with research on improving the technology, steps should be taken to decrease the mean age of the rubber trees. This can be achieved by the replanting old trees which are still under tapping. The investment in the extension programme should be given more importance.

Embodied technological progress has its consequences on the age distribution of the trees. Embodied technological change alters the productivity to be achieved by the newest vintage and has therefore a direct influence on profitability of the crops.

This may be enough to replace otherwise profitable trees by new and more productive trees. Thus increases in embodied technology will act as a catalyst in decreasing the average age of the trees. However, this by itself will not be sufficient. The rubber growing community being dominated by small farmers should be helped to acquire the technology embodied in new inputs. Therefore, a machinery for continuously monitoring the replanting programmes should be setup to arrest the deceleration in productivity growth. In the mean time, intensified efforts should be made for the early adoption of high yielding cultivators on a commercial scale as soon as they are reasonably proved.

The analysis in this chapter showed that one of the reasons for the slow down in the rate of growth of productivity in the second period is a corresponding slow down in the rate at which old trees are replaced by new trees or new varieties are planted. In the seventies, both the new planting and replantings were considerably reduced when compared with the sixties and eighties. The effect of this slow rate of replantings and new plantings was felt on production in the second period of our study. The slow rate of replanting from 1967-68 to mid seventies was a major determinant of lower growth rates in production in the eighties. New plantings and replantings in the eighties have helped in increasing the production in the last two or three years. In an industry in which the government policies have considerable impact on the replanting decisions of the farmer, the slow rate of replanting in the seventies after a fairly good rate of replanting in the sixties could have been avoided.

The industry was successful in improving the technological change in the immature phase of the rubber trees and limiting the deceleration of the technological progress in the productive phase of the trees. The availability of the credit and modern inputs were helpful in this regard. Any move to curtail the subsidies and loan facilities as also the subsidised inputs will hamper the progress of the rubber plantation industry. The production function accommodates two types of technological change viz., embodied technological change and disembodied technological change. The first type can be implemented by utilising the trees. in the productive phase while the second type need to'be embodied in new types of trees which are in the immature, unproductive phase or those trees to be planted in the future. There are two observations worth making about the policy implication of the model. Firstly, use of improved methods of exploitation and improved cultural practices in the productive phase introduced technological progress. Secondly, quality change and improvements in the upbringing of the trees during the immature phase is likely to be an important determinant of growth of rubber output. The present model suggests that the hypothesis that all technological change is of "manna from heaven" is not valid. Since output is increased by embodiment, deliberate allocation of resources should be made for research and development, knowledge dissemination and diffusion of innovations. The short term programmes of increasing the production of natural rubber depends mainly upon increasing the disembodied technological change i.e., improvement in the tehnology of exploiting the trees already in the field. The yield from the existing rubber trees could be enhanced by adopting scientific cultivation practices and modern exploitation techniques.

CHAPTER VII

TECHNOLOGICAL CHANGES IN THE ESTATE SECTOR : AN ANALYSIS

CHAPTER VII

TECHNOLOGICAL CHANGES IN THE ESTATE SECTOR :AN ANALYSIS

In chapter VII, we have analysed the technological changes in the rubber plantation industry on the basis of aggregate time series data. The number of factors that could be included in such an analysis is small. In the present chapter, an attempt is made to analyse the impact of technology in a cross section of estates for the year 1989-90. The analysis is done with in the framework of Cobb-Douglas production function.

A production function is a mathematical expression showing the relationship between the quantities of inputs employed and output produced. In the context of two variable input viz. labour L and capital K and a single output Y, the production function can be written as

$$Y = f(L,K) \qquad (1)$$

Although it is possible to specify the relationship between inputs and output in numerous mathematical functional forms, often it is difficult to select the exact form of the the biological transformation process in agricultural production. There is no point in going for complex functional forms which are not useful for elucidating the nature of the transformation process. In this background, we have chosen the Cobb-Douglas production function. The functional form is

$$Y = A L^{\alpha} K^{\beta} \qquad (2)$$

where A is a constant and α and β are the parameters to be determined empirically.

In the above production function, only capital and labour are considered as input factors. However it is possible to extent the above model to the case where there is a single output and a number of inputs with out making any conceptual difficulty. The generalised form of the Cobb-Douglas production function used in the present analysis is as follows,

$$Y_i = \beta_0 X_{1i}^{\beta_1} X_{2i}^{\beta_2} \ldots\ldots\ldots X_{5i}^{\beta_n} e^{u_i} \qquad (3)$$

Equation (3) can be transformed into the logarithmic form as

$$\ln Y_i = \ln \beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + \beta_4 \ln X_{4i} + \beta_5 \ln X_{5i} + u_i \qquad (4)$$

where

Y_i is the annual output of the ith estate measured in kilograms per hectare.

X_{1i} is the labour employed in the ith estate measured in total number of tappings

X_{2i} is the proxy variable representing the age factor of the ith estate represented by tree index value.

X_{3i} is the expenditure of the ith estate on fertiliser application measured in rupees.

X_{4i} is the expenditure of the ith estate on expenses other than tapping and fertiliser application measured in rupees.

X_{5i} is the size of the ith estate measured in hectares.

U_i is the random disturbance term which is assumed to follow the assumptions of the linear regression model.

β_0 denotes the intercept term.

β_i denotes the parameter of the function which is the partial elasticity of output with respect to the ith input.

The Data

As stated elsewhere in this study, for the empirical estimation of the production function, the input-output data are derived from the research project on the Management Practices in Rubber Plantation Industry in India[1], in which the author worked as a junior research fellow. The project covered 108 estates in the states of Kerala, Tamil Nadu and Karnataka which were chosen using a stratified random sampling procedure. Of the 90 rubber estates in Kerala surveyed for the research project, the data from 49 estates were made use on a selective basis for the present analysis. This restriction, introduces some bias in the sample, probably favouring well managed estates.

Measurement of variables

It is known that a large number of factors affect the production of natural rubber in an estate. These factors include number of trees, farm size, labour inputs in tapping rubber trees,

---

[1] Research Project on "Management Practices in Rubber Plantation Industry in India" sponsored by the Indian Council of Social Science Research at the School of Management Studies, Cochin University of Science and Technology, Cochin.

fertilizer input, pesticides and other plant protection materials weeding, age of the trees, clone or variety of the planting material planting density, and soil and climatic conditions. Because of the data non-availability, some variables have been excluded from the purview of the analysis. However the important factors such as number of tapping trees, labour input, planting density, fertiliser input, pesticides and other plant protection measures, farm size, tapping age and clone or variety of the planting material were included in the present model.

Output

Output is measured as production from one hectare. In cross-section studies, use of total output from the estate can create problems of heteroscedasticity. The chance for heteroscedasticity attaining dangerous levels is high as larger estates may have larger residual variance and smaller plantations, smaller variance. To minimise the problem of heterosceasticity, we divide the total output by total tappable area.

Labour input

The major areas of production process where labour is required are tapping, weeding, fertilizer and spraying and other plant protection measures. In this analysis, only labour input for tapping has been considered because of the lack of reliable data on the labour input for weeding, fertiliser and pesticide application. Labour input for tapping is related to the tapping system followed by the estate.

Tree Index

Tree index value is the index of the number of tappable trees corrected for age effects. The age composition of the tapping trees will be different in different farms. The yield of rubber tree changes according to age of the tress, depicted by an age-yield profile which almost resembles a flattened F-distribution curve. Therefore, it is important to include the age component in the model. The method adopted is similar to the one employed by Yee[2] for Malaysian rubber plantation industry The yield profile used in Chapter VII adjusted for the year 1989-90 has been used in calculating the tree index which incorporates the age factor. The productivity of the tree q_t

---

1 Yee Yuen Loh (1983), "Effect of Yield Stimulation on Profitability and Production Hypersurface in the Estate Sector , *Journal of Rubber Research Institute of Malaysia*,Vol.31,No.1, pp.15-26.

for each age 't' is computed from the yield curve (profile). The tree index value is derived by multiplying the total number of tappable trees in a hectare by an index factor to adjust for differences in the age of the trees. This variable incorporates the planting density also as the number of trees per hectare is considered in arriving the tree index value. The index V is defined as

$$V_i = \frac{\sum_{t=1}^{35} q_t - \sum_{t=1}^{i} q_t}{35}$$

The tree index value is given by

$$X_{2i} = V_i \times T_i$$

Where T is the number of tappable trees per hectare in the estate.

Fertiliser Input

Application of fertilisers is expected to change the output level. Fertiliser expenditure in rupees per hectare has been taken as the fertiliser input.

Other Inputs

Estate expenditure other than fertiliser expenses and tapping expenses have also been included in the model.

Size of the Estate

To determine whether large estates have the advantages of economies of scale, size of the estate was included in the production function analysis. Area under rubber cultivation measured in hectares is used for this purpose.

Type of planting material

The data collected from the estates were broadly classified into those under budgrafts and clonal seedlings. Unselected seedlings were used only in a small section of estates and that too in a small proportion. Therefore only two classes of planting materials were considered in the present analysis. Some estates had more than one type of planting material. To avoid further complication in the analysis, the type of planting material used in the largest percentage of the area was taken as the proxy for planting material for that estate. The analysis was done using the dummy variable T which takes the value

T = 1 for estates where budgrafts are planted

= 0 for estates where clonal seedlings are planted

There can be other variables which are affecting the output of rubber from any estate, but these factors individually may have only a small association with the output. Another factor is that the inclusion of more variables would also decrease the degrees of freedom.

While considering change of technology as manifested by the sample estates, it must not be forgotten that we are dealing with cross-section data. Levels of technology classified according to type of planting materials do not represent sequential stages in the life of any one estate or an identified group of estates, but rather the varied levels of technology at which different groups of plantations happened to be in the year 1989-90.

The following empirical models were used for examining the shift in the production and nature of technological change

$$\ln Y_{Ci} = \ln \beta_{C0} + \beta_{C1} \ln X_{1i} + \beta_{C2} \ln X_{2i} + \beta_{C3} \ln X_{3i} + \beta_{C4} \ln X_{4i} + \beta_{C5} \ln X_{5i} + u \quad \text{——— (5)}$$

$$\ln Y_{Bi} = \ln \beta_{B0} + \beta_{1} \ln X_{1i} + \beta_{B2} \ln X_{2i} + \beta_{B3} \ln X_{3i} + \beta_{B4} \ln X_{4i} + \beta_{B5} \ln X_{5i} + u \quad \text{——— (6)}$$

$$\ln Y_{Pi} = \ln \beta_{P0} + \beta_{P1} \ln X_{1i} + \beta_{P2} \ln X_{2i} + \beta_{P3} \ln X_{3i} + \beta_{P4} \ln X_{4i} + \beta_{P5} \ln X_{5i} + u \quad \text{——— (7)}$$

$$\ln Y_{Di} = \ln \beta_{D0} + \beta_{D1} \ln X_{1i} + \beta_{D2} \ln X_{2i} + \beta_{D3} \ln X_{3i} + \beta_{D4} \ln X_{4i} + \beta_{D5} \ln X_{5i} + \upsilon$$
$$+ \beta_{D6} T + \upsilon_{D} \quad \text{——— (8)}$$

T is the variety dummy variable which takes the value one for Budgrafts (new technology) and zero for clonal seedlings, (old technology) subscripts C, B, P, and D stands for the technology of clonal seedlings, technology of budgrafts, pooled data and pooled data with dummy variable for the variety of planting material respectively. The regressions given above were estimated by least squares method and the results are presented in Table 7.1

Table 7.1

Estimates of the Parameters of the Production Function

	Clonal	Budgrafts	Pooled	Pooled with Dummy
Tree Index	0.2859	0.1800	0.2693	0.2366
	(2.562)	(2.435)	(4.070)	(3.515)
Fertilisers	0.8062	0.3313	0.4693	0.4686
	(4.209)	(3.346)	(4.485)	(4.584)
Other Inputs	0.4542	0.2579	0.1846	0.1934
	(2.766)	(0.255)	(1.823)	(1.953)
Tappings	-0.0886	0.1924	0.2397	0.2170
	(-0.270)	(1.150)	(1.393)	(1.286)
Size of the estate	-0.1253	-0.0337	-0.0673	-0.0701
	(-1.606)	(-0.974)	(-1.778)	(-1.896)
Constant	-3.1820	2.6420	-0.4163	-0.2266
	(-1.612)	(2.039)	(-0.339)	(-0.188)
Dummy for Planting Material				0.1228
				(1.751)
R^2	0.81	0.52	0.63	0.66
SEE	0.2310	0.1776	0.2284	0.2231
F	11 31	5.17	14.81	13.44
No. of Observations	19	30	49	49
Returns to Scale				

It is seen from the Table 7.1 that the old and new technology categories showed positive coefficients for tree index, fertilisers, and other input expenditures. The significance of the coefficients associated with the tree index value under both old and new technologies indicate that the increase in the planting density and decrease in the age of the trees are positively affecting the output. The significance of the tree index value also emphasise the need for further reduction in the average age of the trees by replanting old trees. The higher value of the coefficient of tree index under the old technology means that the age factor and the planting density may contribute to output more than what it does in a situation where it is associated with the new technology.

The response to fertilisers was also higher under the old technology. The coefficient 0.81 under the old technology and 0.33 under the new technology indicate that a one percent increase in the fertiliser usage, keeping other factors of production constant at their respective factor endowment levels, may result in increasing the yield by 0.81 percent under the old technology and 0·33 per cent under the new technology. The higher value of fertiliser coefficient for the old technology, may be because of the under utilisation of fertiliser among estates in this category. The estates in the new technology group may be nearer to the optimum levels of fertiliser use so that further increases in production by increasing the dosage of fertilisers is less. Other inputs coefficient was significant only for the old technology group. The coefficients of tapping labour was also not significant. The coefficients for estate size in both groups were not significant. This is an interesting result, since it implies that the advantages of scale economy could not be accrued by large estates

In estates were budgrafts are used as planting material,the elasticity of output with respect to tree index,fertilisers and other inputs expenses are lower than the elasticities for estates using clonal seedlings. These elasticities indicate that the yield, on the average , increase at relatively smaller proportion in the estates under the new technology than in the estates under the old technology in response to a given increase in a particular input when all other inputs are held constant.

It is found that more than 80 percent of the variations in yield has been explained by the independent variables fitted in the equation in the case of old technology group and it is about 52 per cent with regard to the new technology group The large unexplained variation in the new technology model implies that the factors like climatic conditions, soil type, damages due to natural calamities etc. which are not included in the model were affecting the new variety of planting material than the old variety. Though the average age of the new technology group (1239 Kgs) was higher than the old technology group (1013 Kgs) by 22.31 per cent, planting materials under the new technology is more severely affected by the uncontrollable factors.

The production function analysis reveals that among the factors included in the production function, tree index, fertiliser expenses and other input expenses show greater influence on the yield.

The presence of the shift in the production function was identified by comparing separate regressions (5) and (6) with the pooled regression (7). The procedure adopted is Chow[3] test. This

---

[3] Chow G.C (1960), "Tests & Equality Between Sets of Coefficients in Two Linear Regressions", Econometrica, Vol.28, pp.591 605.

is done by Computing the F ratio,

$$F^{*} = \frac{\{ESS_{B} - (ESS_{C} + ESS_{B})\}/K}{(ESS_{C} + ESS_{B})/(n_{1}+n_{2}-2K)}$$

where ESS_{p} is the Error Sum of Squares of the pooled equation

ESS_{C} is the Error Sum of Squares of the clonal group equation

ESS_{b} is the Error Sum of Squares of the budgrafts group equation

K is the total of coefficients to be estimated including intercept

n_{1} is the number of observations in the clonal group

n_{2} is the number of observations in the budgrafts group

We can compare the observed F^{*} ratio with the theoretical value of $F_{0.05}$ with $\upsilon_{1}=K$ and $\upsilon_{2}= (n_{1}+n_{2}-2K)$ degrees of freedom and if $F^{*}>F_{0.05}$, we reject the null hypothesis, ie we accept that the two functions differ significantly.

The computed F ratio (F = 7.37) exceeded its critical value even at one per cent level of significance. Computed F ratio revealed that the introduction of budgraft technology. in natural rubber caused a shift in production function.

The analysis of covariance technique suggested by Johnston[4] has been used to determine whether the differences in the two production function was due to different slope coefficients or due to change in the intercepts For this analysis, regressions were estimated by pooling the data for both types of planting materials and including a technology dummy D Results of the analysis of covariance are summarised in Table 7.2.

Table 7.2

F Values Derived from the Covariance Analysis

Tested Hypothesis	Calculated F ratio	Degrees of freedom
Differential Intercept test	$F_1 = 3.07$	1,42
Differential Slop test	$F_2 = 3.26^*$	5,37
Overall Homogeneity test	$F_3 = 3.37^*$	6,37

* Significant at 5% significance level.

The F_3 value is significant confirming the hypothesis that there is difference between the production functions of the

---

[4] See Jonnston J., (1972) Econometric Methods, Mc Graw Hill, Tokyo, pp.192-199.

group under the technology of clonal seedlings and the group under budgraft technology. It is found that while the F_2 value is significant, F_1 value is not significant. Thus, the hypothesis of constant slope coefficients is rejectedwhich means that the adoption of budgrafts had shifted the production function in anon-neutral fashion.

One method of examining the nature and extent of the non-neutral shift between the production processes of the old and new technologies is to test the effect of dummy variables for planting materials on the input factors. For this purpose a non-neutral version of Equation (4) was formulated and fitted to the pooled data. The equation is

$$\begin{aligned} \ln Y_i = {} & \ln \beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + \beta_4 \ln X_{4i} + \beta_5 \ln X_{5i} + \\ & + \beta_1 (T.\ln X_{1i}) + \beta_2 (T.\ln X_{2i}) + \beta_3 (\ln X_{3i}) + \beta_4 (T.\ln X_{4i}) + \\ & \beta_5 (T.\ln X_{5i}) + u_i \qquad (9) \end{aligned}$$

Table 7.3

Estimate of the Parameters of the Non-Neutral model for Pooled Data

Input Variable (inlogarithems)	Coefficients	t Value
X_1	0.8041	2.752
X_2	-0.4104	-1.510
X_3	0.6844	4.047
X_4	0.3160	2.255
X_5	-0.0658	-0.974
$T.X_1$	0.8041	2.752
$T.X_2$	-0.0970	-0.715
$T.X_3$	-0.2705	-1.385
$T.X_4$	-0.2037	-1.195
$T.X_5$	-0.0055	0.157
Constant	0.1848	
R^2	0.72	
SEE	0.2127	
F	9.69	
No.of observation	49	

The results of the regression analysis are given in Table 7.3. The non-neutral model indicated that there was significant increase in the coefficient of tapping labour by the introduction of the new technology. All other interaction terms were not significantly different from zero. Overall, the results in Table 7.3 indicate that the impact of the introduction of budgrafts on the production function is non-neutral and increased the marginal productivity of tapping labour.

The estate group under the old technology shows increasing returns to scales while the new technology group shows constant returns to scale. The constant returns to scale in the new technology group mean that allocation of available resources which are under their disposal, are in optimum shape.

