

AN ALMON DISTRIBUTED-LAG MODEL OF TRANSPORT INVESTMENTS
AND AGRICULTURAL DEVELOPMENT IN LIBERIA, 1950-1980

by

SAMUEL MINTZ

M.A., University of the District of Columbia
(1971)

M.C.P., Massachusetts Institute of Technology
(1979)

Submitted to the Department of Urban Studies
and Planning in Partial Fulfillment of the
Requirements of the
Degree of

DOCTOR OF PHILOSOPHY

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

June 1985

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Department of Urban Studies and Planning
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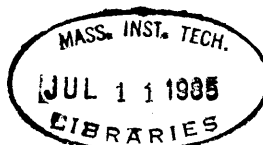
Thesis Supervisor

Certified by: _____

Thesis Supervisor

Accepted by: _____

Chairman, Departmental Committee



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ABSTRACT

This study examines the economic impacts of improved transportation infrastructure on agricultural production and factor inputs. The study is a country-study of transport and agricultural development in Liberia from 1950 to 1980.

The method of inquiry offers an alternative for predicting the economic consequences of transport investment policies to the widely-used transport-demand approach that has found common acceptance in the last twenty-five years. The present study sets forth a behavior methodology that is production-oriented. Unlike the transport-demand approach which is concerned with estimating net reductions in transport costs, this producer-surplus approach focuses on estimating changes in production and other economic consequences, such as those on employment and land cultivation, as transport conditions improve.

This study proposes three empirical models for estimating the economic impacts of transport improvements. The models are econometric and examine the relationship between transport improvements and additions to the production of such perennial tree crops as rubber, coffee, cocoa, and palm kernels. The first model relates an Almon polynomial distributed-lag function of transport investments and producer prices to agricultural production. The second model relates transport accessibility and producer prices to agricultural production. The third model assesses the disaggregated effects of improved transport accessibility on agricultural employment and land cultivation.

The models provide a broader policy analysis framework and more consistent estimates of transport investments impacts than earlier empirical studies. The empirical findings indicate that an Almon distributed-lag model of transport investments provides consistent estimates of how the economic effects are distributed over time as producers respond to economic incentives. The model also offers insights into the magnitudes of the short-run and long-run supply elasticities of producers across crops.

The study found that a statistically significant relationship exists between primary crop production and transport accessibility with producer prices when additional transport capacity is added and when producer prices change. Additional evidence was found to show that the disaggregated effects of improved transport access on cultivated land and agricultural employment were statistically significant.

This study demonstrates empirically that the production-oriented producer-surplus approach provides a framework for public decision-makers to consider broader economic development impacts than other approaches when formulating transport investment policies.

Thesis Supervisors: Karen R. Polenske
Professor of Regional Political Economy
and Planning
Ralph Gakenheimer
Professor of Urban Studies and Planning,
and Civil Engineering

ACKNOWLEDGMENTS

The completion of this dissertation was made possible by many people at M.I.T. and elsewhere. First, I would like to thank my dissertation committee: Karen R. Polenske, Ralph Gakenheimer and Alan Strout for their continuous encouragement, intellectual stimulation, guidance, and support.

As co-chairperson of my dissertation committee and principal academic advisor during my years in the Ph.D. program, Professor Polenske's help has been invaluable. It was Professor Polenske who encouraged me to pursue doctoral studies and she gave me strong support throughout my stay at M.I.T. She provided me with the opportunity to gain both graduate teaching and research experience. Professor Polenske devoted a great deal of her time advising me during various stages of the research and suggesting improvements to earlier drafts. At later stages, she made herself available to assist me when tremendous demands were placed on her time. For this, she has my sincerest gratitude.

Professor Ralph Gakenheimer, as co-chairperson of my committee, has made valuable comments and suggestions beginning as far back as when I first expressed interest in pursuing this thesis topic. His keen insights and suggestions for improvements to the models served to focus the research on the critical issues of study. I am extremely grateful for his encouragement and support during the development of this study.

I am also grateful to Professor Alan Strout who devoted considerable time to working through the empirical results and making useful suggestions. I am especially thankful for his availability during critical periods of this research.

I would also like to thank Boris Pleskovic for his useful comments and advice on earlier drafts of this thesis. I am indebted to Young G. Kwon who provided me with computer assistance when his own research demanded attention. I would like to acknowledge the financial support of Dean John Turner of M.I.T. who provided me with an Institute Fellowship during my first year in the Ph.D. Program and for a scholarship which enabled me to complete this study. I would also like to thank Rolf Engler of M.I.T. who made a grant available to me to carry out the empirical research.

Let me take this opportunity to extend special thanks to Mr. and Mrs. Henry A. Roche who provided me with assistance, encouragement and moral support during some of the most difficult periods of this study. Special acknowledgments are due to E. Anthony Mackall for his fraternal relationship and moral support.

I would like to make special mention of my family. It would have been extremely difficult to complete this study were it not for the encouragement and moral support from my family, particularly my mother. My mother finally can see another of her seven children complete a stage of his education of which she can be proud forever. My two brothers and four sisters also had enormous confidence in me and my ability to complete these studies and I am thankful for their support.

Lastly, but certainly not least, I am eternally grateful to Jaysun Roche for her continuous encouragement, understanding, and assistance during the various stages of this study. She underwent enormous personal sacrifices to assist me. In preparing this dissertation, she provided me with computer assistance; made suggestions and comments; and typed various drafts. If there is anyone to whom I should credit with enabling me to finish this study on time, it is she. For this, I owe her an incalculable debt.

This dissertation is dedicated to my mother for all that she has given me and to Nelson and Winnie Mandela, the heart and soul of the revolution for social progress in South Africa.

TABLE OF CONTENTS

	Page
Abstract	ii
Acknowledgments	iv
Dedication	vi
Table of Contents	vii
List of Tables	xi
List of Figures	xii
 Chapter	
I. INTRODUCTION	1
Empirical Studies of Transport and Development	5
Limitations of Transport-Development Studies	8
Suggestions for Improving Transport and Development Studies	11
Outline of the Study	12
 II. LITERATURE REVIEW	15
PART I. INTRODUCTION	15
Theory of Transport and Development	16
PART II. ANALYTICAL FRAMEWORK FOR TRANSPORT AND DEVELOPMENT	19
The Transport-Demand Approach	20
The Producer-Surplus Approach	25
PART III. ANALYTICAL METHODS FOR TRANSPORT AND DEVELOPMENT RESEARCH	32
Social Cost-Benefit Analysis	32
Linear Programming	37
Input-Output Models	42
Simulation Models	46
Econometric Models	50
PART IV. EMPIRICAL FINDINGS OF ECONOMETRIC MODELS	53
 SUMMARY AND CONCLUSIONS	57