One important finding is that estate size does not significantly affect the production levels. The important factors viz. tree index, fertiliser usage, other input expenses which show positive contribution in maximising output may rightly be exploited by replanting the area under old trees with high yielding varieties and by the efficient use of fertilisers and other inputs

CHAPTER VIII

FINDINGS AND CONCLUSION

CHAPTER VIII

FINDINGS AND CONCLUSION

Kerala, contributes about 92 per cent of the national rubber production. In 1955-56, the output of natural rubber in Kerala was 21,680 tonnes, which increased to 3,44,503 tonnes in 1991-92; an increase of 1583 per cent over a period of 36 years. This spectacular increase in output of natural rubber may be observed as the consequence of the increase in area under rubber cultivation and yield per hectare. For Kerala, a densely populated state in India, the option for increasing the rubber production by increasing the area under cultivation has only limited scope. Therefore, further increase in output of natural rubber, which is a strategic raw material for a large number of industries ranging from tyre manufacturing industry to small units producing rubber bands, lies in productivity improvement through technological advancement.

The Indian natural rubber plantation industry, has over the years, evolved a system of research capabilities that has generated a stream of indigenous technology. At times, the industry has adopted better technologies developed elsewhere which were found to be suitable to our conditions. The productivity in rubber plantation industry depends not only on the advancement of technology, but also on the proper diffusion of new technology among the growers. The present study analysed the technological changes experienced in the rubber plantation industry since 1955-56.

The study is divided into eight chapters. In the first chapter, the problem, objectives and a brief methodology of the study are presented.

It has been found from the survey of literature presented in chapter II that though many studies have been conducted on rubber plantation industry in India and its various aspects, no study has so far focused attention exclusively on the technological changes in rubber plantation industry in Kerala. In that respect, this study is a pioneering attempt at analysing the technological changes and growth performance of the rubber plantation industry

From the discussion in chapter III, it is clear that natural rubber brought to India in the latter part of the 19th century showed a slow but upward trend in area and production in the first half of twentieth century. Initially rubber plantations were owned by Europeans, in the estate sector. Gradually Indians also started rubber cultivation both in the estate sector and the small holding sector. Until rubber manufacturing industries were started in the thirties, natural rubber was fully exported. The British Government took active interest in the development of the rubber plantation industry. Their interest in natural rubber was mainly because of its importance as a raw material for their rubber manufacturing industries. After 1955-56, the growth of the industry was more impressive than in the pre-independence period.

In chapter IV, analysis of the growth performance of the rubber plantation industry since 1955-56 is carried out. In this chapter growth rates were worked out using exponential and kinked exponential models. Test for acceleration/deceleration in growth rates was conducted using a log-quadratic function. The growth in natural rubber production in Kerala and the two other major rubber producing states viz. Tamil Nadu and Karnataka has been decomposed into area effect and yield effect. The instability in the production of natural rubber has been measured and the output variance was disaggregated into area component and yield component

The analysis of growth showed that the rubber plantation industry has revealed continuous spectacular improvement during the period 1955-56 to 1991-92. The growth rate of production in Kerala was 7.9 per cent as against a growth rate of 3.5 per cent in area under rubber cultivation and 3.7 per cent in yield per hectare. The corresponding figures at the national level were 7.8 per cent, 3.8 per cent and 3.5 per cent respectively. It was estimated that the growth rate of rubber production falls annually by small amounts of 0.2 per cent in Kerala, o.22 per cent in Tamil Nadu and 0.12 per cent at the national level. Karnataka, however, had experienced an acceleration in growth rate. For tappable area and yield per hectare also, deceleration was experienced in Kerala, Tamil Nadu and India. Here also Karnataka was an exception which experienced acceleration in growth rates.

Separate growth rates were found out for the two periods 1955-56 to 1976-77 and 1977-78 to 1991-92. The major reason behind the decision of taking the cut-off point at 1976-77 is the introduction of high-yielding varieties of planting materials developed in India. New high-yielding varieties developed in India were put to commercial use in the late sixties. Considering a lag of about seven years of immaturity period, the production in the period after 1976-77 is expected to reflect the impact of the new high-yielding varieties developed in India. It was seen that the growth in the period 1977-78 to 1991-92 failed to keep pace with the period 1955-56 to 1976-77. The most striking observation is that in the States of Kerala and Tamil Nadu as well as the national level yield grew faster during 1955-56 to 1976-76. Decomposition analysis of production growth indicated that the area component was the major component of output growth. However, the contribution of the yield component also was impressive. Of the 7.9 per cent rate of growth in aggregate rubber production in Kerala, 53.16 per cent could be attributed to growth in area and 46.84 to yield growth.

The instability or year to year fluctuations in rubber production has increased during 1977-78 to 1991-92 for all the three states. However, this period was characterised by lower growth rates. This led us to conclude that, apparently, there is no positive relationship between growth rate and instability in natural rubber. Further, the decomposition analysis of production instability revealed that the yield component of production instability was significantly reduced in the period after 1976-77 indicating that the increase in production instability can not be attributed to productivity oriented research. The yield instability could be further reduced by investing on research towards evolving of cultivars. which are suitable for the existing agro-climatic conditions. The cultivation of rubber in less endowed areas and extension of cultivation to marginal or submarginal lands might have contributed to higher production instability during 1977-78 to 1991-92.

An interesting thing that may be noted in the analysis is the closeness of the estimates for the Kerala state and for the whole country. This is true for growth rates, acceleration/deceleration, instability or the decomposition measures. The main reason for this phenomenon is that other states really contribute very little to the national figures. So we are justified in analysing national level data whenever the state-wise data for Kerala is not available.

A major determinant of technological change in rubber plantation industry in India has been the introduction and adoption of high yielding varieties. Since rate of diffusion is the rate at which a new technique is actually put into use it is a critical determinant of the rate of growth of productivity. If certain groups are quicker to diffuse a new, more efficient technique, they are quicker to attain the resulting increases in productivity. A measurement of the rate of diffusion is helpful in planning for future innovations

It is found from the analysis in chapter IV that the small holding sector is lagging behind the estate sector in the adoption of high yielding varieties of planting materials Rubber Board should allocate more resources to the problems of the small holders. Technologies should be developed in such a way that it is easily adoptable and profitable to the small holding sector which contributes the lion's share of the production of natural rubber in the country. The Rubber Board should take steps to effectively diffuse such technologies with the help of the recently started Rubber Producers Societies.

It has been found from the discussion in chapter V that the rubber plantation industry in India witnessed significant changes in the technology of production. The most important change being the change in the quality of the planting materials. High yielding planting materials developed in the research centres inside and outside the country were widely used by the farmers High yielding planting materials with a reduced immaturity period were also developed. The use of high-yielding planting materials were supplemented by improved cultural practices, scientific application of fertilisers and pesticides, rainguarding and use of yield Stimulants. All these factors have helped in improving the production of natural rubber. Changes were also experienced in other aspects such as preparation of land for planting, clearing the land for planting, lining, pitting, planting, density of planting etc.

In chapter VI, the analysis of technological changes in rubber plantation industry is presented. Technological changes in rubber plantation industry can be broadly classified into disembodied technological changes and embodied technological changes. In the rubber plantation industry, disembodied technological change indicates the changes in technology during the productive phase. Disembodied technological change, experienced in the rubber plantation industry include better tapping methods, application of fertilisers according to the results of soil and leaf analysis, disease and weed control measures, rain guarding, application of yield stimulants and better cultural practices. Embodied technological change is the change embodied in different vintages of plants. The production of natural rubber depends on the technology embodied in the trees at the time of planting and during the immature phase. Embodied technology will depend on factors like the type of planting material, planting density, propagating and planting techniques, land quality and soil type, which are all factors determined at the planting time. In addition to this, other factors like disease and weed control, fertiliser application, use of cover crops and general maintenance during the long immature phase contribute to embodied technological change.

Analysis of technological change has been done in the framework of a simple vintage production function. Vintage production has the advantage that it admits the heterogeneity of capital of different vintages, ie.,the rubber trees of different years of planting. In natural rubber, a crop in which the type of planting materials used and the upbringing of trees during the immature phase are important determinants of technological change, a vintage production function approach is suitable. The production function accommodates the two types of technological change viz. embodied technological change and disembodied technological change. The first type can be implemented by utilising the trees in the productive phase while the second type need to be embodied in new types of trees which are in the immature, unproductive phase or those trees to be planted in the future.

The short term programmes of increasing the production of natural rubber depends mainly upon increasing the disembodied technological change. The yield from the existing rubber plantation could be enhanced by adopting scientific cultivation practices and modern exploitation techniques Discriminatory use of fertilisers based on soil and leaf analysis, spraying, rain guarded tapping and use of chemical yield stimulants. The long-term programmes should be directed towards increasing embodied technological change.

It was found that the disembodied technical change or 'manna from heaven type' technological change was of the order of 2.0 per cent per annum for the period 1955-56 to 1990-91. But after leaving allowance for quality improvement of trees of newer vintages, a part of the disembodied technological change appears to have disappeared. When the embodiment effect of technological progress is brought into the analysis, we come to the conclusion that embodiment effect has favourable influence upon the growth rate of productivity. For measuring embodied technological change which the quality of the planting material is a major component, the period after 1967-68 was taken as a separate period. This was done to measure the effect of the high yielding varieties developed in India which were put to commercial use in the late sixties. The embodied technological change was found to be greater during the period after 1966-67.

The Study showed that the productivity growth was lesser in the period after 1976-77, not because of any decrease in the rate of technological progress, but because of the increase in the mean age of the trees. The average age of the trees in the in the period before 1977-78 was about three years lower than that of the trees after 1977-78. Therefore, along with research on improving the technology, Rubber Board should take initiative in decreasing the mean age of the rubber trees. This can be achieved by replanting old trees which are still under tapping. Therefore investment in the extension programmes should be given more importance.

During the long immature phase of the rubber tree, very little or no cash revenue is earned by the farmers, while expenditure on planting material, inputs, equipments and consumption must be made in cash. The only additional income available with the rubber growers at the time of starting a new production cycle is the revenue from the trees cut down at the time of replanting. The fact that this income will not be sufficient for meeting the cash needs for the next seven years makes the position of growers vulnerable. Sufficient credit facilities will facilitate the consumption of greater purchased inputs and thus increases the productivity of rubber. This potential gain in productivity is one motivating force underlying the government programmes to provide subsidy and credit facilities at subsidised interest rates. Therefore any move to curtail the subsidy and credit facilities would be harmful to the growth of the rubber plantation industry.The sprayers, dusters rollers and other equipment should also be made available to the needy cultivators at subsidised rates.

The rate of increase in productivity slow down during the period after 1976-77 was due to the drag of the older and lesser productive backlog of trees planted earlier. The pace of replanting has been slowed down in the latter part of the sixties and the first half of the seventies. Though the quality of the planting materials have improved during this period, the backlog of the old planting materials which were retained because of the slow replanting rate was the major reasons for the low growth in productivity in the second half. In addition to this, newplanting also was considerably reduced during this period. In an industry in which the governments policies have a great impact on the replantings decision of the farmer, the slow rate of replanting in the seventies after a fairly good rate of replanting in the sixties could have been avoided.

In chapter VII, the impact of technology in a cross section of estates in Kerala was studied for the year 1989-90. The analysis is done with in the framework Cobb-Douglas production function.

The analysis in chapter VII indicated that the age factor and the planting density may contribute to output under the old technology more than what it does in a situation where it is associated with the new technology. The response to fertilisers was also higher under the old technology. The estimated coefficients indicated that a one percent increase in the fertiliser usage, keeping other factors of production constant at their respective factor endowment levels, may result in increasing the yield by 0.81 percent under the old technology and 0.33 per cent under the new technology. The higher value of fertiliser coefficient for the old technology, may be because of the under utilisation of fertiliser among estates in this category. The estates in the new technology group may be nearer to the optimum levels of fertiliser use so that further increases in production by increasing the dosage of fertilisers is less. Other inputs coefficient was significant only for the old technology group The coefficients of tapping labour was also not significant. The coefficients for estate size in both groups were not significant. This is an interesting result, since it implies that the advantages of economies of scale could not be accrued by large estates

In estates where budgrafts are used as planting material, the elasticity of output with respect to tree index, fertilisers and other inputs expenses are lower than the elasticities for estates using clonal seedlings. These elasticities indicate that the yield, on the average, increased at relatively smaller proportion in the estates under the new technology than in the estates under the old technology in response to a given increase in a particular input when all other inputs are held constant. This has happened probably because, the estates under the new technology group are nearer to the optimum input usage. It is found that more than 80 percent of the variations in yield has been explained by the independent variables fitted in the equation in the case of old technology group and it is about 52 per cent with regard to the new technology group The large unexplained variation in the new technology model implies that the factors like climatic conditions, soil type, damages due to natural calamities etc. which are not included in the model were affecting the new variety of planting material than the old variety. Though the average age of the new technology group (1239 Kgs) was higher than the old technology group (1013 Kgs) by 22.31 per cent, planting materials under the new technology is more severely affected by the above factors.

It was revealed that the introduction of budgraft technology in natural rubber caused a shift in the production function in a non-neutral fashion. The non-neutral model indicated that there was significant increase in the coefficient of tapping labour by the introduction of the new technology.

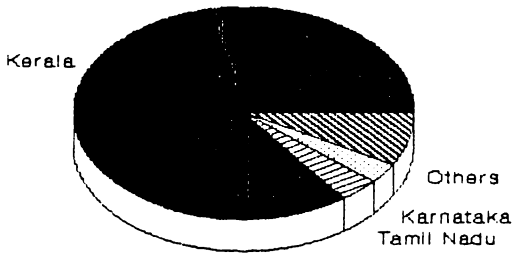
One important finding is that size of the estate does not significantly affect the yield per hectare. The important factors viz. tree index, fertiliser usage, other input expenses which show positive contribution in maximising output may rightly be exploited by replanting the area under old trees and by the efficient use of fertilisers and other inputs.

Impact of technological changes on rubber plantation industry have been enormous. Indeed, the industry could not have survived in its present shape and size without the higher productivity that the new technologies have made possible. To conclude, the technological changes experienced during the last four decades have a very positive impact on the rubber plantation industry in Kerala.

APPENDIX I

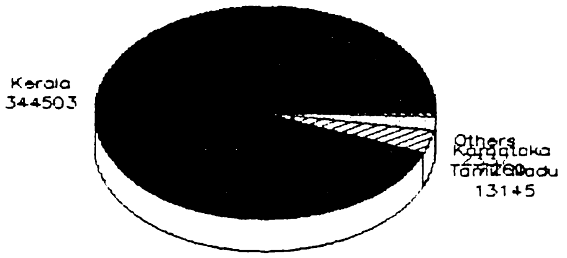
FIGURES

FIGURE A1
SHARE OF MAJOR RUBBER PRODUCING STATES



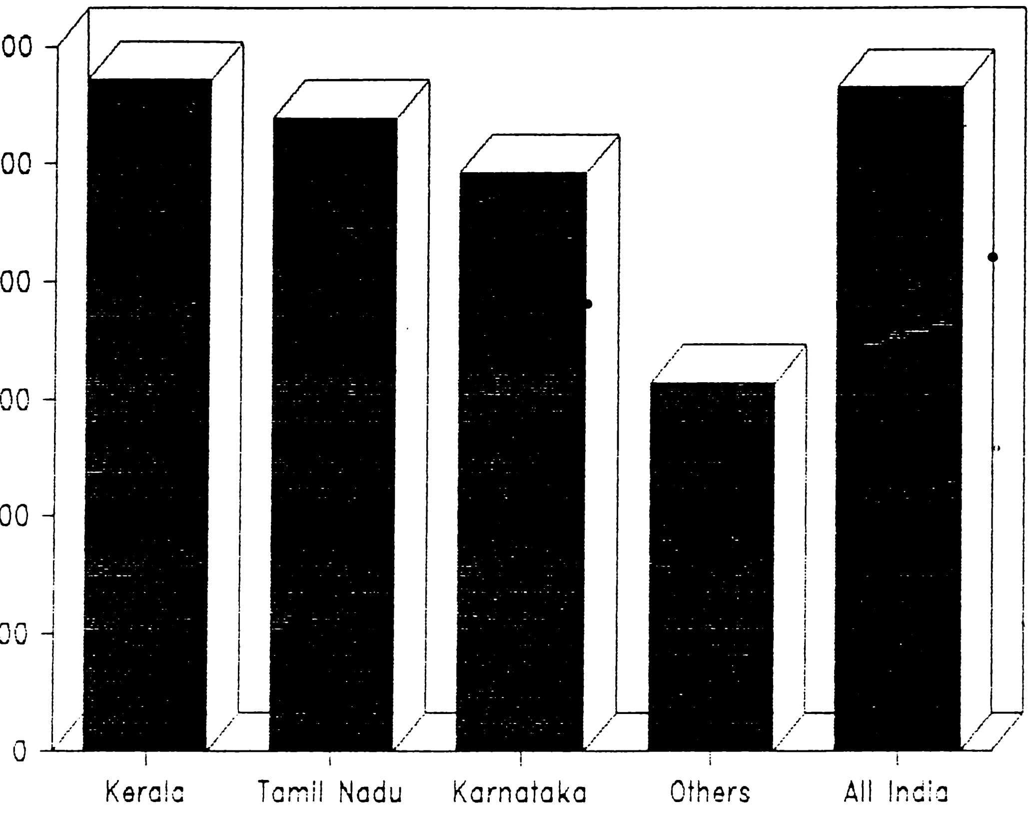
AREA UNDER RUBBER

FIGURE A2
SHARE OF MAJOR RUBBER PRODUCING STATES



PRODUCTION OF RUBBER

FIGURE A2
YIELD PER HECTARE

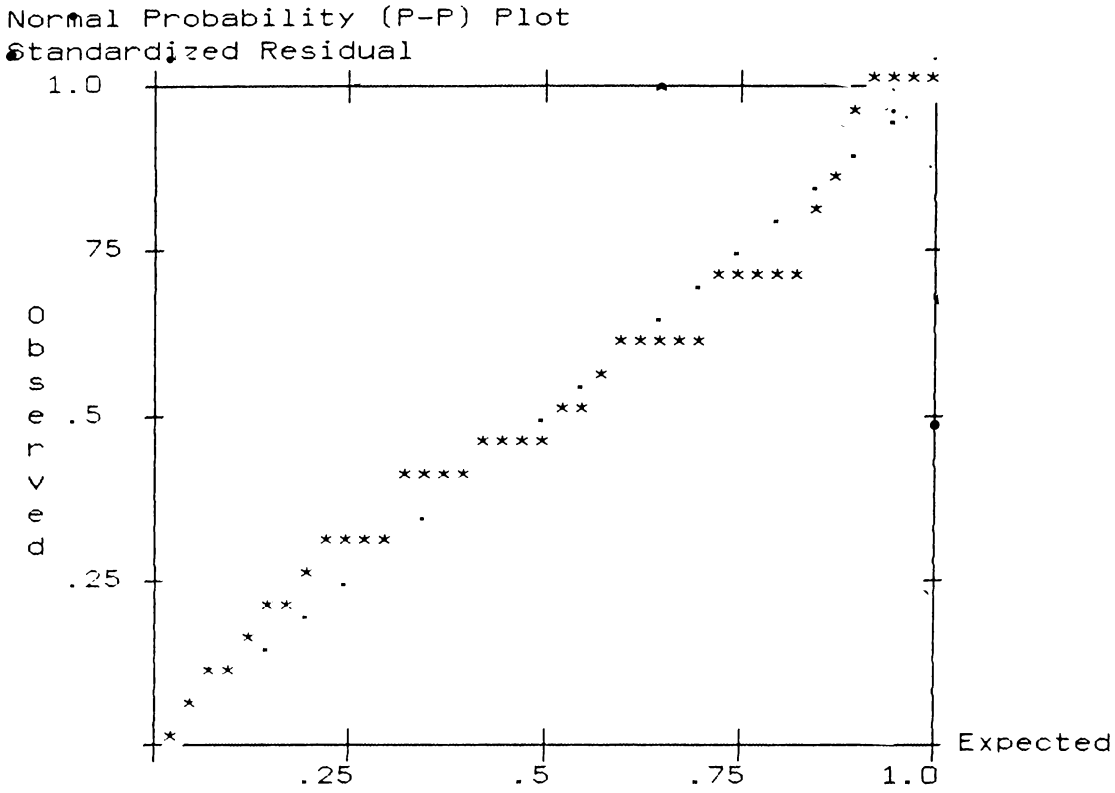


APPENDIX II

NORMAL PROBABILITY PLOTS OF RESIDUALS OF REGRESSIONS IN CHAPTER IV

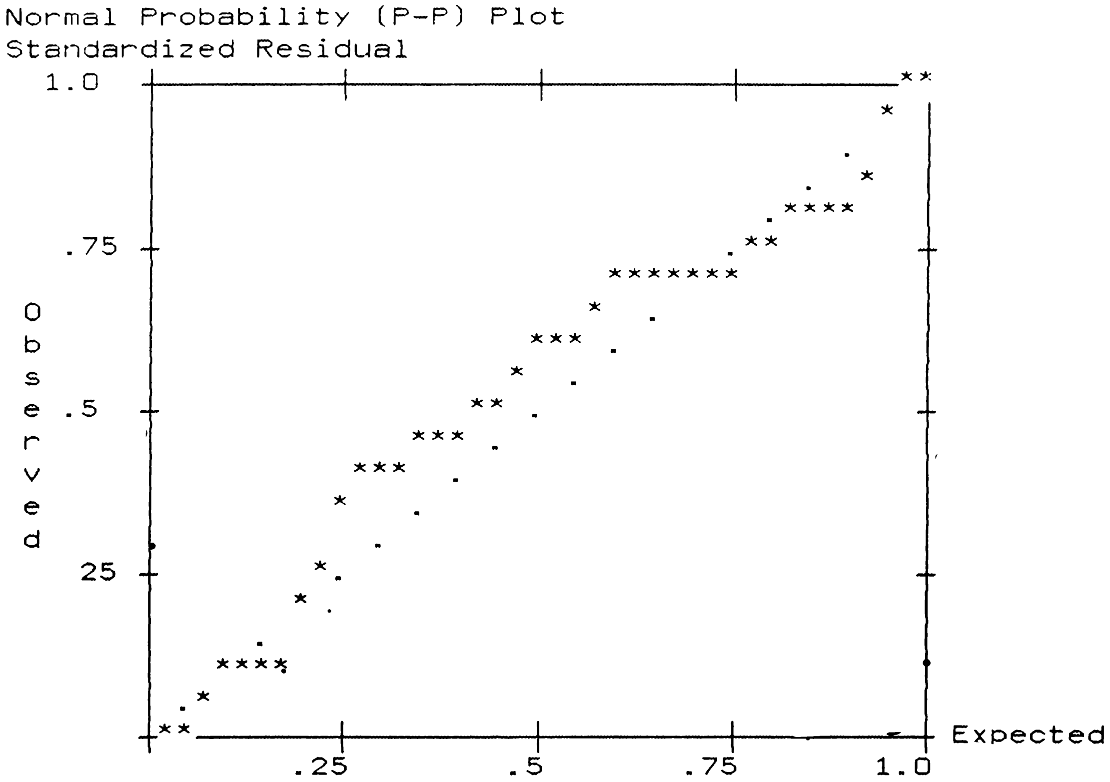
KERALA - TAPPABLE AREA

Estimated function is $\ln Y_t = a + bt$



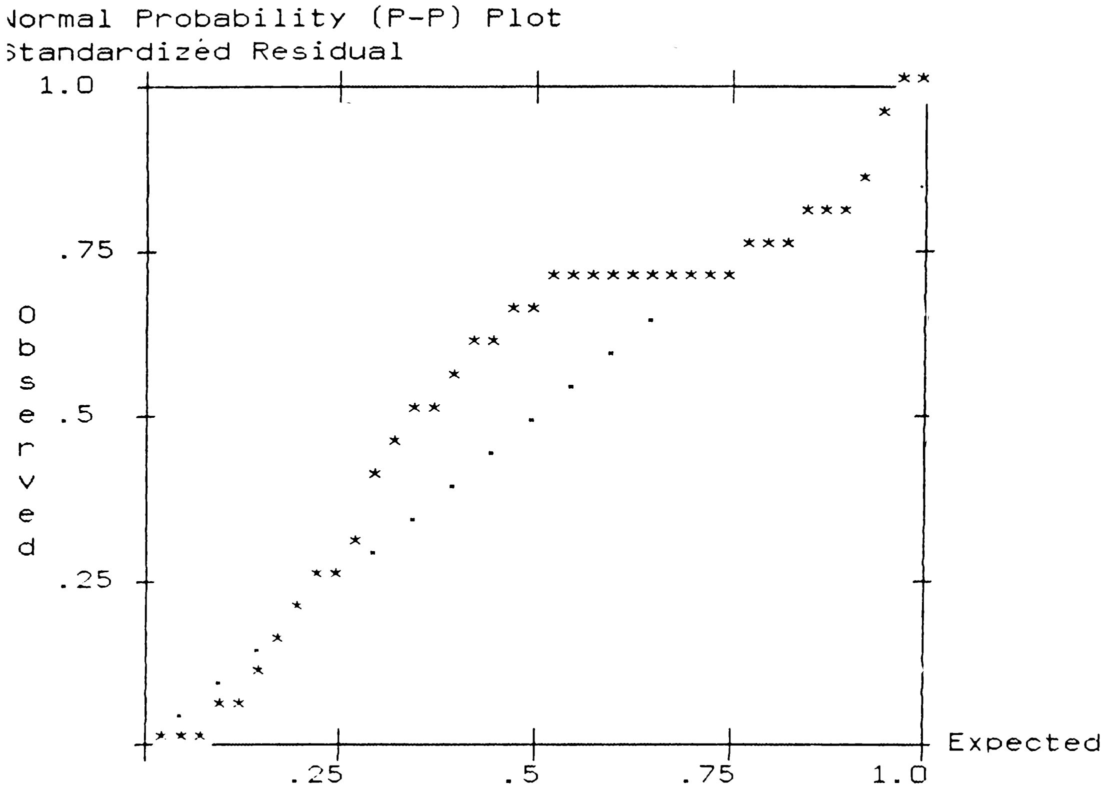
KERALA - PRODUCTION

Estimated function is $\ln Y_t = a + bt + U_t$



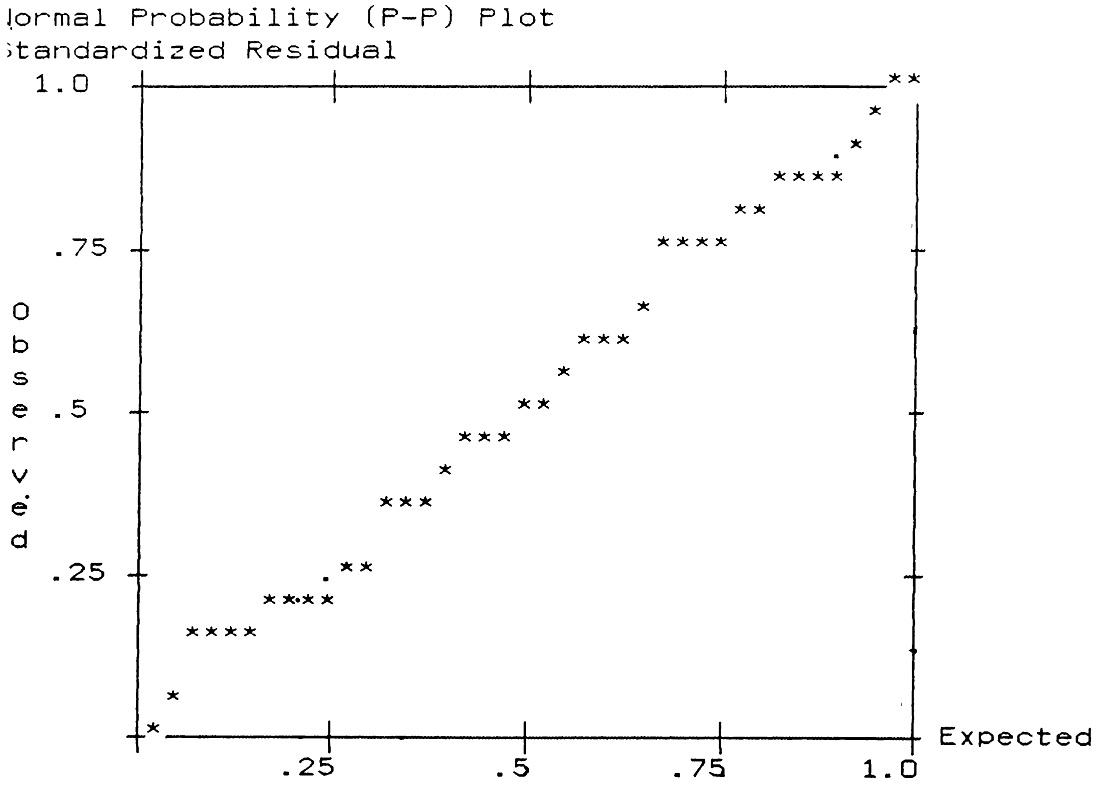
KERALA - YIELD

Estimated function is $\ln Y = a + bt + U$



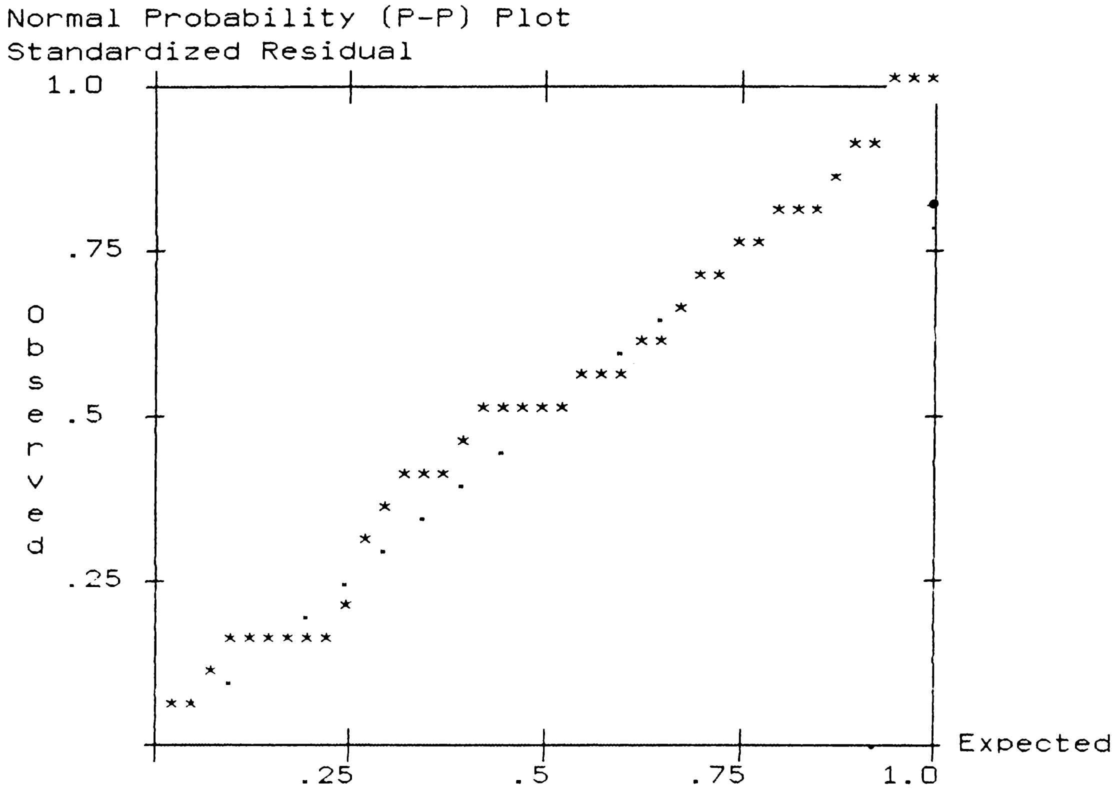
TAMILNADU - TAPPABLE AREA

Estimated function is $\ln Y_t = a + bt + U_t$



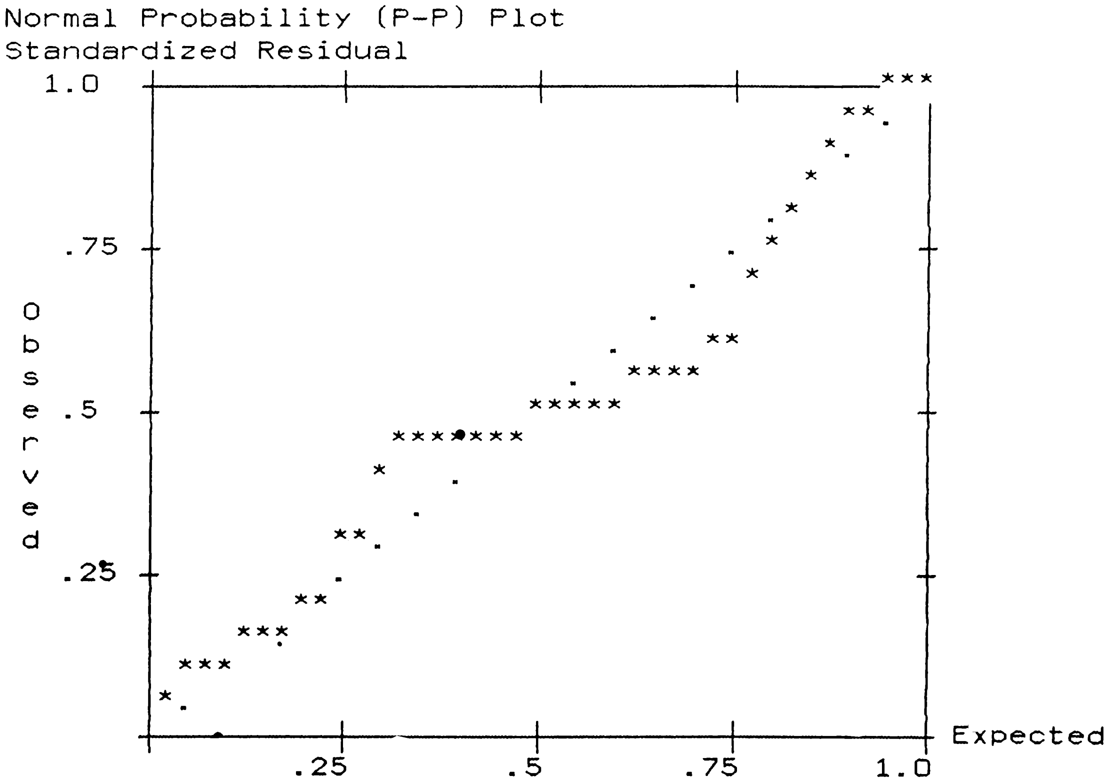
TAMILNADU - PRODUCTION

Estimated function is $\ln Y_t = a + bt + U_t$



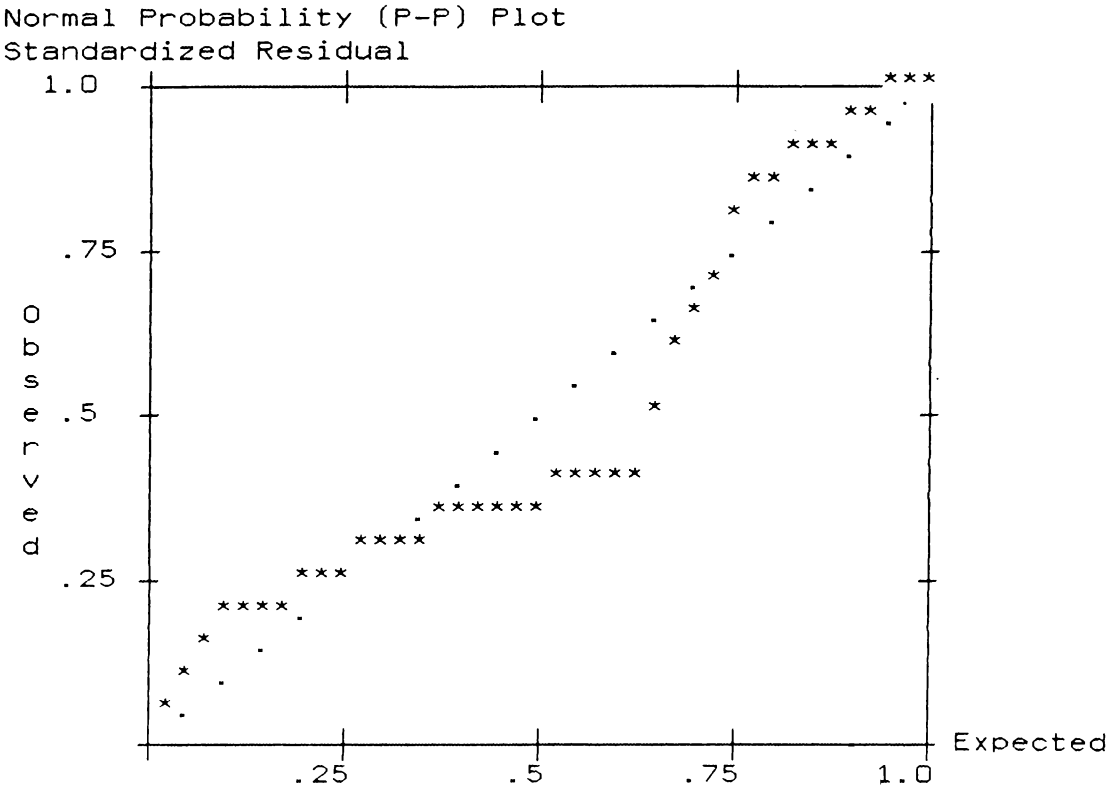
TAMILNADU - YIELD

Estimated function is $\ln Y_t = a + bt + U_t$



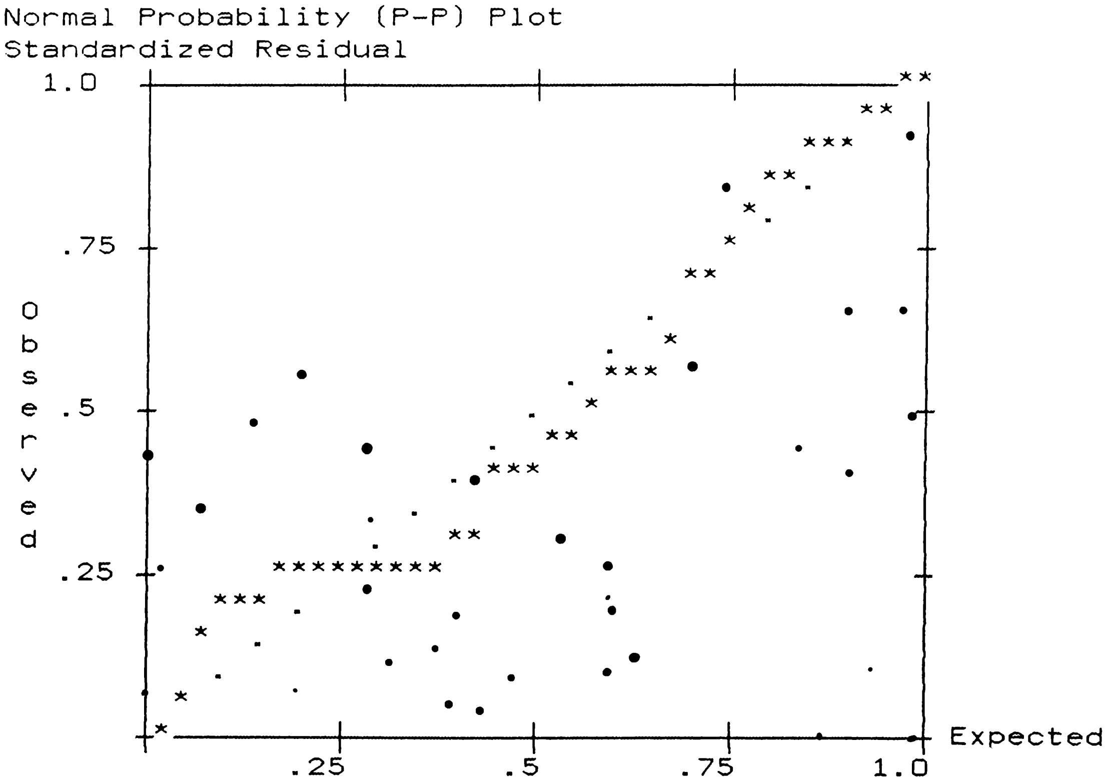
KARNATAKA - TAPPABLE AREA

Estimated function is ln Y_t = a + bt



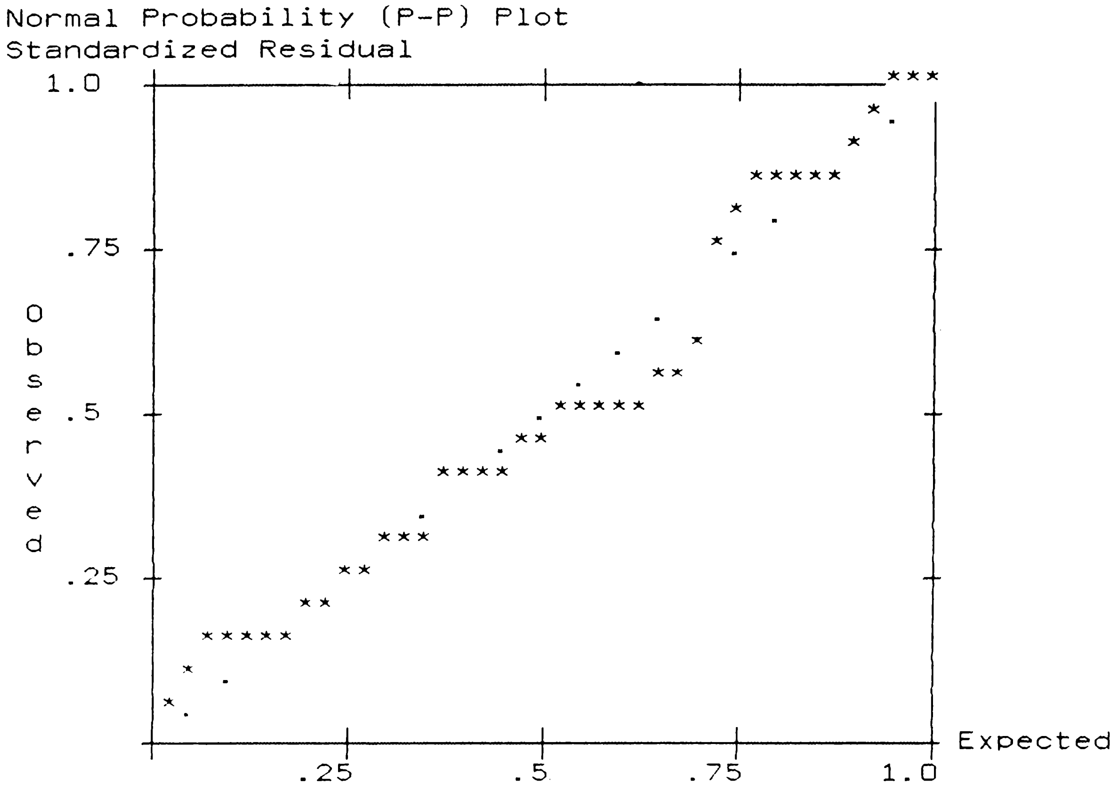
KARNATAKA - PRODUCTION

Estimated function is ln Y_t = a + bt



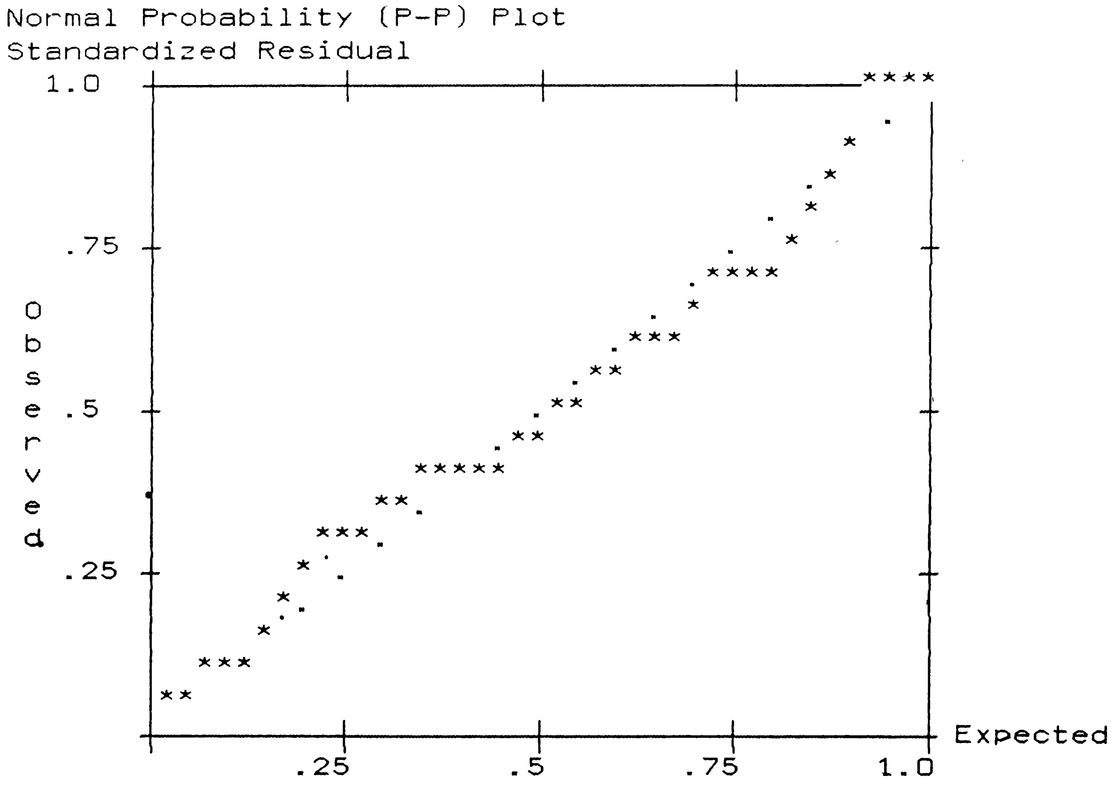
KARNATAKA - YIELD

Estimated function is $\ln Y_t = a + bt$



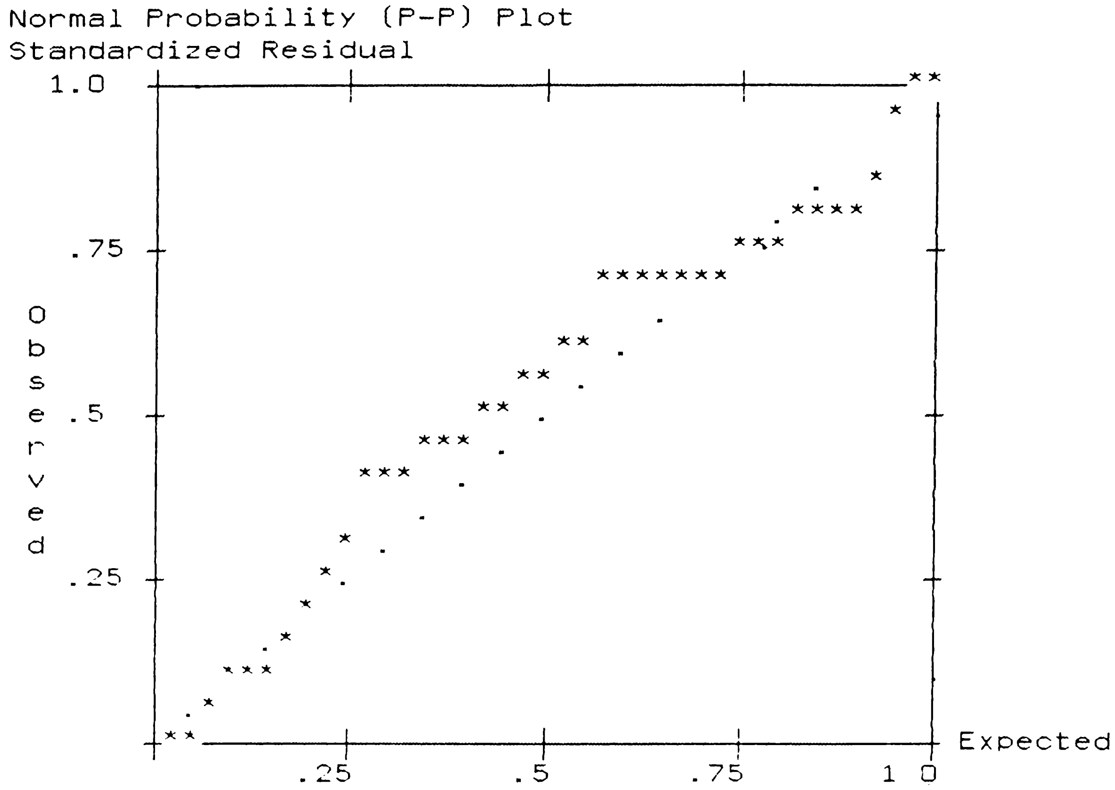