	Page
III. A MODEL OF TRANSPORT AND AGRICULTURAL DEVELOPMENT	61
PART I. INTRODUCTION	61
Liang's Models of Transport and Development	64
PART II. A MODEL OF TRANSPORT AND AGRICULTURAL DEVELOPMENT	68
Basic Organization of the Transport-Investment Model	71
Hypothesis of the Model	75
Assumptions of the Transport-Investment Model	77
Testing of Significant Relationships	78
Distributed Lags and Transport Investments	79
The Transport-Accessibility Model	83
The Factor-Input Model	86
SUMMARY	88
IV. TRANSPORTATION, AGRICULTURE AND THE ECONOMY: AN OVERVIEW	93
PART I. INTRODUCTION	93
Background	95
Geography	95
People	95
Political Economy	98
Political History	100
The Structure of the Liberian Economy	102
The Monetary Economy	105
The Traditional Economy	108
Sectoral Growth Patterns	110
Mining	111
Agriculture	115
PART II. THE TRANSPORT SECTOR	117
The Road Network	120
Transport Investment Policy	124
Road Financing and Transport Investments	127
Vehicle Registration	131
Petroleum Products Consumption	133
Road-User Taxes	133
Railroads and Rail Transport	137
Ports and Shipping	137
Airlines and Air Transport	140
PART III. THE AGRICULTURAL SECTOR	144
Commercial Estate Agriculture	145
Rubber	145
Cash Crop Mix and Production Volumes	149
Coffee	149
Cocoa	150
Palm Kernels	150

	Page
Agricultural Employment	152
Land Cultivation	154
SUMMARY	157
V. EMPIRICAL APPLICATIONS AND ESTIMATED RESULTS	160
PART I. INTRODUCTION	160
Description of the Variables and Data Used in the Study	161
Agricultural Production	161
Producer Prices	163
Transport Investment	163
Transport Accessibility	164
Cultivated Land	164
Agricultural Employment	164
The Transport-Investment Model with a Distributed Lag	164
Procedures and Applications	165
Criteria for Selecting the Best Distributed- Lag Model	165
Preliminary Results and Empirical Irregularities	166
Empirical Results of the Distributed-Lag Models	168
Output Supply Responses	170
Price Elasticities	172
Interpretations of the Empirical Results	174
PART II. THE TRANSPORT-ACCESSIBILITY MODEL: ESTIMATED RESULTS	176
Hypothesis Testing on Ordinary Least Squares Estimates	177
Interpretations of the Estimated Results	180
PART III. THE FACTOR-INPUT MODEL: ESTIMATED RESULTS FOR RUBBER INPUTS	182
Agricultural Employment	183
Cultivated Land	186
SUMMARY	187
VI. SUMMARY, CONCLUSIONS AND POLICY IMPLICATIONS	191
Policy Implications	196
Transport Investment Policy Implications	197
Agricultural Policy Implications	199
Directions for Further Research	200
REFERENCES	203

	Page
APPENDIXES	
APPENDIX A: THE ALMON DISTRIBUTED-LAG MODEL: MATHEMATICAL PROCEDURES	217
APPENDIX B: NATIONAL ACCOUNTS AND SOCIAL DATA	222
APPENDIX C: AGRICULTURE AND TRANSPORT SECTOR DATA	225
APPENDIX D: EMPIRICAL RESULTS OF MODELS	231

LIST OF TABLES

		Page
II-1	Analytical Research Techniques: Their Advantages and Disadvantages	59
IV-1	Gross Domestic Product by Sector Origin in Current Prices	104
IV-2	Liberia: Resources and Expenditures	109
IV-3	Liberia: Iron Ore Production, 1959-1978	114
IV-4	Investments in the Transport Sector	122
IV-5	Development of the Highway System	125
IV-6	Investments in the Transport Sector by Mode	128
IV-7	Liberian Expenditures for Highways, 1971-1976	132
IV-8	Vehicle Registrations	134
IV-9	Total Consumption of Petroleum Products	134
IV-10	Revenues from Road-User Charges	135
IV-11	Road-User Taxes as a Per Cent of Total Revenues	136
IV-12	Railroads in Liberia	138
IV-13	Main Ports Facilities in Liberia	141
IV-14	Port Traffic by Major Facilities	141
IV-15	Commercial Air Traffic in Liberia	143
IV-16	Liberian-Owned Rubber Farms	147
IV-17	Percentage Employment in Liberia by Major Sectors, 1977-1980	153
V-1	Variables Used in the Models	162
V-2	Final Regression Results: Agricultural Production on Transport Investments and Producer Prices	169
V-3	Final Regression Results: Agricultural Production on Transport Accessibility and Producer Prices	178
V-4	Final Regression Results: Factor-Inputs on Accessibility	184

LIST OF FIGURES

		Page
II-1	Transport-Demand Approach (Road-User Savings Approach)	21
II-2	Producer-Surplus Approach	27
IV-1	Map of Liberia	96
IV-2	Population of Liberia, 1950-1980	97
IV-3	Liberia's Gross Domestic Product	106
IV-4	Total GDP Disaggregated into Monetary Economy and Traditional Economy	107
IV-5	Sectoral Origins of GDP by Selected Sectors	112
IV-6	Agriculture's Share of GDP	116
IV-7	The Transport Sector's Share of GDP	121
IV-8	Nonurban Roads in Liberia	123
IV-9	Investments in the Transport Sector for Roads	129
IV-10	Rubber Export Earnings as a Share of GDP	146
IV-11	Domestic Rubber Production, 1950-1980	148
IV-12	Domestic Coffee Production, 1950-1980	148
IV-13	Domestic Cocoa Production, 1950-1980	151
IV-14	Domestic Palm Kernels Production, 1950-1980	151
IV-15	Domestic Employment in Rubber Production, 1950-1967	155
IV-16	Land Cultivated for Rubber Production, 1950-1970	156

CHAPTER I

INTRODUCTION

The impact of transportation investments on development has been the subject of many studies over the last twenty years. All of these studies are in agreement that improved transport accessibility reduces the unit cost of transport and can expand the market for agricultural goods, as well as improve the marketability of extractive resources. However, there is substantial disagreement regarding the exact role of transport in the process of economic growth. The main issue of this disagreement centers around three points of view. Some researchers suggest that transport follows rather than induces development, Fogel (1962), Cootner (1963), and Heymann (1965). These studies assign a passive role to transportation by suggesting that transportation as a derived demand serves simply to relieve the friction of distance generated by supply and demand relationships.

Other researchers, such as Wilson (1966), Owen (1969), Cole (1968), Kraft et al. (1971), Roberts and Kresge (1971), Heinze (1975), Coatsworth (1979), and Liang (1981), have argued that transportation investments induce economic development and lead to secondary effects on the area serviced by

the transport system. The results of these studies indicate that transport plays a more active role in the development process by stimulating economic development.

A third point of view suggests that there is a reciprocal relationship between transport and development (Straszheim, 1972). This argument is based on the notion that the role of transportation depends on the level of development and that a cause and effect role cannot be assigned to transport. The direction of causation between output and transport investment may run either way, depending on the level of geographical aggregation (i.e., local, regional, or national) and the extent to which political influences dictate how transport investments are allocated. For example, the presence of political influences in allocating resources implies that new transport capacity may not have always been added where transport demand indicated it should be. This may present a special problem at the local level where political influences might predominate. The results are that the supply of transport is developed unrelated to where the demand exists (Straszheim, 1972).

Much of the research undertaken above represented a strictly normative approach to transport and development. Additionally, many of the studies were project-specific and sought, using cost-benefit analysis, to determine the economic impact of a specific road link or railroad connection,

Wilson (1966). The Harvard transport model for Colombia and later research at the World Bank broadened the scope of the transport and development research from a microeconomic project-specific focus to a macroeconomic framework by relating the transport sector, through a system of equations, to the rest of the economy. The analytical tool used in these studies was the simulation model.