INDIA - TAPPABLE AREA

Estimated function is $\ln Y_t = a + bt$



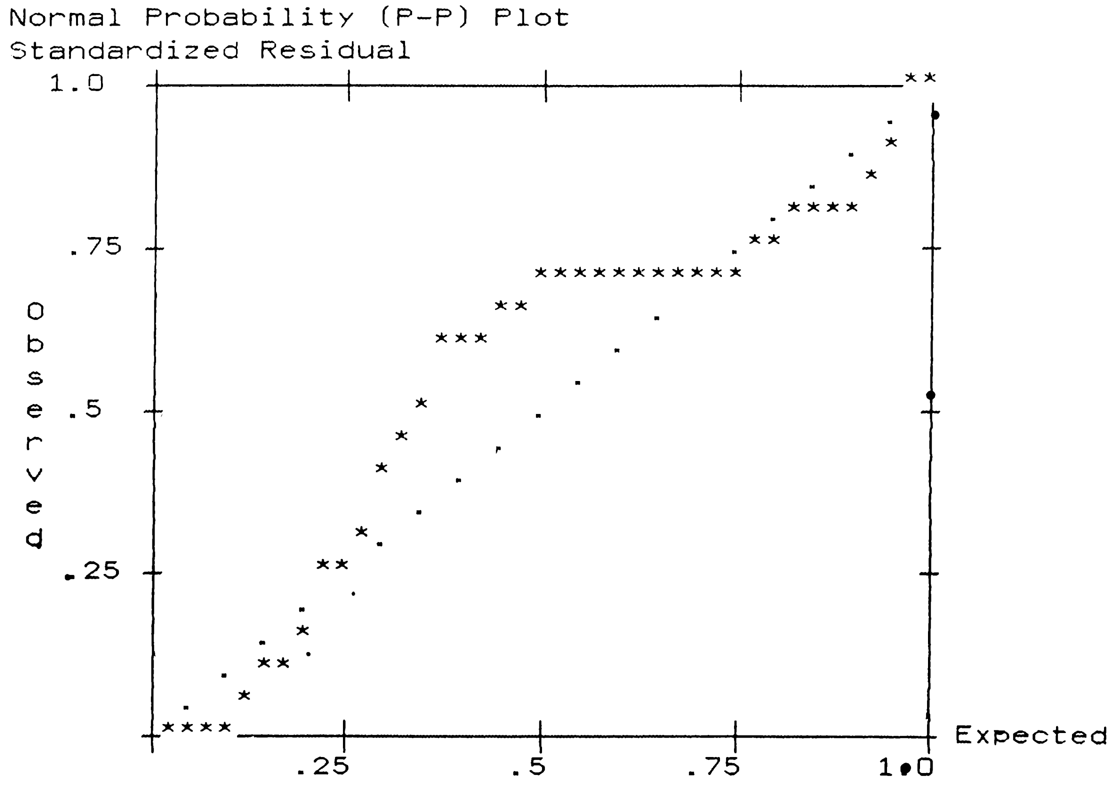
INDIA - PRODUCTION

Estimated function is $\ln Y_t = a + bt + U_t$



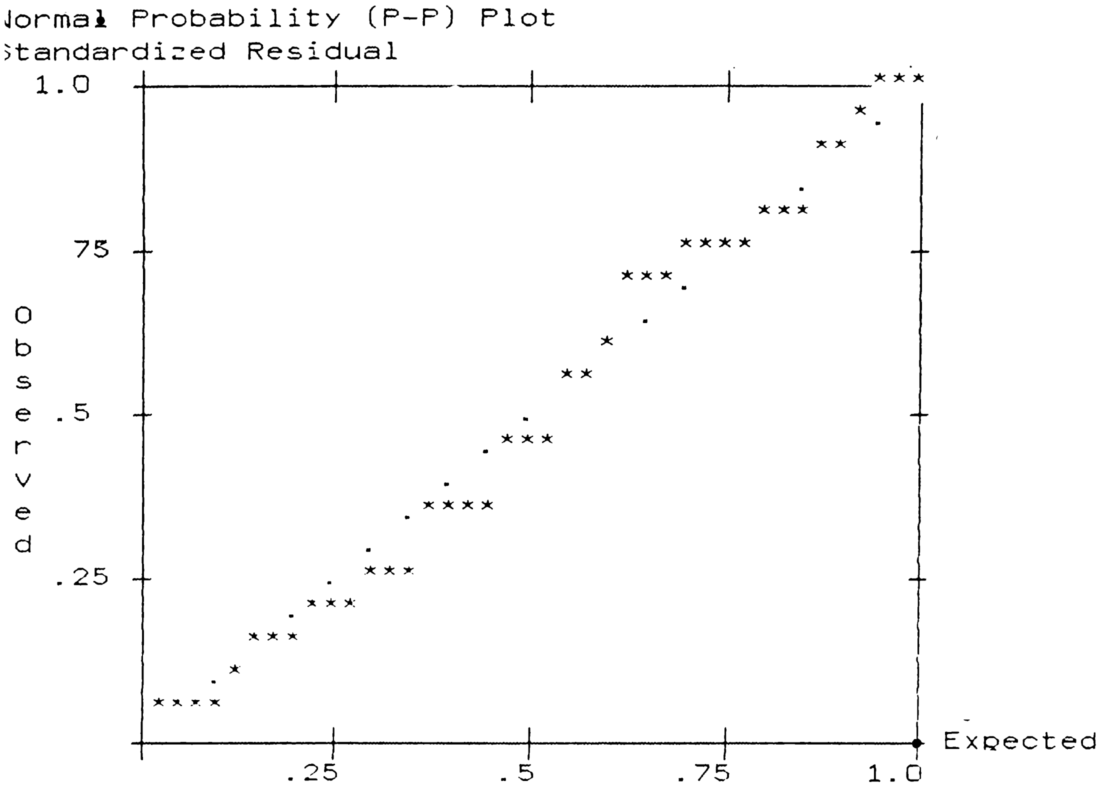
INDIA - YIELD

Estimated function is $\ln Y_t = a + bt + U_t$



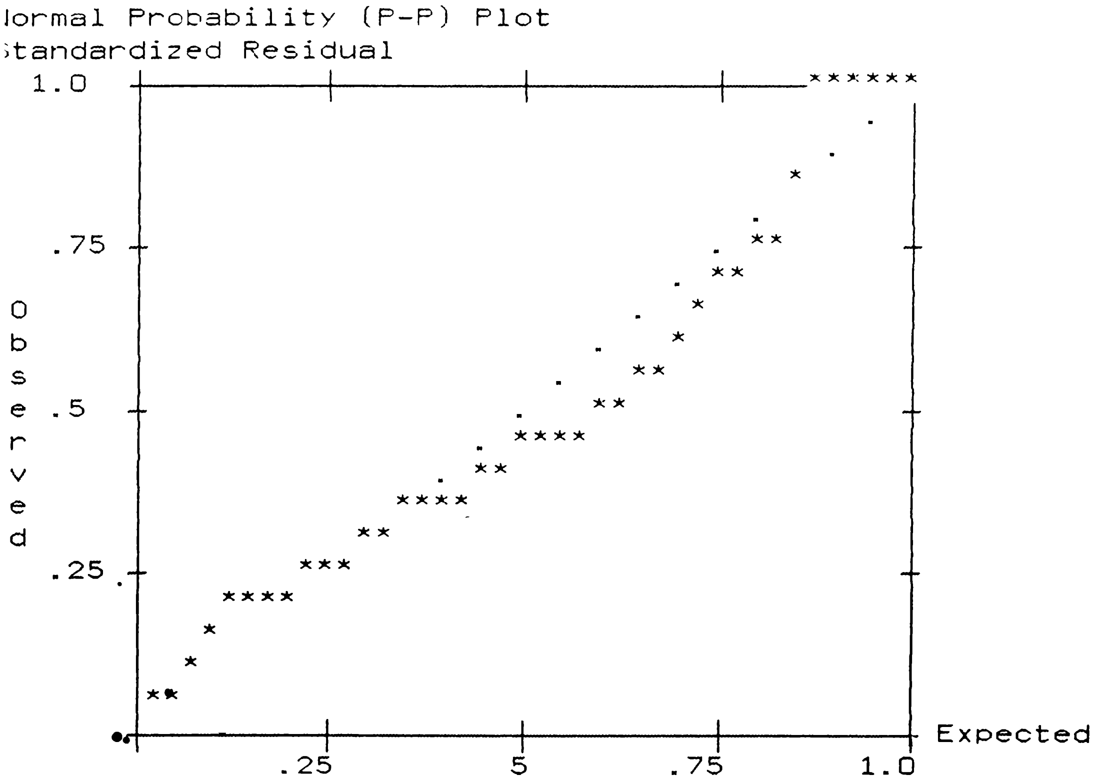
KERALA - AREA

Estimated function is $\ln Y_t = a + bt + + U_t$



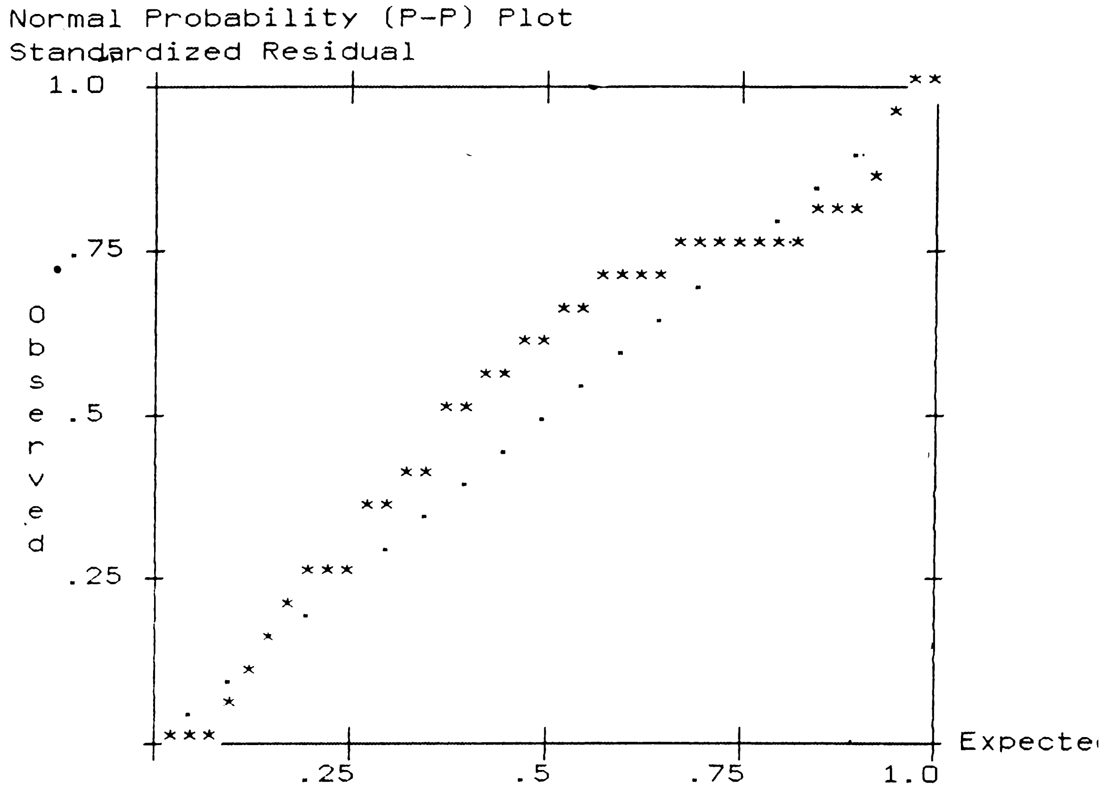
TAMILNADU - AREA

Estimated function is $\ln Y_t = a + bt + U_t$



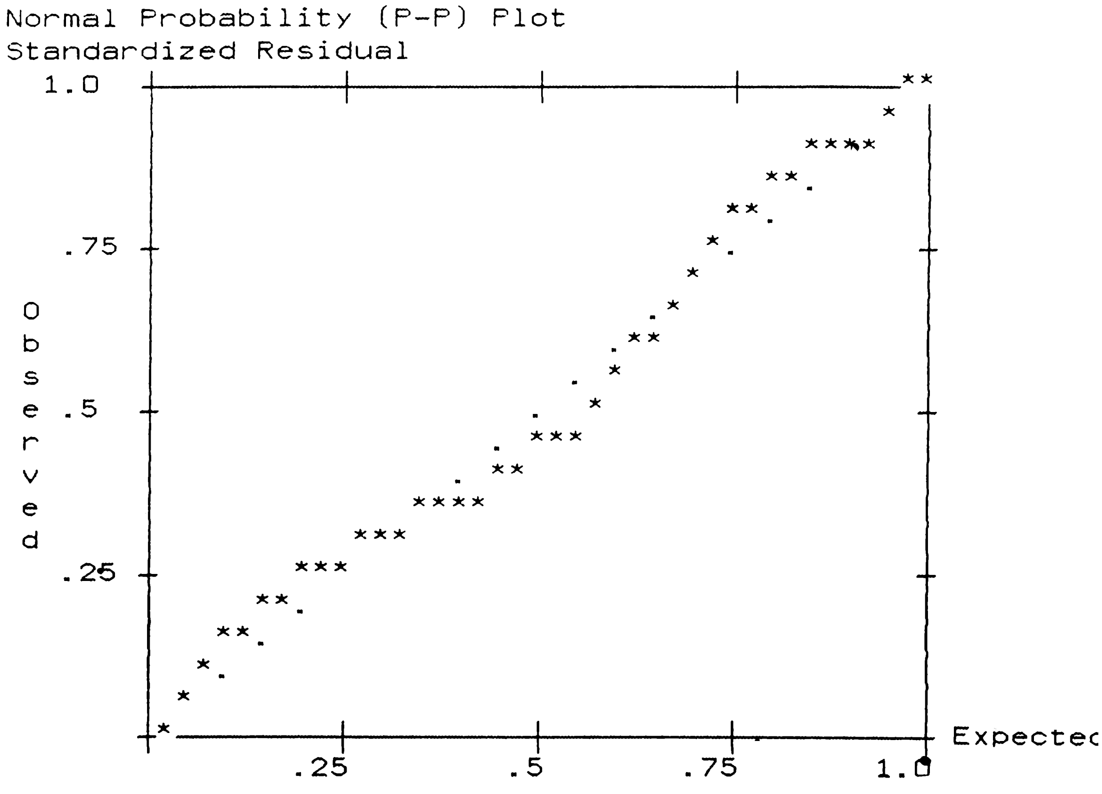
KARNATAKA - AREA

Estimated function is $\ln Y_t = a + bt + U_t$



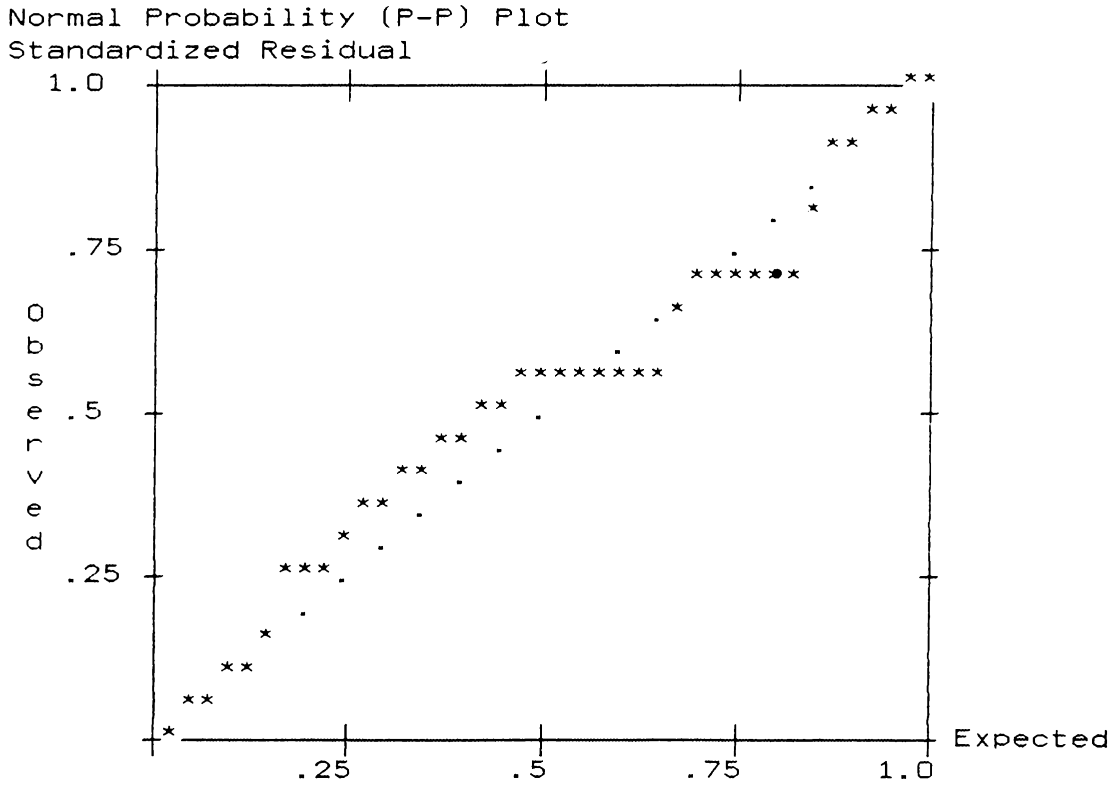
INDIA - AREA

Estimated function is $\ln Y_t = a + bt + U_t$



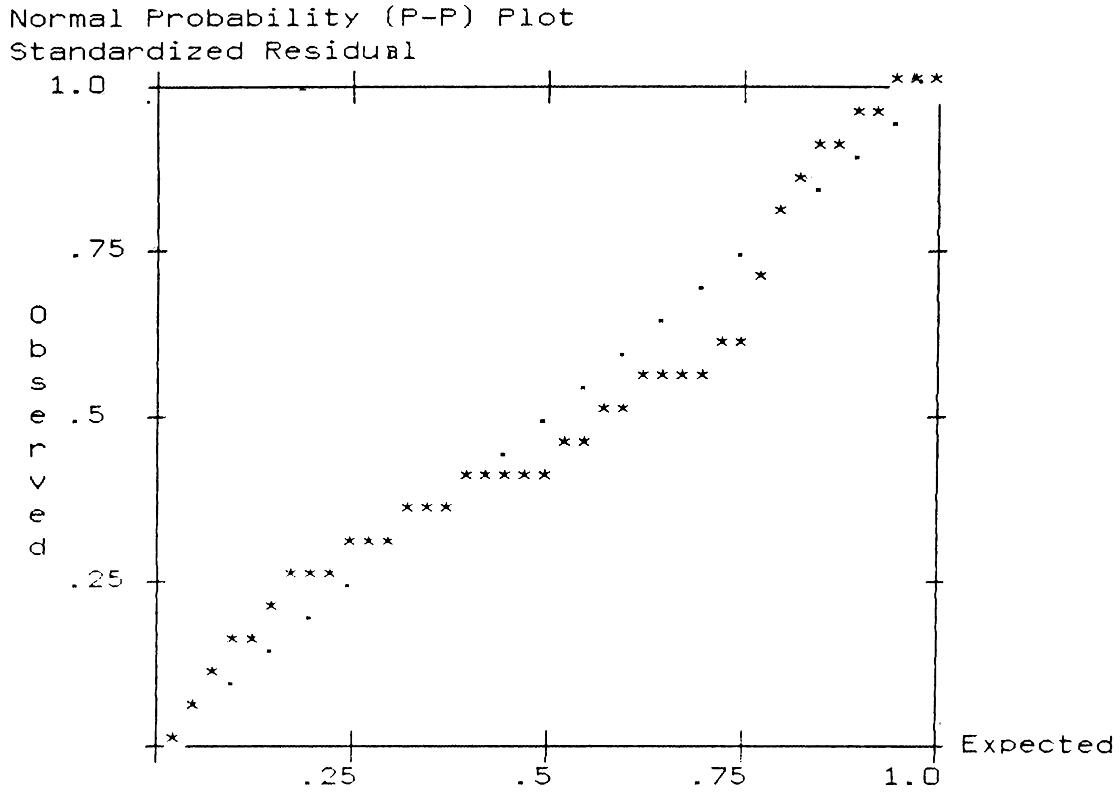
KERALA - PRODUCTION

Estimated function is $\ln Y_t = a + bt + ct^2 + U_t$



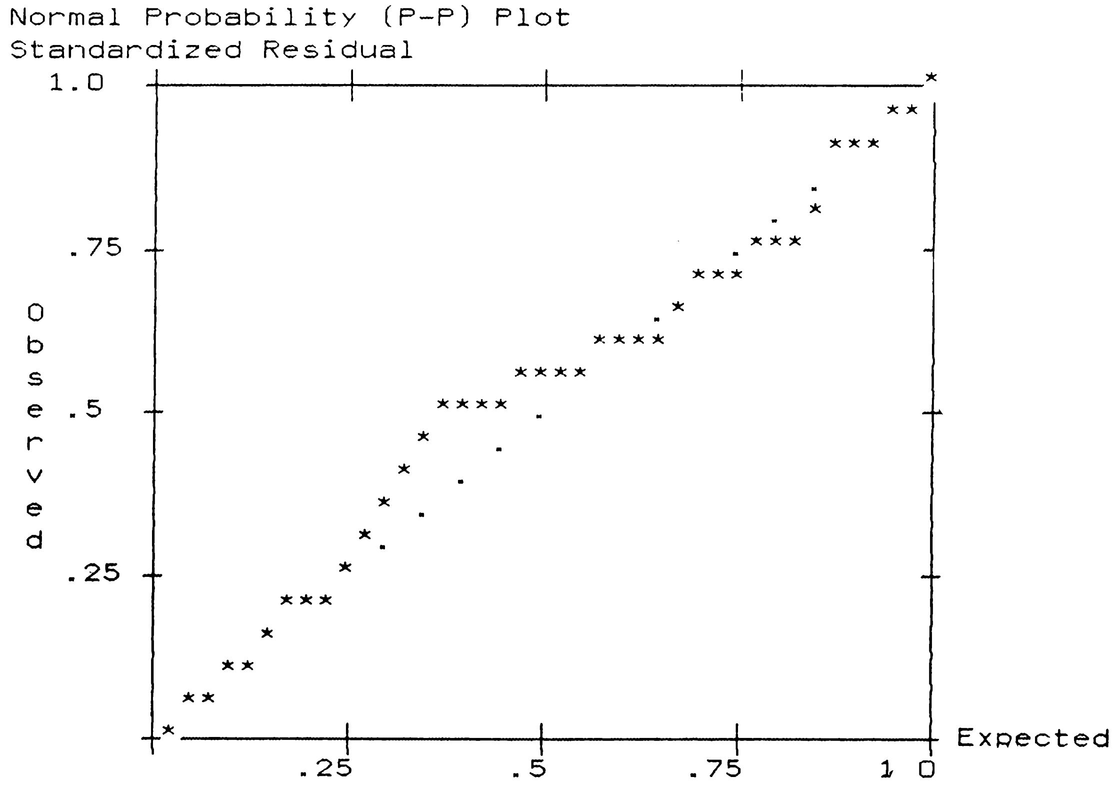
KERALA - TAPPABLE AREA

Estimated function is $\ln Y_t = a + bt + ct^2 + U_t$



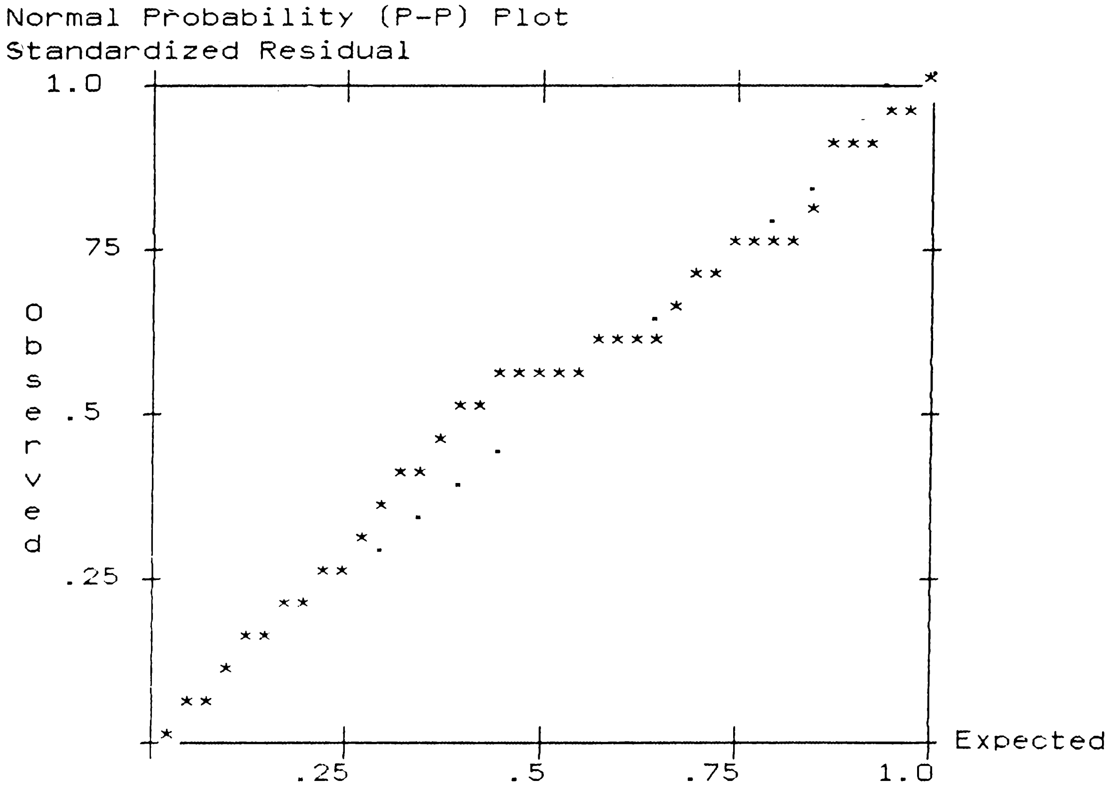
KERALA - YIELD

Estimated function is $\ln Y_t = a + bt + ct^2 + U_t$



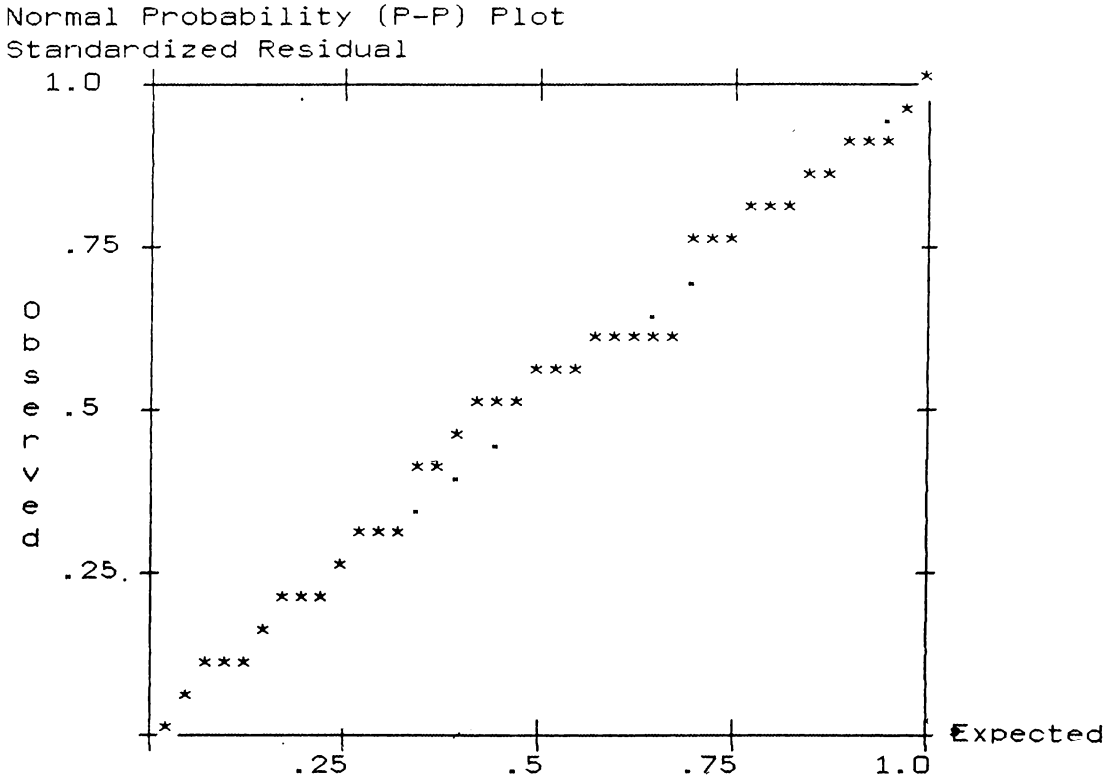
KERALA - YIELD

Estimated function is $\ln Y_t = a + bt + ct^2 + U_t$



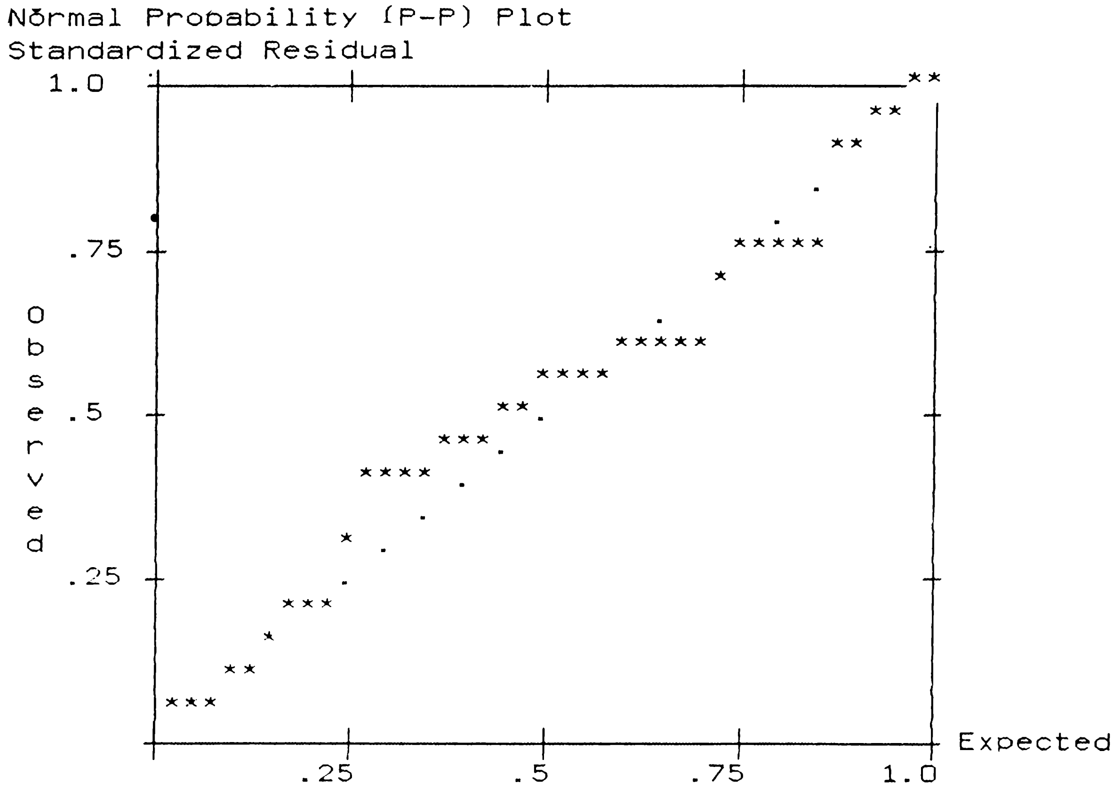
TAMILNADU - TAPPABLE AREA

Estimated function is $\ln Y_t = a + bt + ct^2 + U_t$



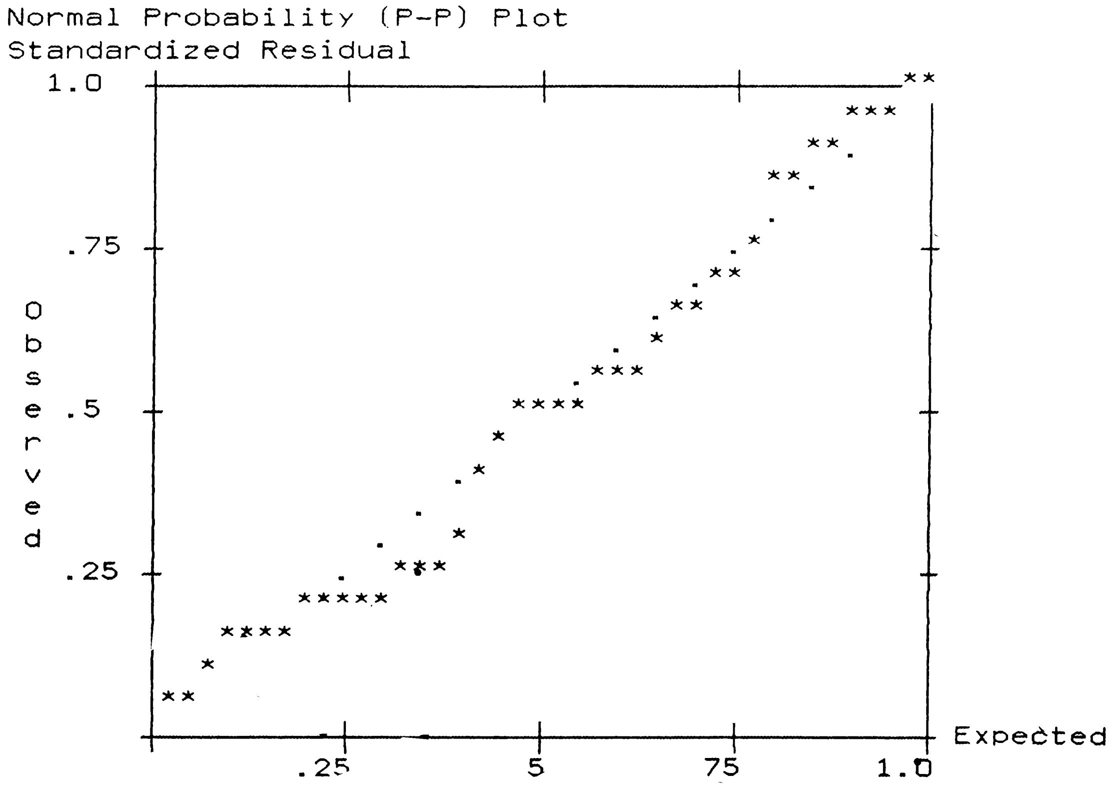
TAMILNADU - PRODUCTION

Estimated function is $\ln Y_t = a + bt + ct^2 + U_t$



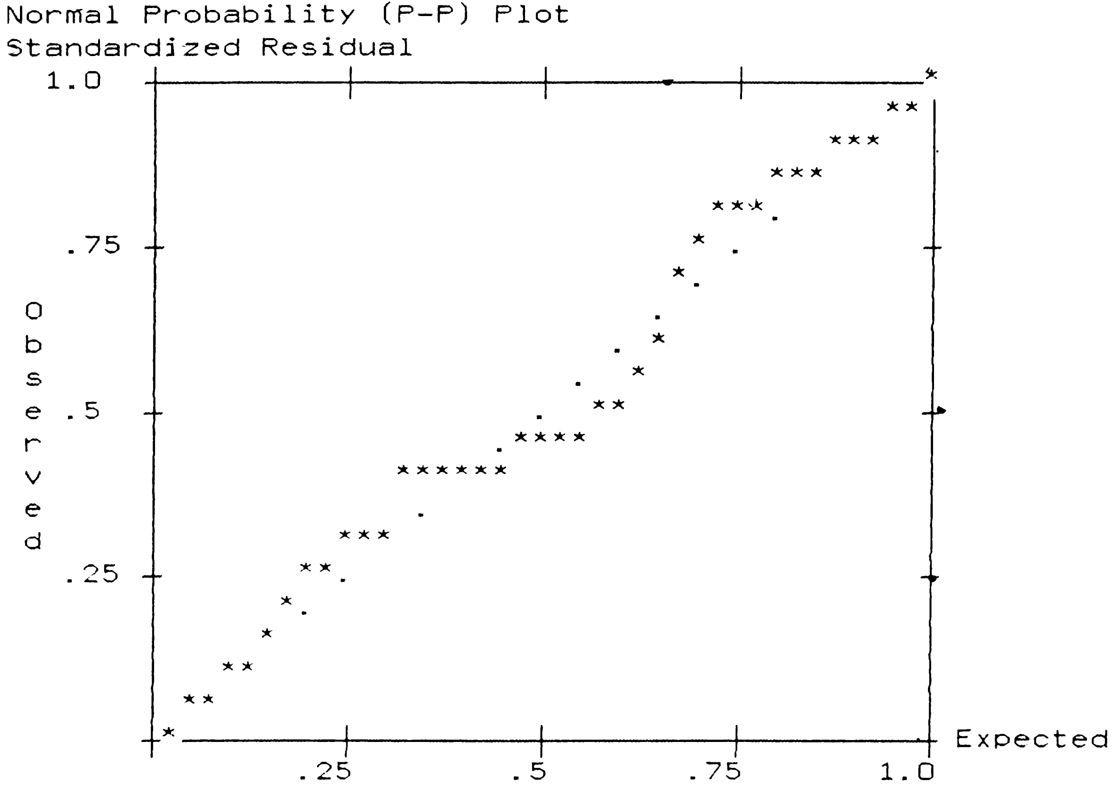
TAMILNADU - YIELD

Estimated function is $\ln Y_t = a + bt + ct^2 + U_t$



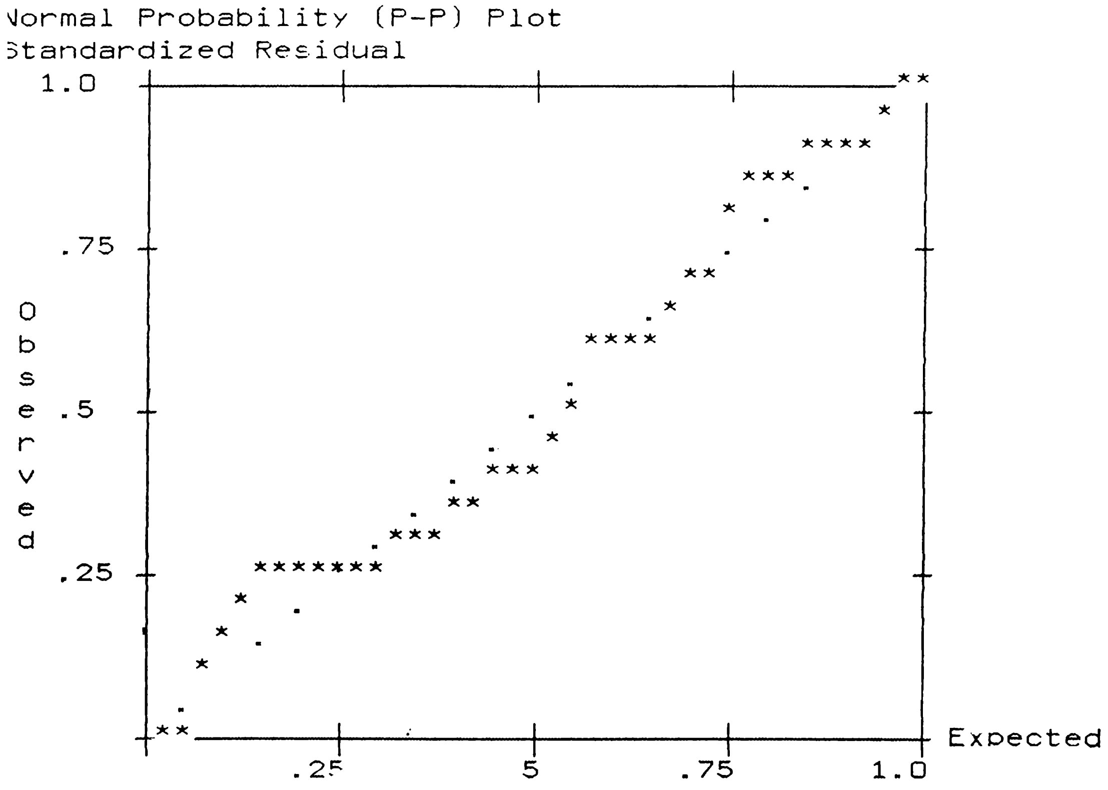
KARNATAKA - TAPPABLE AREA

Estimated function is $\ln Y_t = a + bt + ct^2 + U_t$



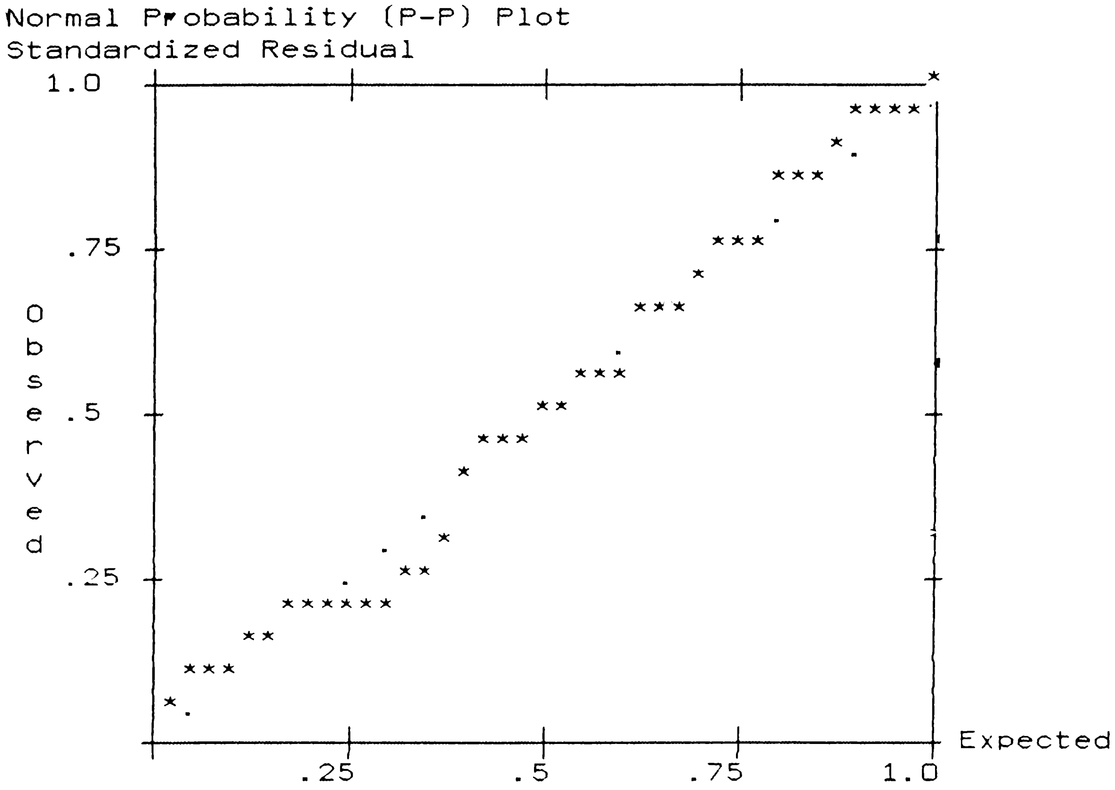
KARNATAKA - PRODUCTION

Estimated function is $\ln Y_t = a + bt + ct^2 + U_t$



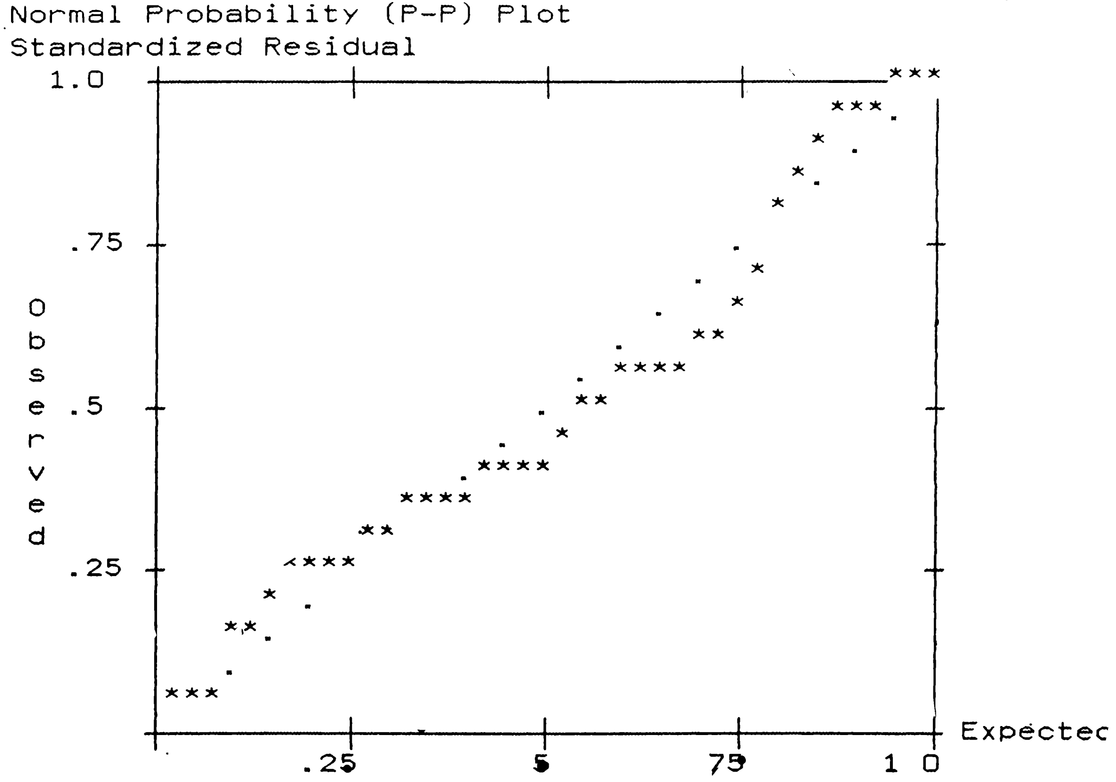
KARNATAKA - YIELD

Estimated function is $\ln Y_t = a + bt + ct^2 + U_t$

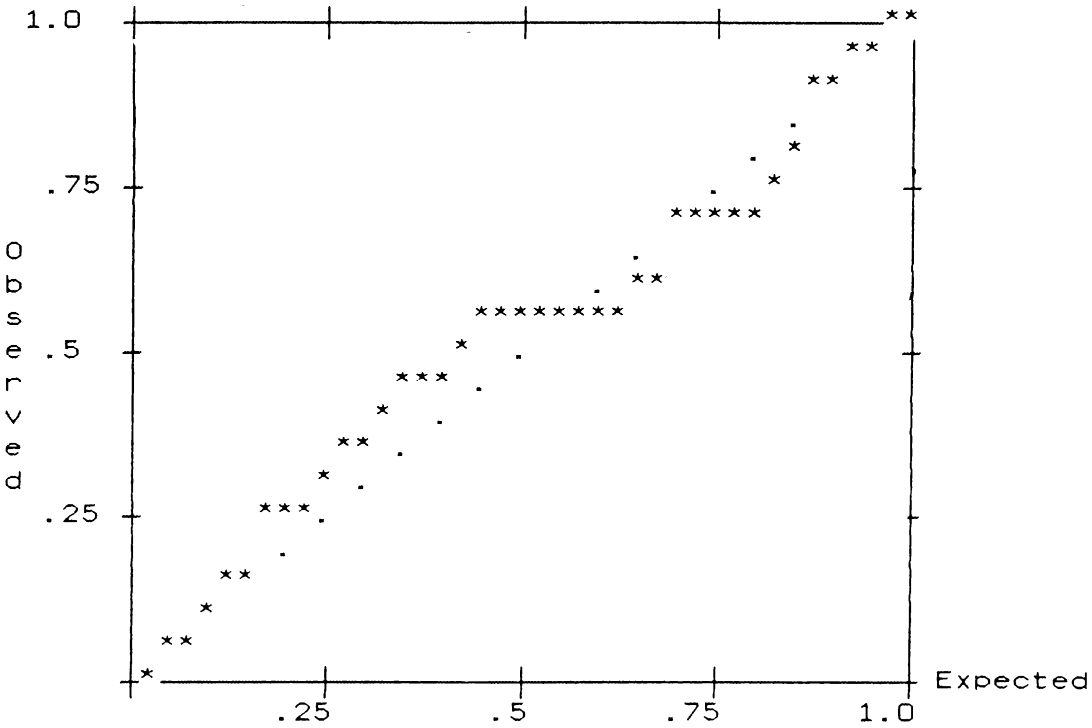


INDIA - TAPPABLE AREA

Estimated function is $\ln Y_t = a + bt + ct^2 + U_t$



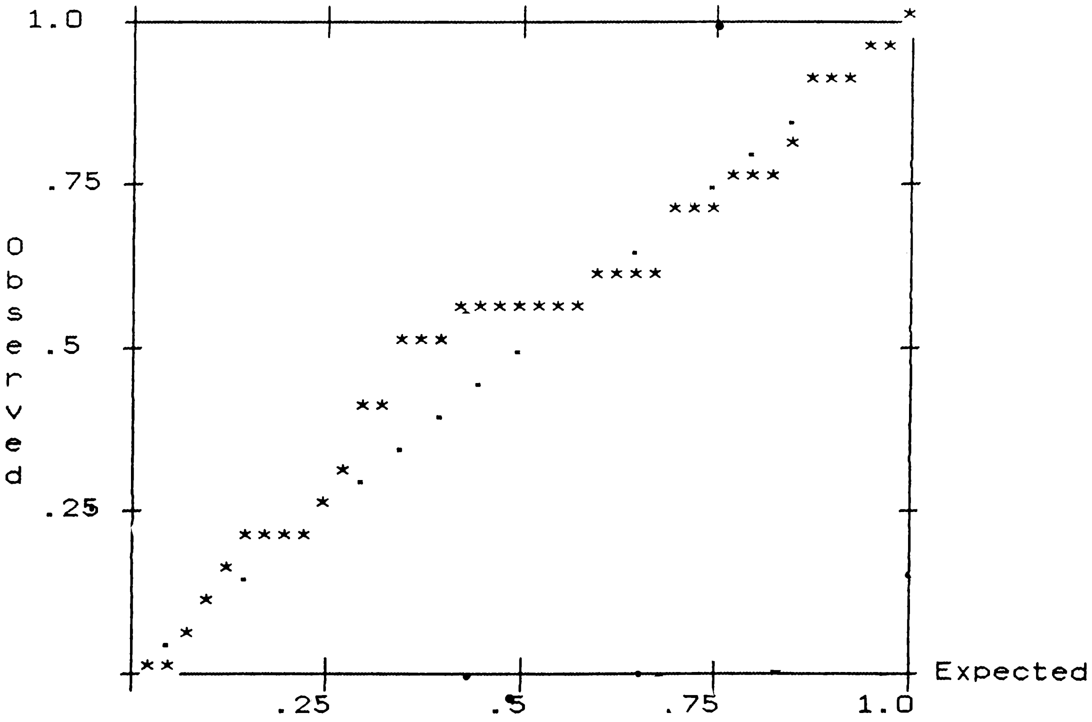
Estimated function is $\ln Y_t = a + bt + ct^2 + U_t$



Normal Probability (P-P) Plot
Standardized Residual

INDIA - YIELD

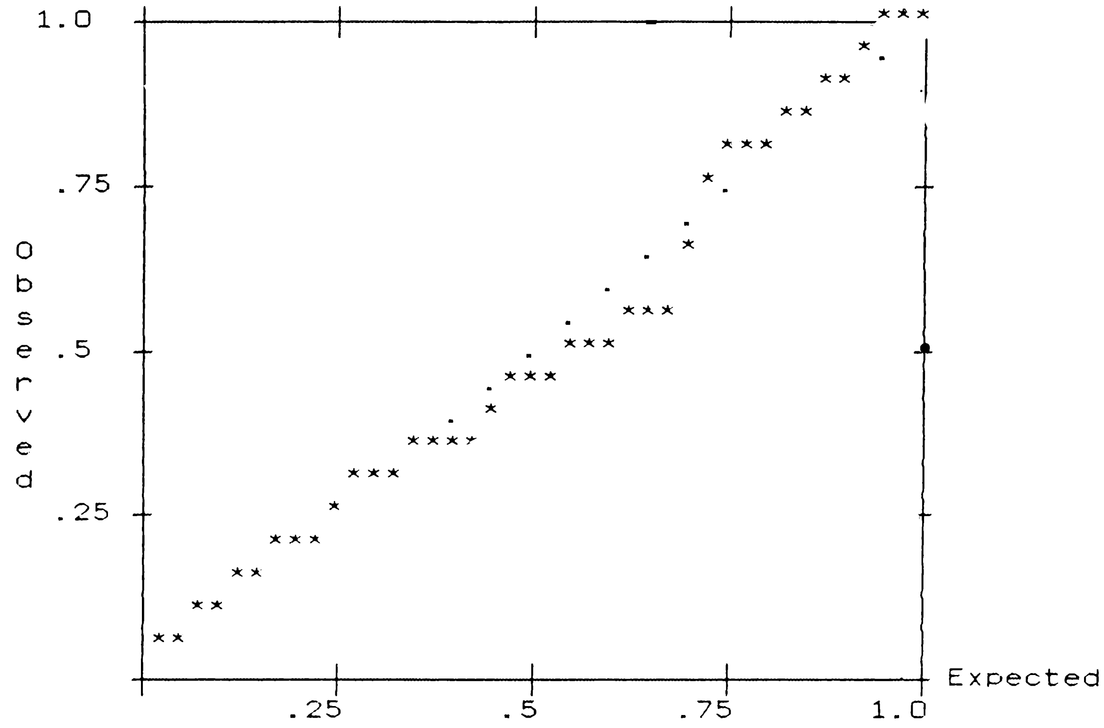
Estimated function is $\ln Y_t = a + bt + ct^2 + U_t$



Normal Probability (P-P) Plot
Standardized Residual

KERALA - AREA

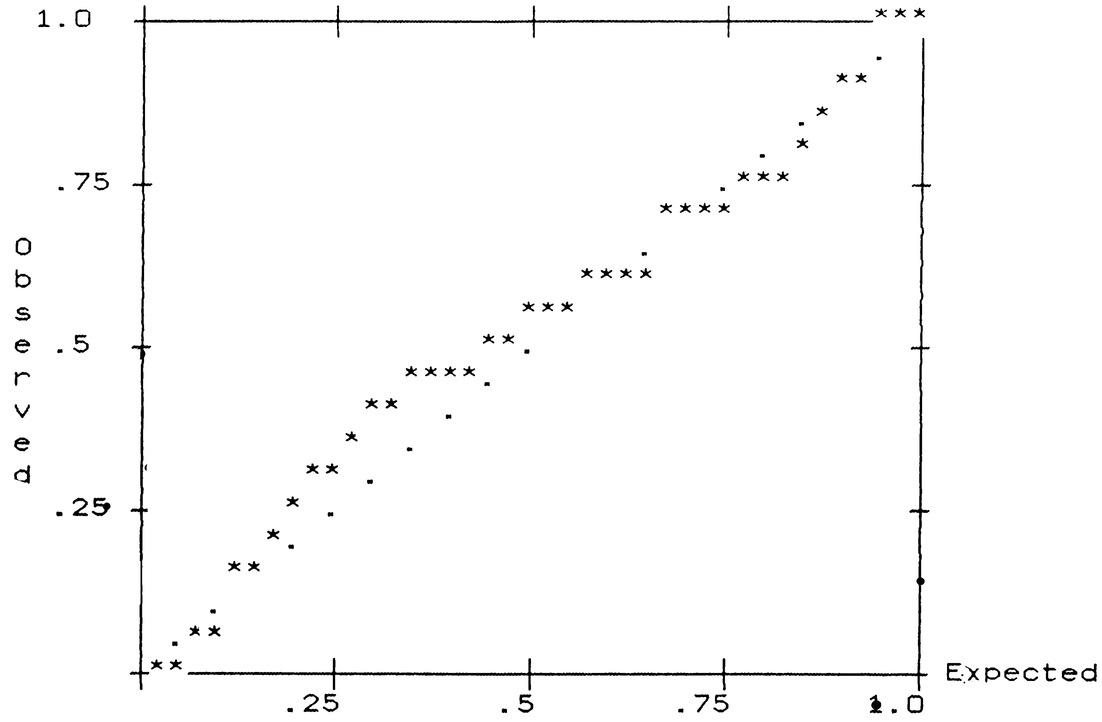
Estimated function is $\ln Y_t = a + bt + ct^2 + U_t$



Normal Probability (P-P) Plot
Standardized Residual

TAMILNADU - AREA

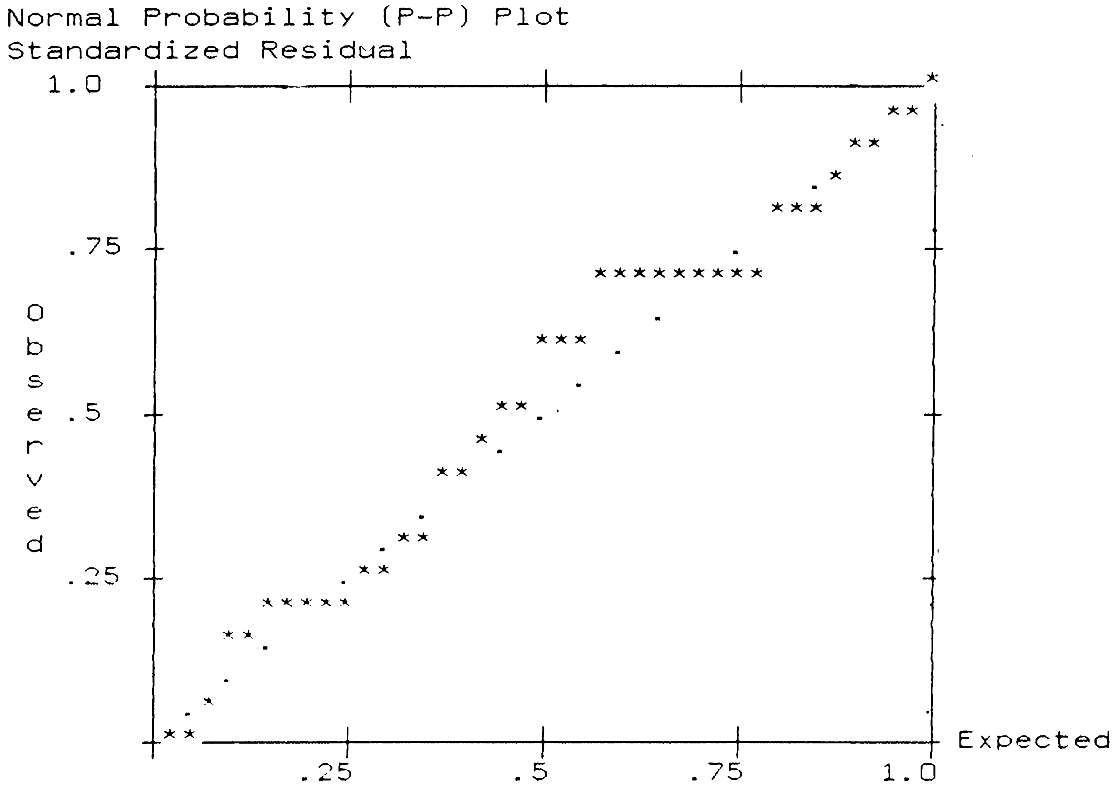
Estimated function is $\ln Y_t = a + bt + ct^2 + U_t$



Normal Probability (P-P) Plot
Standardized Residual

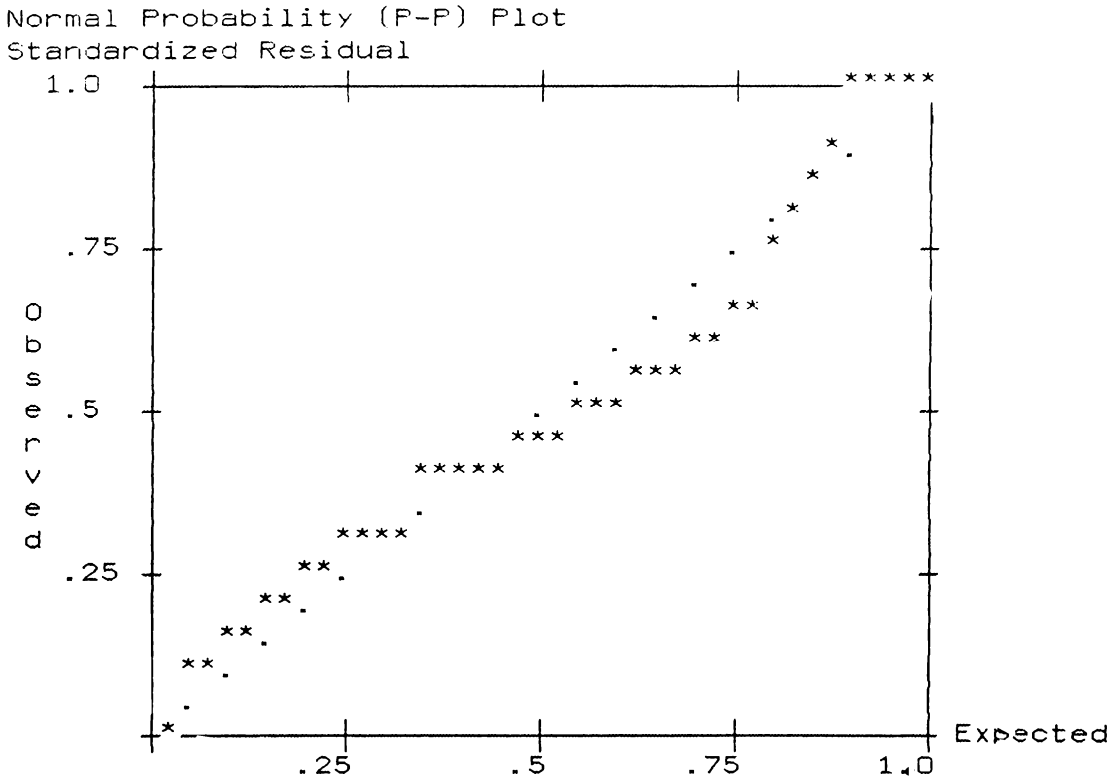
KARNATAKA - AREA

Estimated function is $\ln Y_t = a + bt + ct^2 + U_t$



INDIA - AREA