The converse of the normative approach to transport and development research was indicated in studies by Fujita and Armano (1970) in Japan, Katzman (1977) in Brazil, Coatsworth (1980) in Mexico, and Liang (1981) in China. These studies investigated the empirical relationship of changes in output and changes in transportation capacity using multiple linear regression techniques.

What clearly emerges from a review of the literature is that vastly different analytical techniques were used. They have included cost-benefit analysis, input-output techniques, linear-programming models, simulation models, and econometrics, as well as a combination of these. An important technique that has been widely applied recently in transport development studies is the econometric model. The econometric technique can be used in several ways, one of which is to relate changes in output to changes in transportation capacity or costs using annual data or cross-sectional data. Another way is to relate proportional transport investments

to output. It is with this focus in mind that the recent econometric models by Liang (1981) and Coatsworth (1979) influenced this study.

This research begins with a review and analysis of the basic theoretical concepts and empirical studies of transport and development. Because different analytical tools are used in the empirical literature, it was important to determine which research tool is most appropriate for this study. The approach adopted for this study is the econometric model. The model is a two-sector model and consists of testing the relationship between the changes in transportation and changes in agricultural production.

This inquiry is a country-study of transportation and development in Liberia. The method of inquiry differs from previous approaches that have found common acceptance in the literature. This study extends the econometric model of previous transport studies by introducing a lagged explanatory variable. The main empirical model will be of the polynomial distributed-lag type applied to transport investments and commodity production.¹ Other empirical models, such as the relationship between accessibility and agricultural output and the factors of production to accessibility, will be analyzed. However, there are two basic requirements that

¹/ A polynomial distributed-lag model is one in which a dependent variable is determined by a weighted sum of past values of an independent variable.

must be satisfied before the models can be implemented. To begin with, the theoretical relationship of how transport investments and improved transport conditions affect the level of agricultural production must be clearly understood and explicitly stated. Second, it is imperative that the functional form of the models be properly specified in order that the effects of investments and accessibility on output and factor inputs can be captured.

The models are outlined at the end of this chapter and are presented in more detail in subsequent chapters. The remaining sections of this chapter present a brief review of the basic concepts, empirical findings, and the limitations of previous empirical studies.

EMPIRICAL STUDIES OF TRANSPORT AND DEVELOPMENT

Except for a few studies, much of the empirical research undertaken in the past regarding the impact of transportation on the rest of the economy has focused on predicting the spatial distribution of economic activities. Very few studies sought to measure ex post facto the impact of the changes in transport cost or capacity on the economy. Notable exceptions have been mode-specific or project-specific studies that have included: studies on railways in the United States (Fogel, 1964); railways in Mexico (Coatsworth, 1979); roads in Latin America (Wilson et al., 1966); and roads in Iran (Van der Tak and de Weille, 1969).

Research conducted by Kresge and Roberts (1968) at Harvard University, studies undertaken by the World Bank (1970) and research conducted at the Brookings Institution by Wilson et al. (1966) represent some of the main body of thought on the subject of transport and development impacts. While country studies by individual researchers are widespread, it was those studies carried out by these institutions that appear to be more widely applied and cited as the primary body of literature.

The common basis of earlier studies by Adler (1967), Van der Tak and de Weille (1966), Wilson (1966), and Waters (1968) is found in their methodologies, i.e., measuring the reduction in vehicle-operating costs by estimating the existing and generated traffic of the improved transport facility. The reduction in vehicle-operating costs are taken as user benefits and are estimated against the cost of the improved facility in a cost-benefit analysis framework to determine the project's worth. This methodology continues to be widely applied today, although it has been adapted in recent years to incorporate income-distribution considerations rather than merely emphasizing economic efficiency.

The study that has received the most attention in the literature is the Harvard transport model developed by Kresge and Roberts (1968) for Colombia. This study represents the most ambitious analytical research in the trans-

port field to date. It attempted the tasks of setting up a simulation model of the Colombian economy that was to be sufficiently sensitive to transport costs so as to respond to changes in the transportation system. This was attempted while simultaneously attempting to incorporate feedback effects from the changing economy on the transportation system. The model was severely criticized in a review article by Holland and Harral (1972) on the basis of having an insufficient data base to draw such far-reaching conclusions. Holland (1972) in a more extensive appraisal of the Harvard model found statistical deficiencies that he suggested could have been overcome by additional time and resources. Holland also found structural problems with the model in that the level of aggregation in the model was of a nature such that meaningful relationships were impossible to establish.

Country studies by the World Bank (1970) in Dahomey (now Benin), the Sudan, and Brazil were further attempts to implement the Harvard model. Israel's analysis (1972) in Thailand, like these of the World Bank, was more successful than previous studies. These studies avoided the shortcomings of the Harvard model by focusing on the transportation system as opposed to the economic system (Schuster, 1974).

The literature does not reveal any other attempts of such a large-scale effort having been undertaken since. However, a number of empirical studies have concentrated simply

on testing empirical relationships using a two-sector model. These studies include work by Fujita and Armano (1970), Katzman (1977), Liang (1981), and Coatsworth (1980). The common denominator of these studies is in their use of econometrics as the analytical tool. All of these studies found that decreasing the friction of distance or improving accessibility resulted in significant increases in economic output. The basic differences among these studies is in their data base. Some employed cross-sectional (regional) data, while others relied on time-series (annual) data, or pooled both annual and regional data. The research by Fujita and Armano employed both econometric and input-output models using cross-sectional data.

LIMITATIONS OF TRANSPORT-DEVELOPMENT STUDIES

There are several theoretical and methodological problems with the conventional empirical studies that sought to measure the impact of transport on development. The main theoretical problem relates to whether or not the causal variable is changes in output or changes in the unit cost of transport. In addition, there are two related theoretical issues.

The first theoretical problem with conventional empirical studies is that many failed to consider how the combination of factors, such as higher yields, increased prices, and reduced unit transport costs, influenced economic activities (Wilson, 1965). Reduction in unit transport costs come about through

additional transport capacity or from improved regulatory measures that permit the transport rates to be responsive to market forces. Higher yields may result from improved production inputs, such as new technologies, better labor techniques, or better land. Higher prices can come about through changes in production costs, reduction in transport costs, and improved marketing conditions.

The second theoretical problem with previous research is that many of the transport models treat quantity demanded of a specific commodity as a given and then seek to determine prices. This is in sharp contrast to economic theory that treats the demand for a good as being responsive to changes in its prices; changes in prices of competing and complementary goods, and changes in consumer income. Many models have ignored the interactions between price, income, and quantity demanded.

The methodological problems of the previous studies are related to the particular analytical techniques used. The most widely used research techniques consist of: social cost-benefit analysis; input-output; linear programming, and simulation. The problem with social cost-benefit analysis is that it has, in general, been applied in a microeconomic project-specific/mode-specific context. This technique is not sufficiently broad to model the secondary effects of transport investment decisions. Additionally, the technique is

not adaptable for incorporating spatial dimensions, such as regions or nations, into the analytical framework.

Although the input-output model is a strong analytical tool, its most serious objection is the requirement that ordinarily there is no technical change and that the technical coefficients are stable, if the static model is used, and data are generally not available to implement a dynamic model. The data requirements for implementing even a static input-output model are frequently burdensome in low-income countries.

The problem with the linear-programming model for use in the proposed research is that it does not permit cross-hauling between regions, which may result in an underestimate of interregional exchanges or output. Additionally, linear-programming models can potentially result in unstable programming solutions, whereby small changes in prices or resource availability can induce large, rapid, and compositional shifts in output. As with the input-output model, the data requirements for linear-programming models are enormous.

Simulation models are also burdened with methodological difficulties for research in developing countries; the primary of which is the problem of data. The data requirements exceed the normal data base for most national planning needs. The model's usefulness depends on the validity of the assumptions and the possibility of representing the behavior relationships empirically.

SUGGESTIONS FOR IMPROVING TRANSPORT
AND DEVELOPMENT STUDIES

As presented in the previous section, there appears to be a need for reconciling the data problems by reducing the data requirements, such as those found in large-scale simulation, input-output, and linear-programming models. There is a companion need for an analytical technique that reduces the data requirements, while at the same time augmenting the analytical capability.

The analytical framework that is most useful in developing countries where data tend to be scarce is one in which the research design is flexible enough to permit trade-offs between economic theory and the researcher's intuition. The possibility of using officially-published time-series or cross-sectional data or pooling both, if they exist, instead of undertaking costly surveys might serve to overcome the problem of data.

Empirical research can also be improved by having a clearly stated research objective whereby each assumption made about the incremental changes in output, prices, and transport capacity are explicitly stated. Holland (1972) notes that a number of ingenious attempts have been made to model the effects of transportation on investment and growth patterns that have included a number of very dubious functional specifications. He goes on to suggest that rather than attempting the overly ambitious dynamic simulation

models, what should be undertaken is empirical research that relies on a consistency or projection model. Such a model could be used to assure consistency among the projections for various sectors in terms of capacity and production, demand and supply, consumption patterns, investment, and input requirements. Holland (1972) also notes that empirical knowledge of economic relations consists of knowing what independent variables are significant in determining the behavior of another variable and in knowing how each exerts its influence on the other.

OUTLINE OF THE STUDY

Transport development researchers have applied a range of analytical techniques and methodologies over the last twenty years. As noted earlier, such techniques have included social cost-benefit analysis, input-output, linear-programming, econometric, and simulation models. The empirical literature appears not to suggest any standardization for conducting transport research, although the cost-benefit technique is commonplace. Rather, the previous research techniques appear to have been more a function of the available data and perhaps the abilities of the researchers.

The conventional empirical studies of transport development represented, in the main, a partial-equilibrium, static analysis of the transport impact on development, particularly those studies employing the cost-benefit technique. This,

of course, does not include those multisector models built around the dynamic input-output model and simulation models.

The purpose of this inquiry is to analyze the changes in agricultural output as they relate to the historical pattern of transport investment in Liberia from 1950 to 1980. This study attempts to improve upon previous empirical research by incorporating existing theoretical knowledge in the field and by proposing an analytical framework that is not burdened with cumbersome data or methodological problems. Additionally, the research technique enables the policy analysts to have flexibility in the research design by specifying relationships that model dynamic output responses.

This study hypothesizes that agricultural productivity, defined as changes in agricultural output, is positively correlated with past and current investments in transportation infrastructure. This is the result of decreasing friction of distance or increased accessibility, which tends to induce additional output, cultivation of new land, and additional employment in agriculture.

The analytical procedure that will be employed in this study is the ordinary least-squares regression technique. The study will rely on secondary data of annual agricultural production statistics, national accounts data, and other data from official sources.

A review of the theoretical and empirical models of transport and development research is presented in Chapter II.

A formal presentation of the models and the data employed in the study is discussed in Chapter III. The historical development of the Liberian economy with a focus on national aggregates, sectoral components, and growth patterns is presented in Chapter IV. The empirical application of the transport models, estimated results, and interpretations are discussed in Chapter V. The conclusions of the research, policy implications, and issues for further research are discussed in Chapter VI.

CHAPTER II

LITERATURE REVIEW

PART I. INTRODUCTION

Other literature relevant for an understanding of how transportation affects economic development has been integrated into Chapters I, III, and V of this study. The main review of the literature is presented in this chapter and is divided into four categories. This review provides the theoretical basis and the analytical framework in which the present inquiry is conducted. The four categories of literature consist of: i) the theoretical literature of the relationship between transport and economic output; ii) the analytical research framework; iii) the analytical methods literature; and iv) the empirical studies of transport and development.

The purpose of this literature review is threefold. First, to demonstrate that a theoretical basis exists to conduct the present inquiry. Second, to outline the principal analytical research methodologies used in the field for transport-policy analysis. Third, to show that rigorous analytical techniques are available to the researcher for research in low-income countries only under certain circumstances.

The chapter begins with an introductory review in Part I of some of the main theoretical literature of transport and

development. The section covers location theory, spatial-price theory, international-trade theory, and factor-mobility theory. Part II sets forth two general analytical frameworks for an economic analysis of the impacts of improved transport conditions on agricultural production. The analytical frameworks discussed are the transport-demand approach and the producer-surplus approach. The shortcomings and strengths of each of these approaches are also presented. Part III surveys the analytical methods for transport and development research and outlines both the theoretical and methodological limitations of each technique with an explicit focus on their application to research in low-income countries. Part IV reviews some of the empirical findings of the econometric studies and presents evidence of how incremental changes in output can be induced by unit transport-cost reductions.

THEORY OF TRANSPORT AND DEVELOPMENT

The theoretical basis of transport and development is discussed in this section. It is not the intention of this review of the literature to recount all of the researchers who have contributed to the theory of transport and development. Rather, the purpose here is to present a brief sketch of the main theoretical literature in the field and to suggest that the problems of spatially-separated product and factor markets are also governed by transport cost considerations.

The prospects for transportation policy to affect economic development and reduce income and regional disparities

have been the subject of many studies over the past two decades. These prospects have been explicitly suggested by the central role played by transportation in microeconomic theory of the firm and household location, in international and inter-regional-trade theory of comparative advantage, and in spatial-price theory. Although these theories are not without difficulty in explaining transport and development impacts, they generally assign a positive role to transportation in the course of economic development. The general theories that explicitly assign a positive role to transportation in the development process are outlined below. It should be pointed out, however, that these theories are not of central concern to this research but are presented solely to indicate that a sufficient theoretical basis exists, as we suggested above, to conduct the present research. The reader is directed elsewhere for a more comprehensive treatment of these theories.

The theoretical relationship between transportation and economic development is indicated in different aspects of economic theory. Transportation is given a very prominent role in choosing the optimum location of the firm in the classical location theory of Weber (Friedrich, 1929) and Moses (1958). An optimum location is chosen given certain constraints of market prices, production costs, and demand functions. The optimum location for the profit-maximizing firm is one in which the transport costs are minimized assuming market demands and

factor supplies at fixed locations; prices of all commodities; constant input-output relationship, and no scale effects.

Spatial-price theory also suggests a prominent role for transportation. The models by Hitchcock (1941) and Koopmans (1949) sought to determine the optimal flow of commodities over the transport system by minimizing transport costs. Enke (1951) solved the problem of competitive equilibrium among spatially-separated markets using electric analogs. Samuelson (1952) suggested that instead of minimizing transport costs, the objective function should be to maximize a net social payoff.¹ He showed that the price of factors and products between two regions can differ, at most, by their unit transport costs.