Estimated function is $\ln Y_t = a + bt + ct^2 + U_t$



BIBLIOGRAPHY

BIBLIOGRAPHY

BOOKS

Andreae Berna (1980), *The Economics of Tropical Agriculture*, Oxford & IBH Publishing Co., New Delhi.

Ashok Basu (1978), *Technological Possibilities of Indian Agriculture*, Firma KLM (P) Ltd., Calcutta.

Barlow, Colin (1978), *The Natural Rubber Industry, Its Development, Technology and Economy in Malaysia*, Oxford University Press, Kualalumpur.

Bepin Behari (1974), *Economic Growth and Technological change in India*, Vikas Publishing House (p) Ltd, Delhi.

Bhatty I.Z. (1978), *Technological change and Employment- A case study of Plantations*, The Macmillan Company of India Ltd., Delhi.

Burmeister, E. and Dobell, R (1970), Mathematical Theories of Economic Growth, Macmillan, London.

Daniel Green (1979), *A plantation Family*, The Bydell Press, Ipswich.

Domar, E.D.(1957), *Essays in the theory of Economic Growth*, Oxford University Press, New York.

Ghosh, H.H. (1928), *Realm of Rubber*, J.B. Daymond, Calcutta.

Goldar B.N. (1986), *Productivity Growth in Indian Industry*, Allied Publishers, New Delhi.

Gujarati, Damodar N. (1988), *Basic Econometrics*, Mc Graw-Hill Book Company, London.

Habibah Suleiman and Lim Sow Ching (1987), *Some Economic Aspects of Productivity in the in the Rubber Estate sector. Proceedings of Rubber Growers conference 1987*, Johore, Rubber Research Institute of Malaysia, Kualalumpur pp.349-359.