The classical theory of trade was formulated by Ricardo (1911) and further extended by Ohlin (1933) and Heckscher (1950). The theory states that two nations (regions) will exchange those goods in which they have a comparative advantage. Intervening transport costs can offset the price equalization between nations (regions) with different factor endowments, as suggested by Heckscher and Ohlin. The effect of a general decrease, for example, in transport costs gives rise to greater locational influence to production cost differentials between two areas.

Factor-mobility theory, on the other hand, assumes zero transport costs and postulates that, if factor mobility is per-

¹/ Samuelson (1952) defined the net social payoff as the sum of all separate payoffs for all regions minus the total cost of all shipments.

fect and commodity mobility is not, factors will move in such a way as to equalize factor and commodity prices (Mundell, 1957). Richardson (1978) suggested that the zero transport-cost assumption is unrealistic and that the prices of imperfectly mobile factors differ among regions by the marginal unit cost of transport between regions.

The above theories have suggested the importance of transportation facilities in overcoming the friction of distance between spatially-separated markets and the existing obstacles to the optimum utilization of resources and economic expansion. Two analytical research approaches have emerged from these general theories in terms of how to quantify the economic changes in the product and factor markets as the friction of distance is reduced. The two approaches are the transport-demand approach and the producer-surplus approach, each of which is discussed in Part II.

PART II. ANALYTICAL FRAMEWORK FOR TRANSPORT AND DEVELOPMENT

The object of this discussion is to introduce the transport-demand and producer-surplus approaches for estimating changes in economic activities as transport conditions improve. These two approaches represent the main analytical frameworks used by economists and transport planners to quantify the impacts of increasing transport capacity on other sectors of the economy. We are concerned in this section with answering the question as to which approach offers the broader analytical

framework for public-policy analysis for predicting the economic consequences of changes to the transport system.

The Transport-Demand Approach

The conventional transport-demand or, more specifically, the road-user savings approach in a perfectly competitive market treats the total benefits from an improved transport facility as being fully measured by the sum of road-user savings and developmental benefits. The transport-demand model is presented graphically in Figure II-1. The total benefits from improved transport are represented along the vertical axis as (C) transport cost (e.g., changes in cost per ton kilometer) and the volume of transport on the horizontal axis as (Q) in tons. The transport-demand function is a downward sloping line. The demand function assumes that all factors of production receive the value of their marginal product. As unit transport cost falls because of new road investments, the volume of transport increases. The volume increases because of traffic generated by the improved transport facility. The benefits from normal traffic (i.e., savings in road-user charges) and other benefits (e.g., net agricultural output) induced by the reduction in transport costs represent the total benefits from the investment (i.e., the area under the demand curve and above the price line in Figure II-1).

As we pointed out in Chapter I, studies of the impact of changes to the transportation system (e.g., railways and roads) on economic activities abound in the transport develop-

ment literature. These studies were conducted within the broad theoretical proposition that unit transport-cost reductions influence economic output. The focus of many of these studies was on estimating the demand for transportation; an issue that is taken up here.

Evidence was offered in many of these studies that confirmed the economic theory that the price elasticity of demand for transport is negative under a regime of competitive markets. Under conditions of competitive markets, savings in the cost of transportation are normally passed on to the users (producers and consumers) of the system as unit transport-cost reductions (Churchill, 1972). Such savings, as the literature suggests, further stimulate additional output as factor costs are minimized.

In a study by Van der Tak and de Weille (1969) in Iran for the World Bank, however, it was found that the elasticity of demand for road transport was zero. This result, in effect, meant that reduced transport costs had no effect on producers' output and income. This finding resulted in spite of the fact that there were considerable public investments in improving roads to reduce transport costs. Van der Tak and de Weille (1969) reasoned that the noncompetitive nature of the system of marketing and distribution accounted for this phenomenon. They specifically pointed out that the lack of a competitive marketing and distribution system allowed middlemen to keep the savings that resulted when transport facilities were improved.

The transport-demand approach used by Van der Tak and de Weille above was inappropriate because the benefits of improved road conditions were measured only in terms of road-user savings instead of the broader economic impacts (such as production increases, employment generation, and land cultivation, etc.). This is because the transport-demand approach, usually related to benefits in a cost-benefit analysis framework, is based on traffic volumes induced by the cost reductions. Because the transport-demand approach focuses on net reductions in road-user savings as the benefits, it does not answer the question of what are the impacts on increased production and income when the normal traffic levels are negligible, as would be the case in remote agricultural regions.

The transport-demand approach seems reasonable for those cases in which normal traffic and traffic generated by investments in transport facilities are sufficient to be translated into road-user savings as a reliable measure of the expected benefits. It is less useful for impact analyses when the level of economic activity is low and when almost no traffic exists.

There are several shortcomings of the transport-demand approach that restrict its usefulness as the appropriate analytical framework for the present research. First, as we indicated above, the demand-for-transport approach relies on quantifying the benefits accruing to users of the transport facility. This presents a problem when the level of economic activity is low

and when traffic levels are not significant. The problem arises because the savings to the road users plus the induced development traffic, particularly for a low-volume road, may not be sufficient to justify making the investment. The cost of building the road may exceed the discounted stream of future benefits measured in road-user savings. The volume of output transported over the improved transport facility plus other economic changes taking place seems more appropriate as the measure of the economic consequences of the investment decision. Second, the demand-for-transport approach is not very useful beyond project-specific analysis of a particular road link, rail line or terminal facility. It has little or no promise for regional or interregional analysis of the economic effects of improved transport conditions. The reason for this is because the approach cannot easily capture the full value of secondary effects or spatial development impacts that may take place, such as other changes in the production of goods or services surrounding the transport facility.

In recent years, the transport-demand approach has been broadened to take into account social welfare objectives and development impacts on income distribution and on employment creation within the framework of social cost-benefit analysis. Historically, its focus was principally on economic efficiency (i.e., maximizing the return on investments by selecting those projects with the highest cost-benefit ratio or highest net present value as measured in money terms).

The main shortcoming of the transport-demand approach is that it reflects economic effects only indirectly as changes in traffic volumes, whereby the demand for transport is a derived demand. In remote agricultural areas where head-loading is the predominant mode of getting goods to market, the net additions to agricultural output should be the focus of the analysis when transport improvements are made.¹ The transport-demand approach, in this case, does not offer the advantages in terms of measurement of the economic changes occurring as it does in areas of high economic activities. This, in turn, reduces its ability to inform public policy with respect to i) how are the benefits distributed between producers and consumers; 2) what is the net value change in agricultural production, and 3) what are the other economic consequences (e.g., changes in employment, changes in income, and cultivation of new land, etc.).

As we shall demonstrate in the next section, the producer-surplus approach provides a broader and a more consistent measure for policy analysis of changes in economic activities induced by transport improvements than the transport-demand approach does.