Harold Brown, (1918), *Rubber- Its Sources, Cultivation and Preparation*, John Murray, London.

Herbert Ashplant, (1927), Para Rubber, Department of Agriculture, Kampala

Hicks J R. (1963) The theory of Wages, Macmillan, London

Johnson Norman L. and Kotz, Samuel (1987), Distributions in Statistics : Continus Univariate Distribution -1, John Wiley & Sons Inc., New York.

Keizo Tsuchiya, (1976), Productivity and Technical Progress, in Japanese Agriculture, University of Tokyo Press. Tokyo

Krishnan Kutty, P.N. and Haridasan,V. (1976), Family budget of Rubber Plantation Workers in Kozhikode District, Rubber Board, Kottayam.

Lave Lester B. (1966), Technological change : Its conception and Measurement, Prentice-Hall, London.

Maddala G.S.(1977), Econometrics, Mc Graw - Hill Book Company, London.

Mansfield, E. (1968), The Economics of Technical Change,W.Norton, New York.

Mukhopadhyay A.K. and Rao Somasekhara V.B.R.S. (1980), Small Farms Resource Use and Technology - A Study in Maharashtra, National Institute of Rural Development, Hyderabad.

Nair, M.N.V. (1986), Natural Rubber marketing: Issues and Problems, UPSAI, Coonoor.

National Council for Applied Economic Research (1980), Ten Year Perspective Plan for Rubber 1980-81 to 1989-90, National Council for Applied Economic Research, New Delhi.

Nelson Richard R.(ed.) (1982), Government and Technical Progress- A Cross Indstry Analysis, Pergamon Press, New York.

Norris Keith and Vaizey John (1973), The Economics of Research and Technology, George Allen and Unwin Ltd., London.

Paul Stoneman, The Economic Analysis of Technological Changes, Oxford University Press, New York 1983.

Pillai, P.P. (1982), "Growth of Agricultural Output in Kerala During 1952-53 to 1978-79", in : Pillai P.P (Ed), Agricultural Developmnt in Kerala, Agricole Publishing Company, New Delhi

Pindyck, Robert. S. and Rubinfeld Daniel L. (1981) Econometric Models and Economic Forecasts, Mc Graw-Hill Book Company, London, pp. 473-484.

Rao C.H.H. (1975), Technological Change and Distribution of Gains in Indian Agriculture, Macmillan Co. Ltd, New Delhi

Reddy D.V. (1950), Marketing Organisation for Rubber, Indian Rubber Board, Kottayam.

Rod Coombs, Paolo Saviotti and Vivien Walsh (1987), Economics and Technological change, Macmillan Education Ltd, Hampshire.

Romesh Diwan and Renu Kallianpur (1986), Productivity and Technical Change in Foodgrain, Tata McGraw-Hill Publishing Company Ltd., New Delhi.

Rubber Board (1984), Hand Book of Natural rubber Production in India, Rubber Board, Kottayam.

Rutherberg, H. (1976), Farming Systems in the Tropics, Clarendon Press, Oxford.

Salter W.E.G (1966), Productivity and Technical Change, Cambridge University Press, London.

Sita Ram Singh(1986), Technological Parameters in Agricultural Production Function, Ashish Publishing House, New Delhi.

Smith H.P.(1982), The World Rubber Economy to the Year 2000. Vrije Universiteitte, Amsterdam.

Solow R.M (1960), "Investment and Technical Progress in Arrow,K.,Karlin S.and Suppes,P.(Eds.)Mathematical Methods in Social Sciences, Stanford University Press.

Speer, S.G. (1953) (ed.) UPASI 1893 - 1953, United Planters Association of South India, Coonoor.

Stevens, H.P. and Clayton Beadle (1915), Rubber-production and Utilisation of the Raw Product', Sir Isaac Pitman & Sons Ltd., London.

Tandon H.L.S (ed.) (1988), Fertilizer Management in Plantation Crops - A Guide Book, Fertilizer Management and Consultation Organisation, New Delhi.

Tan Suan, C (1984), World Rubber market Structure and Stabilisation - An Econometric Study, World Bank Staff Commodity Paper No.10, World Bank, Washington.

Umadevi, S. (1989), Plantation Economy of the Third World, Himalaya Publishing House, New Delhi.

UPASI (1989), Eighth Five-Year Plan for Plantations - A development Perspective, UPASI, Coonoor.

ARTICLES IN JOURNALS

Abalu G.I. (1975), "Optimal Investment Decisions in Perennial Crop Production. A Dynamic Linear Programming Approach", Journal of Agricultural Economics, Vol.36, No.3, pp.383-393.

Alshi M.R., Kumar.P and Mathew V.C. (1983), "Technological Change and Factor shares in Cotton Production : A Case Study of Akola Cotton Farms", Indian Journal of Agricultural Economics, July-September, Vol.38, No.3, pp. 407-415.

Ananth K.C. (1963), "A Note on the Trends of Manuring Mature Rubber", Rubber Board Bulletin, Vol.7, No.2 & 3, pp.64-66.

Asimakopulos A. and Weldon J.C. (1963), "The Classification of Technical Progress in Models of Economic growth", Economica, Vol.30, Nov.1963, pp.372 - 386.

Barlow C. and Peries O.S. (1977), "On Some Biases in the Generation of Technologies by Rubber Research Institutes", Journal of Rubber Research Institute of Malaysia, Vol.54, No.2, pp.445-459.

Bechman.M.J. and Sato R.(1968), "Neutral Inventions and Productio Functions", Review of Economics Studies, Vol.35, pp 57-66.

Bhaskaran Nair V.K.(1984), "Report of Survey Made in Vakathanam Village", Rubber Board Bulletin, Vol. 20, No.1, pp.16-21.

Boyce James K.(1986), "Kinked Exponential Models for Growth Rate Estimation", Oxford Bulletin of Economics and Statistics, Vol. 48, No.4, pp.385-391

Brown.C.P (1974), "International Commodity Controls Through National Bufferstocks : A case Study of Natural Rubber" Journal of Development Studies , Vol. 10, No.2, pp.188-212.

Chandrasiri G.R.et al. (1977), "The Specification and Estimation of a Production Function for Small holding Rubber in Srilanka" Journal of Rubber Research Institute of Srilanka, Vol.54, No.2 p.40.

Chandy K.M. (1975), "Industry Poised for a Big Leap Commerce, November 1, p.10.

Cherian P.P. (1988), "Rubber Yield and Brownbast Incidence", Planters Chronicle, February, p.1-2.

Chew .T.A (1984), Measuring the Rate of Technological Change in Chinese Rubber Small Holdiings -A Micro-Economic Approach, Journal of Rubber Research Institute of Malaysia, Vol.32, part.3, pp.191-197.

Clemhout S.(1968), "The class of Homothetic Isoquant Production Functions", Review of Economic Studies, Vol.35, No.1, pp 91104.

Dand Mohd Naji Bin (1983), "A Forecasting Methodology as Applied to Rubber Prices", Journal of RRIM, Vol.31, Part 3, pp.188-203.

Denision Edward F. (1964), "The Unimportance of the Embodied Question", The American Economic Review, Vol.LIV, No.2, pp.90-94.

Dharam Narain, (1977), "Growth and Productivity in Indian Agriculture", IJAE, Vol.XXXII, No.1, pp.1-44.

Dixon Robert (1980), Hybrid Corn Revisited, Econometrica, Vol.48, No.6, pp.1451-1461.

Domar E.D (1961), "On the Measurement of Technological Change", The Economic Journal, Vol. LXXl, No.284, pp.109-729.

Edward. N.C and Wood. B.J. (1987), "The Role of Research and Development in Plantation Profitability", The Planter, Vol. 63, pp.236-248.

Elsamma Job and Mukundan K. (1984), "Economics of Rubber Cultivation by Small Holders in Kottayam District", Indian Journal of Agricultural Economics, Vol.39, No.1, pp.99-106.

Ethrington D.M. and Jayasuriya S.K.W.(1977), "The Economics of Rubber Planting Cycles : An interpretive Essay", Journal of Rubber Research.. Institute of Srilanka, Vol.54, Part.1, No.2, pp. 460-477

Feder Gershon et al. (1990), "The Relationship Between Credit and Productivity in Chinese Agriculture : A Micro Economic Model of Disequillibrium", American Journal of Agricultural Vol.72, No.5, pp.1151-1160.

George J. (1985), Bovine Milk Production Estimate in India An Exercise in Decomposition, Agricultural Situation in India, Vol.40, No.1, pp.13-18.

Grilliches Zvi (1957), "Hybrid Corn: An Exploration in the Economics of Technological Change", Econometrica, Vol.25, pp.501-522.

Grilliches Zvi (1980), "Hybrid Corn Revisited: A Reply" Econometrica, Vol.48, No.6, pp.1463-1465.

Hall R.E (1968), "Technical Change and Capital from the Point of View of the Dual", Review of Economic Studies, Vol.XXXV, pp.35-46.

James Bonner (1977), "How can we Most Rapidly Increase the Production of Natural Rubber", Journal of Rubber Research Institute Srilanka, Vol.54, pp.259-262.

Jane Julia and Mchugh (1987), "The Role of Embodied Technological Change in the Decline of Labour Productivity", Southern Economic Journal, Vol 53, No.4, pp.915-924.

Jansen Han G.P, Walker Thomas and Randolph (1990), "Adoption Celings and Modern Coarse Cereal Cultivars in India", Indian Journal of Agricultural Economics, Vol.72, No.3, pp.653-663.

Jarris S. Larell (1981), "Predicting the Diffusion of Improved Pastures in Uruguay", American Journal of Agricultural Economics, Vol.63, No.3, pp.495-502.

Jayasuriya S.K.W. (1977), "Decision Making in Smallholding Rubber Attiludes to Replanting in Srilanka", Journal of Rubber Research Institute of Srilanka, Vol.54, No.2, pp.381-397.

Joseph John (1984), "Mechanical Weed Control Methods in Rubber Plantations", Rubber Board Bulletin, Vol.20, No.1, pp.22-23.

Kannan K.P. and Pushpangadhan K. (1988), "Agricultural Stagnation in Kerala — An Exploratory Analysis", Economic and Political Weekly, Vol.XXIII, No.39, pp.A.120-A.128.

Kempton R.A. and Talbot M (1988), "The Development of New Crop Varieties", Journal of Royal Statistical Society, Series A, Vol.151 part.1., pp.327-341.

Kennedy C. and Thrilwall A.P. (1972) "Surveys in Applied Economics-Technical Progress", *The Economic Journal*, March, pp.11-72

Krishnan Kutty P.N. and Sreenivasan K.G. (1984), "Evaluation of Planting Material under Commercial Planting -Second Report" *Rubber Board Bulletin*, Vol.20, No.2, pp.22-26.

Kuruvila V.O.(1984), "Drip Irrigation helps in Efficient use of Fertilisers", *Rubber Board Bulletin*, Vol.20, No.1,. pp.14-15

Lim Son Ching (1976), "Ethrel Stimulation - Constraints to the Transfer of Technology to Malaysian Rubber Small-holdings" *Malaysian Rubber Review*, Vol.2, No.1, pp.20-31.

Lingrad J. and Rayner A.J. (1975), "productivity Growth in Agriculture: A Measurement Framework", *Journal of Agricultural Economics*, Vol.36, No.1, pp.87-104.

Mandal, G.C.(1991), "Role of Aggregate Productivity in Farm Technologies in Economic Development", *Economic and Political Weekly*, Vol.26, No.52, pp.A-157-158.

Martin J, Murray (1992), "'White Gold' or 'White Blood ? The Rubber Plantation of Colonial Indo China, 1910-40, *Journal of Peasant Studies*, Vol.19, Nos.3,4.

Mc Hale.T.R (1964), "Changing Technology and Shifts in the Supply and Demand for Rubber: An Analytical History", *Malayan Economic Review*, Vol.9, No.2, pp.24-48.

Mettugh Richard and jane Julia (1983), The Embodiment Hypothesis : An Interregional Test, *The Review of Economics and Statistics* Vol.LXV, No.2, pp.323-327.

Mohammed Alauddin and Clem Tisdell (1986), "Decomposition Methods Agricultural Productivity, Growth and Technological Change: A Critique supported by Bangladeshi Data", *Oxford Bulletin of Economics and Statistics*, Vol.48, No.4, pp.353-372.

Mukundan menon, R. (1989), "Short Term Techniques for Boosting Rubber Productivity", *Ruuber Board Bulletin*, Vol.24, No.4, pp.3-4

Nair C.K.N. (1974), "Recent Developments in Rubber Research" *Rubber Planter's Conference Souvenir*, Rubber Board, Kottayam.

Narayana, D. and Nair K.N., (1988) "Trends in Area, Production and Productivity of Coconut in Kerala"' Indian Journal of Agricultural Economics, Vol.44, No.2, pp.159-167

Phelps Edmund S. (1962), "The New View of Investment: A Neoclassical Analysis", The Quarterly Journal of Economics, Vol. LXXVI, No.1, pp.548-567.

Radhakrishnan Pillai P. N.(1976), "Aerial Spraying Against Abnormal Leaf Fall Disease", Rubber Board Bulletin, Vol.13, No.3, pp. 116 - 118.

Rajasekharan P. and Haridasan V. (1927), Diffusion and Adoption of Innovations in Rubber Smallholdings, Indian Journal of Natural Rubber Research, Vol.5, No.142, pp.188-194.

Rao C.H.H. (1989), "Technological Changes in Indian Agriculture-Emerging Trends and Perspectives", Indian Journal of Agricultural Economics, Vol.44, No.4, pp.385-398

Sekhar B.C. (1977), "Natural Rubber - Plans for the Future", Journal of Rubber Research Institute of Srilanka, Vol.54, No.2, pp.306-315.

Selvaratnam, V. (1988), "A Theoretical Perspective in the Study of Plantation Systems; Malaysian Case" Economic and Political Weekly, Vol.23, No.21.

Sen S.R. (1967) "Growth and Instability in Indian Agriculture" Agricultural Situation in India, Vol.21, No.10.

Sidhu D.S. and Derk Byerlee (1991), "Technical Change and Wheat Productivity in Post - Green Revolution Punjab" Economic and Political Weekly, Vol.26, No.52, pp.A-159-A-166.

Solow R.M. (1957), "Technical Change and the Aggregate Production Function", Review of Economics and Statistics, Vol. No.pp.312-320

Sudarsanan Pillai, P. (1989). "Management of Rubber Plantation in India : An Overview", Indian Manager, Vol.XIX, No.2, pp.55-56.

Suleiman Habibah and Lim Ching (1988), "Some Economic Aspects of Productivity in the Rubber Estate Sector", Proceedings of: RRIM Rubber Growers Conference 1987, RRIM, Kuala Lumpur.

Sunil Mani (1984), "Price Movements for an Agricultural Raw Material with Inventory Adjustment :Case of Indian Natural Rubber Market in 1970's", Economic and Political Weekly Vol.19, No.51-52

Chew T.A. (1984), "Measuring the Rate of Technological Change in Chinese Rubber Small holdings - A Micro-economic Approach", Journal of Rubber Research Institute of Malaysia, Vo.32, Part 3, pp.191-197.

Tharian George K., Tomy Joseph and Toms Joseph (1988) "Evaluation of the yield Performance of Selected Rubber Planting Materials in the context of the Planting Policy", Indian Journal of Natural Rubber Research, Vol.1, pp.66-78.

Tharian George, K. Haridasan, V., and Sreekumar, B. (1988), "Role of Government and structural Change in Rubber Plantation Industry", Economic and Political Weekly, Vol.23, No.26, pp.MI58-MI68, November 26.

Toms Joseph, Haridasan, V. and Joy Cyriac (1989), "Economics of RAinguarding - A Comparative Analysis", Indian Journal of Natural Rubber Research, Vol.2 No.2, pp.125-130.

Uzawa. H, (1961)," Neutral Inventions and the Stability of Growth Equilibrium", Review of Economic Studies, Vol.28, pp.117-124.

Vaidyanadthan K.E. (1961), "Indias of Yield in Agriculture", The Indian Journal of Agricultural Economics", Vol. 16, No.2, pp.51-56

Varma. K.S (1983), "Economics of Rubber Plantation and Scope for Cost Reduction", Rubber Board Bulletin, Vol.18, No.4, pp.21-24.

Viju Ipe C. and Prabhakaran T. (1988), Price Response of a Perennial Crop : A Case of Indian Natural rubber, Indian Journal of Agricultural Economics, Vol.43, No.4, pp.624-630.

Yee, Y.L. (1983), Effect of Yield Stimulation on Profitability and Rubber Production Hyper-Surface in the Estate Sector", Journal of Rubber Research Institute of Malaysia, Vol.31, No.1, pp.5-26.

Yee Y.L. Longworth, J.W. and Strong, S.M. (1983), "Impact of Technological Changes on Input Demand and Cost functions in the Malaysian Rubber Industry", Journal of Rubber Research Institute of Malaysia Vol.31, No.2, pp.71-87.

UNPUBLISHED RESEARCH WORKS

Bhattacharya A (1976), Some Aspects of the Rubber Economy in Kerala, M.Phil Dissertation, Jawaharlal Nehru University, New Delhi

Ciciliyamma Thomas (1984), An Economic Analysis of Rubber cultivation in Kerala, M.Phil Thesis, Department of Economics, University of Kerala, Trivandrum.

Umadevi, S. (1984), The Impact of Plantations of Kerala's Economy with special Reference to Rubber: Some Historical and Quantitative Aspects, Ph.D Thesis, Department of Economics University of Kerala, Trivandrum.

George, P.S. and Chandan Mukherjee (1986), Rice Economy of Kerala: A Disaggregate Analysis of Performance", Working Paper 213, Centre for Development Studies, Trivandrum.

Haridasan. V. (1979), An Enquiry into the Management Practices followed in Rubber Estates in India, Ph.D Thesis, Cochin University of Science and Technology.

Harley, Michael J., Marc Nerlove, R. Kyle Peter Jr. (1984). The Supply Response for Rubber in Sri Lanka, World Bank Staff Working Paper No. 657, World Bank, Washington, U.S.A.

James, P.J. (1985), Role of subsidies in Rubber Cultivation in Kerala, M.Phil Thesis, Department of Applied Economics, Cochin University of Science and Technology.

Jose Thomas (1979), The Economics of Rubber Plantation Industry in Kerala, Ph.D. Thesis, School of Management Studies, Cochin University of Science and Technology.

Joseph Kochukudi, D. (1990), The Performance of Rubber Cultivation in Kerala, M.Phil Dissertation, CUSAT, Cochin.

Michael, T.T. (1989) The Economics of Rubber Cultivarion with reference to Small Holders, M.Phil Dissertation, CUSAT, Cochin.

Narayanan P.K. (1991), Rubber Pproducers Societies : Agencies of Change, Paper presented at the National Rubber Conference organised by Indian Rubber Growers Association, Cochin.

Pillai P.P. (1977), Variability in Agricultural Production in Kerala and Factors Contributing to it, Paper Presented at the 17th Indian Econometric Conference, Trivandrum.

Raju, K.V. (1988) The Economics of Rubber-Based Industry in Kerala - An analysis of Kottayam District, M.Phil. Thesis, Department of Applied Economics, Cochin University of Science and Technology Cochin.

Sunil Mani (1983), An Analysis of the Indian Natural Rubber Market, M.Phil Thesis, Jawaharlal Nehru University, New Delhi.

Sunny George (1991), Paper Industry in Kerala, An Evaluation of Labour Absorption, Capacity Utilisation and Environmental Pollution, Ph.D. Thesis, Cochin University of Science and Technology, Cochin.

Tan, Suan C. (1984) World Rubber Market Structure and Stabilisation ; An Econometric Study, World bank Staff Commodity Working Paper no.10, World Bank, Washington, U.S.A.

REPORTS AND OTHER PUBLICATIONS

Abdullah T.M. (1968), Report of the Rubber Small Holdings Economics Enquiry Committee (1968), Rubber Board, Kottayam.

Madhava Menon, P. (1956), Report of the Plantation Inquiry Commission Part III, Rubber, Manager of Publications, Government of India, New Delhi.

Rama Varma (1963), Report of the Delegation to Malaya, Rubber Board, Kottayam.

Sudarsanan Pillai, P. (1993), A Study of the Management Practices in Rubber Plantation Industry in India, Research Project Sponsored by Indian Council of Social Science Research, School of Management Studies, Cochin University of Science and Technology, Cochin.

Unny, R.G. and Geroge Jacob (1972), Rubber Small holdings in India - Report of the Sample Survey 1969-70, Rubber Board, Kottayam

UPSAI (1962), Replies to the questionnaire and Memorandom Submitted to the Central Wage Board for Rubber Plantation Industry, UPSAI, Coonoor.

UPASI (1987) UPASI Presentation at the National Conference on Rubber Productivity and DEvelopment, Bangalore.