The Producer-Surplus Approach

In contrast to the transport-demand approach, the producer-surplus approach, suggested by Carnemark et al. (1976), focuses

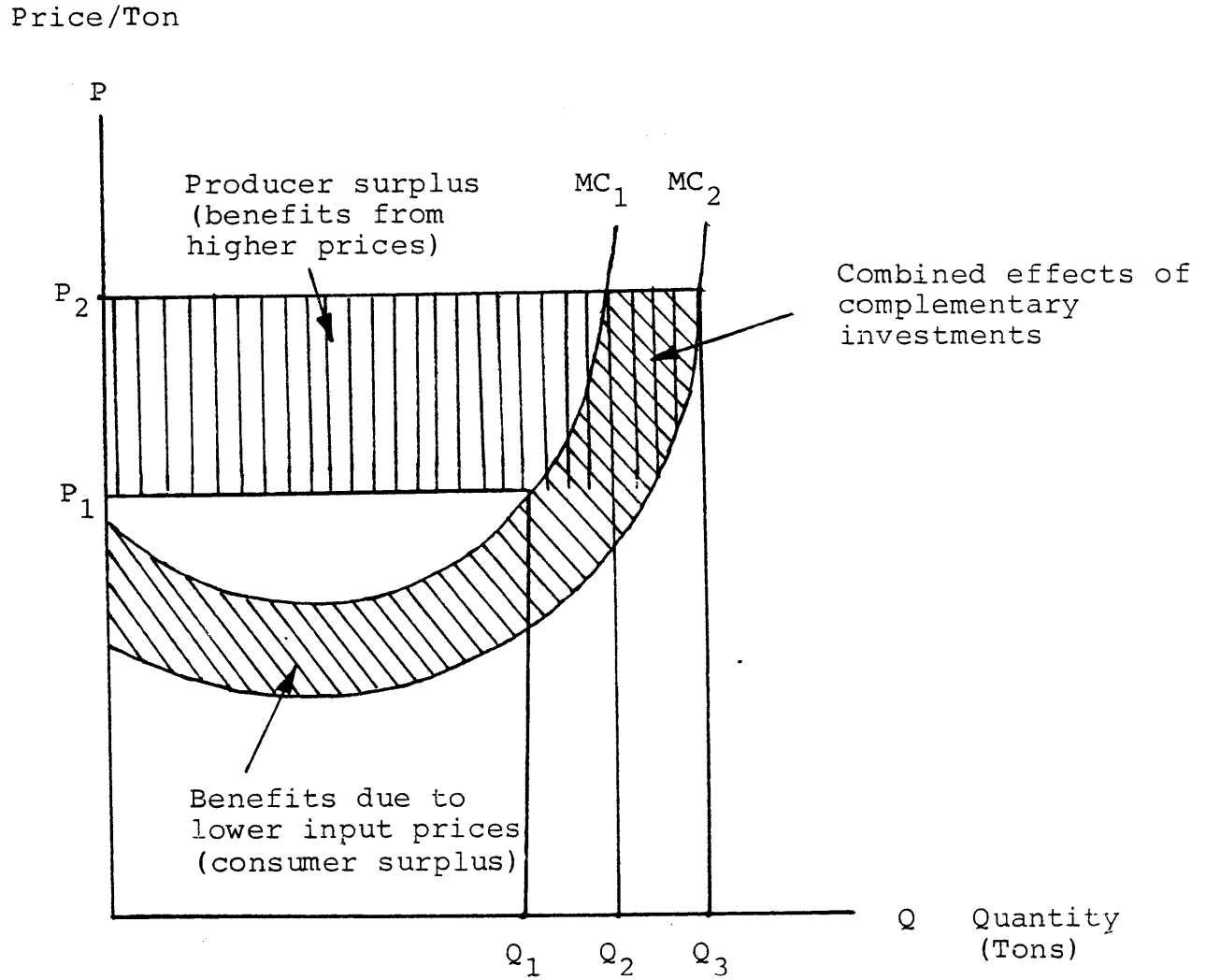
¹/ Head-loading refers to farm laborers carrying crop production, usually in excess of their own weight, by foot to the nearest agricultural market center or collection point.

on estimating the net increases in agricultural production and net income to producers instead of benefits from road-user savings. The producer-surplus approach differs fundamentally from the transport-demand approach in that its emphasis is on quantifying changes in production, as opposed to quantifying savings in vehicle-operating costs as the transport-demand approach does.

The producer-surplus approach is presented graphically in Figure II-2. The approach consists of producer prices (P) on the vertical axis and quantity supplied (Q) along the horizontal axis. The supply curve is a downward sloping marginal cost curve. With an improvement in transport conditions, producer prices for agricultural goods increase which then signals producers to expand output. Because the supply response is assumed to be elastic with respect to transport price, each percentage point increase in accessibility (i.e., additional miles of roads) results in an additional percentage increase in output. The road-user savings from improved transport are passed on to the agricultural producers in terms of higher producer prices.

The producer-surplus approach provides a broader view, from the vantage point of public policy, of the economic effects of transport improvements than the transport-demand approach. The economic effects can be measured as additions to output, changes in income, cultivation of new land, employment creation, and changes in capital stock, etc. The transport-demand

FIGURE II-2
PRODUCER-SURPLUS APPROACH



Source: Carnemark, C., J. Biderman and D. Bovet. (1976). "The Economic Analysis of Rural Road Projects", I.B.R.D. Staff Working Paper, No. 241, Washington, D.C.

analysis is usually applied within a cost-benefit analysis framework and is more concerned with savings in vehicle-operating costs as the primary measure of an investment decision. Other economic effects such as those indicated above are not explicitly considered. However, the transport-demand analysis is technically capable of incorporating these effects.

The producer-surplus model is an analytical approach that focuses on a specific agricultural product (e.g., coffee) and improved transport accessibility (e.g., new roads). Carnermark et al. (1976) have identified five basic assumptions that are fundamental to this production-oriented approach. These are:

- i) transport-cost reductions are fully passed on to producers through higher producer prices and lower production costs.
- ii) production costs are reduced at the margin due to new technologies and/or to complementary investments.
- iii) area of cultivated land is fixed.
- iv) crop production is insufficient to influence the price at the market (i.e., marginal revenue is equal to price).
- v) crop production is transported over the improved transport system.

The producer-surplus approach is presented graphically in Figure II-2. Production, in this case, of coffee is presented

with and without new transport investments. In the "without" investment case, coffee production of quantity Q_1 is produced at price P_1 in year T_1 . Because marginal cost (MC_1) equals marginal revenue (P_1) at this point, this is the position in which producers maximize their profits.

In the "with" investment case, agricultural output in year T_1 is at the higher production level of Q_3 at price P_2 . Such an increase in output results from:

- a) transport-cost savings of farm outputs from P_2 to P_1 per unit output (ton) are fully passed on to producers through producer prices (i.e., P_2).
- b) transport-cost savings from farm inputs result in a lowering of production cost for any level of output represented by a shift of the marginal cost curve from MC_1 to MC_2 . With the new producer price of P_2 , output increases from Q_2 to Q_3 .
- c) when the transport savings from farm inputs and outputs are combined, production increases from Q_1 in the T th year, without new transport investments, and to Q_3 in year T with the transport investment.

The theoretical basis of the producer-surplus approach is that profit-maximizing firms produce that level of output where their marginal costs equal marginal revenues. Because of the assumption of perfect competition, each firm (farm unit)

regards its marginal revenue curve as a horizontal line at the prevailing market price P_1 or P_2 . Any production above the horizontal line is taken as surplus production.

Carnemark et al. (1976) used a partial-equilibrium, static analysis to demonstrate how changes in output, income, and/or land cultivation respond to changes in the price of transport. In their studies of remote agricultural areas, they set forth a producer-surplus model and show how it can be used to quantify the output arising from the interaction of agriculture and transport sectors following investments in transport. The producer-surplus approach is intended to make it clear what economic changes are independent of the transport investments, as complementary agricultural investments would be, or are integral to transport investment, such as new road construction, better facility maintenance, and better management practices or regulatory actions. When formulating a model of transport and development, if the economic variables in the model are not properly specified as an independent variable or dependent variable based on which exerts a causal force on the other, bias may result and too much (too little) of the effect may be assigned to investments in transportation infrastructure. For example, the impacts of complementary investments (e.g., new seed varieties, farm credits, fertilizers, etc.) and their contribution to development output may be underestimated (overestimated) if they are not properly specified in the model.

One of the shortcomings of the producer-surplus approach represented in Figure II-2 is that it is a static model, which implies that each of the marginal cost curves reflects short-run marginal costs. A more promising and realistic model is the dynamic model, which analyzes producer prices and lowered production costs to transport investments over time. Because of time lags, producer prices may not adjust immediately to short-run marginal costs such as lowered transport costs. Farm production costs may fall even slower as producers figure out how to maximize their use of cheaper inputs, new or different technological mixes, and improved market accessibility. Holland (1972) argues that producers do not respond to transport cost reduction until at least a year after the investment patterns are determined.

The producer-surplus approach does, however, represent an improvement over the traditional approach, such as the transport-demand approach, by offering a broader analytical framework for public policy analysis. However, several important issues remain to be answered. The present study examines such issues as: 1) how should time-lag adjustments of producer responses to falling transport costs induced by new transport investments be represented; 2) what magnitude of transport-cost reductions are required to induce additional output; 3) what is the impact of producer prices on output supply, and 4) how does the short-run and long-run responses of producers to im-

proved transport accessibility vary among crops. These issues will be taken up further in Chapter III.

The discussion that follows below will focus on specific analytical methods used to quantify the impacts of transport on economic activities.

PART III. ANALYTICAL METHODS FOR TRANSPORT AND DEVELOPMENT RESEARCH

There are several research methodologies and analytical techniques used for the analysis of transport and economic development policies. This section does not attempt to examine the entire range of analytical procedures; instead, it focuses on some of the more rigorous techniques as well as those most widely employed in the fields of economics, transportation policy, and economic development.

The analytical research methods reviewed here include: social cost-benefit analysis; linear programming; input-output; simulation; and econometrics. The intent of this review is two-fold. First, to present the theoretical basis and underlying assumptions of these techniques and to determine their usefulness in assessing the influence of the transport sector on economic output. Second, to determine which technique(s) might be most appropriate for the present research.

Social Cost-Benefit Analysis

Social cost-benefit analysis is an analytical technique for project appraisal that has undergone substantial revisions in the last two decades. As an appraisal tool, it is primarily

concerned with the appraisal of discrete transport projects from the point of view of the economy as a whole. The essence of social cost-benefit analysis is the comparison of the future stream of benefits from a project with the initial and future costs in order that decision-makers can determine whether to allocate resources to a given project or to allocate resources elsewhere.

Private investment decisions differ in several ways from decisions about allocating public resources. To begin with, the individual or firm allocates its resources in a way that seeks to maximize its private return on investment at a rate that exceeds its alternative or opportunity cost of capital. Public decision-makers, by comparison, seek to allocate resources so as to maximize the social welfare of the entire society. For example, public decision-makers may take into account the impact of projects on regional income disparities, on employment, on additions to national output, on foreign exchange earnings, and so on. Social cost-benefit analysis identifies the net contribution (e.g., reduction in transport cost) that a project will make to the economy and to the improvement of the national output as measured by some social-welfare function. This has meant, with regards to transport projects, estimating those benefits accruing to users such as reductions in vehicle-operating costs, in the case of roads, and improved regulatory measures (e.g., weigh stations, etc.), in the case of road haulage.

Mishan (1975) argues correctly that social cost-benefit analysis is an extension of welfare economics with its underlying assumptions based on the notion of Pareto improvement (i.e., allocating resources in a way that some groups are made better off without making other groups worse off).

Because future receipts from a project may not adequately reflect the true scarcity of resources in market prices, Little and Mirrlees (1974) and others have suggested the use of shadow prices or accounting prices. Shadow prices are used to correct distortions in the foreign exchange rate, in the wage rate, and in the rate of interest. Divergence in unskilled labor rates, interest rates, and foreign exchange rates oftentimes comes about if the government sets wages higher than their marginal product, if it uses import quotas and/or tariff restrictions, or if it sets the discount rate not equal to the marginal product of investment such as government policies that cause commercial lending rates to diverge from the marginal product of investment under equilibrium conditions. Another market imperfection is when monopsonies influence labor rates and other factor input prices.

The use of shadow prices in social cost-benefit analysis is not without objections from some researchers. One of the main theoretical objections to the use of shadow prices is that, because everything depends on everything else, an adjustment in one price requires adjustments in all other prices. If this criticism were true, economists cannot expect to esti-

mate a particular shadow price (e.g., unskilled labor) without at the same time reestimating all other prices in the system. However, because all prices do not always depend on all other prices, at least in any significant degree, a strong case can be made for focusing on certain economic activities, projects, or sectors, etc. by using shadow prices.

The decision criterion that is often used in the framework of social cost-benefit analysis by international development agencies, such as the World Bank, is the Net Present Value (NPV) method. Simply put, the method requires that the flow of social benefits minus costs over the life of a project should be discounted to the present at a given discount rate. As a result, a project should be accepted or rejected according to whether its NPV is positive or negative, respectively. Over the long-run, the discount rate represents the premium society places on present consumption. The NPV method directly incorporates the principle that benefits and costs are of different values depending on the time at which they occur.

In contrast to the NPV method that requires some predetermined social rate of discount is the widely used Internal Rate of Return (IRR) method. The IRR method, like the NPV method, can be used in the context of social cost-benefit analysis. The IRR is equal to that interest rate that would yield an NPV of zero. This rate may then be compared to a predetermined

discount rate. The decision criterion for accepting or rejecting a project is to accept a project that yields an Internal Rate of Return greater than the predetermined discount rate or greater than the IRR of some alternative project.

The Net Present Value method relies on the choice of a social discount rate. The IRR method, on the other hand, determines the interest rate internally. Mathematically, the Net Present Value and the Internal Rate of Return methods can be represented as follows:

$$NPV = \sum_{t=1}^T \frac{B - C}{(1 + r)^t} > 0$$

$$IRR = \sum_{t=1}^T \frac{B - C}{(1 + i)^t} = 0$$

Where: B - C = net benefits

r = discount rate

i = internal rate of return

T = length of life of the project

t = time

The difficulty with social cost-benefit analysis as a relevant analytical technique for the present study is that it may not easily capture the secondary effects resulting from all of the transport investment decisions. Mera (1984) argues that cost-benefit analysis does not provide a comprehensive

picture of the impact of a project (such as induced growth of demand). He goes on to suggest that cost-benefit analysis is suitable for incremental changes but not for large changes. The relationship of estimated benefits to increases in production is unanswered. In addition to Mera's arguments, the project-specific approach is narrow in its application to inter-modal transport research. The temporal dimension of the research is not compatible with a social cost-benefit approach because both costs and benefits are occurring for different projects at different time intervals. As a result, it is not feasible to aggregate the costs and benefits across regions or nationally. Given this, social cost-benefit analysis is not given further consideration as the analytical method to be used in this study.

Linear Programming

The second analytical method for policy analysis to be considered here is linear programming. Linear programming (LP), as an analytical technique, has a great deal of appeal to economists and planners because of its reliability and computational feasibility. LP is a technique for allocating resources under conditions where the supplies are limited. LP is similar to the input-output technique, although there are important theoretical differences. Similar to the input-output model, LP models fulfill the resource consistency check. Unlike the input-output model which is concerned solely with consistency, LP is concerned with optimization. All LP models are

concerned with maximizing or minimizing an objective function subject to some constraints. This implies that the solution obtained not only is feasible, but is the best solution within the feasible set.

Additionally, LP imposes conditions that prevent the objective function from being too large or too small. Such conditions are called constraints. LP also has choice variables that are chosen in order to maximize (minimize) the objective function. The choice variables can be interpreted as the extent to which an action is to occur (e.g., scale of construction of a particular transport facility or the location of a terminal facility, etc.).

The LP model can be represented numerically as the following. Let X_{ij} denote the nonnegative number of tons of commodities shipped from farm i to market j , and C_{ij} represent the transport cost per ton mile for shipments between farm i and market j . Because the producer at farm i is sensitive to the transport cost, the sum to be minimized is total transport cost (T). This relationship is expressed as the following:

$$\text{Min } T = \sum_i \sum_j C_{ij} X_{ij} \quad \begin{array}{l} i = (1, \dots, n) \\ j = (1, \dots, m) \end{array} \quad (1)$$

To achieve the minimum, any values of X_{ij} that satisfy the following restrictions are selected. First, shipments planned for each farm must not exceed the production capacity of that farm. Second, the total shipment of farm commodities

to each market must equal or exceed the demand at that market. Third, the amount of commodities shipped cannot be negative. The objective function is to find the values of X_{ij} that minimize total transport costs subject to the following constraints.

$$\sum_j X_{ij} \leq K_i \quad \begin{array}{l} i = (1, \dots, n) \\ K_i = \text{capacity of farm } i \end{array} \quad (2)$$

$$\sum_i X_{ij} \geq D_j \quad \begin{array}{l} j = (1, \dots, m) \\ D_j = \text{demand at market } j \end{array} \quad (3)$$

$$X_{ij} \geq 0 \quad \begin{array}{l} i = (1, \dots, n) \\ j = (1, \dots, m) \end{array} \quad (4)$$

The LP model can specify that local supply equals local demand or:

$$\sum_{i=1}^n K_i = \sum_{j=1}^m D_j \quad (5)$$

Thus, the constraints (2) and (3) are converted into equalities. Equations (1) to (4) are known as the primal. Because all LP problems come in pairs, the primal is related to another set of equations called the dual. While the structure of the dual to the transportation problem is straightforward, it is necessary to define two new sets of variables. These variables consist of, in this case, U_i and V_j . Let U_i equal the shadow price of capacity at farm i for all $i = (1, \dots, n)$ and let V_j equal the shadow price of demand at market j for all $j = (1, \dots, m)$. The dual problem, thus, is to:

$$\text{Max } Z = \sum_{j=1}^m D_j V_j + \sum_{i=1}^n -K_i U_i \quad (6)$$

$$\text{Subject to: } V_j - U_i \leq C_{ij} \quad \begin{array}{l} i = (1, \dots, n) \\ j = (1, \dots, m) \end{array} \quad (7)$$

To impose an additional constraint, we assume a price P that represents production cost including profit at all locations. This can be incorporated into the constraint (7) as:

$$(V_j + P) - (U_i + P) \leq C_{ij} \quad \begin{array}{l} i = (1, \dots, n) \\ j = (1, \dots, m) \end{array} \quad (8)$$

without changing the constraints. The term $(U_i + P)$ is the price at production point i and $(V_j + P)$ is the delivery price at market j .

While the LP model represents a strong analytical technique for policy analysis, it is not as straightforward as the above implies. One of the technical difficulties associated with the use of LP in, for example, regional analysis, is that the model does not allow cross-hauling between regions. Hence, interregional exchanges may be underestimated. Second, there is a potential instability of the programming solution with LP models. That is to say, small changes in prices or resource availabilities may induce large, rapid, regional and compositional shifts in output. Finally, the data requirements for implementing

an LP model are enormous and may represent one of its greatest obstacles for research applications in low-income countries.

There are four primary assumptions that are essential to the execution of an LP model. First, LP models assume a fixed unit-transportation cost across regions. The validity of this assumption depends in large measure on how regions are defined, because unit transport costs between regions are a function of the region's size. The second assumption is that of fixed-production capacity for each good in each region. This assumption is essential to initiating an LP model. Most LP models tend to ignore joint products. This introduces the additional problem of determining transport rates between one product and another because the products may not be that distinguishable from each other. LP models try to overcome this difficulty by adopting a broad definition of products. The results, however, cause prices and quantities demanded of the composite to become rather vague, if not misleading, concepts.

Third, LP models also assume a fixed endowment of primary resources; an assumption similar to that of fixed-production capacity except that it pertains to such resources as land and labor as opposed to equipment. The labor category, for example, can be further broken down to include skilled and unskilled labor as different resources. The resource endowments of each region are assumed to be immobile across regions.

The final assumption is that of a linear production function. The essence of this assumption is that the costs

of each factor input do not vary with the quantity of output produced. Typically, input-output coefficients differ between regions and between goods. However, detailed information on regional input and output is often unavailable in most countries. The result being that national coefficients are oftentimes substituted for regional coefficients. The technical requirements (e.g., data inputs) and the related costs of collecting the necessary data and of running the LP model appear to make the use of a linear-programming model as the analytical technique for the present research less useful than other methods discussed here.

Input-Output Models

Input-output (I-O) models are discussed next and, as we have said, these models are in some ways related to LP and simulation models. The theoretical basis for an I-O model is that production in any sector of the economy is a function not only of the primary factors of production (e.g., land, labor, capital, etc.), but also of the intermediate goods and services produced by other sectors that use them as inputs. This underlying theoretical proposition provides a way of representing the structure of the economy by setting out the flows of goods and services in value added terms from one sector of production to another. This is commonly referred to as either an input-output matrix, a transaction matrix, or an interindustry accounting system. Each sector of the economy that appears in an input-output matrix represents a producer of output and a

user of output. The elements in each row represent how the output of a particular sector is used for intermediate demand or final demand (private or government consumption, for export, or for investment, etc.).

There are five basic assumptions of the static I-O model. These include: no joint products; no extra-model, non-linear interaction between sectors (i.e., no external economies or diseconomies); the amount of each input used in production by any sector depends on the level of output of that sector; constant returns to scale, and fixed technical coefficients of production with no possibility for substitution.

The I-O model can be represented as a closed model or an open model. In the closed model, all inputs are both produced and consumed in the system. That is to say, inputs come only from current production and outputs in turn are used only as inputs. The open model, on the other hand, treats all primary factors as emanating from outside the model and final consumption is exogenously determined.

A typical I-O structure can be represented mathematically (Pleeter, 1980) as:

$$\sum_{j=1}^n X_{ij} + \sum_{f=1}^t Y_{if} + e_i = X_i \quad i = (1, \dots, n) \quad (1)$$

Where: X_{ij} = sales of industry i to industry j
 Y_{if} = domestic sales of industry i to domestic final demand sector f

e_i = export sales of industry i
 X_i = total sales of industry i
 n = number of industries
 t = number of final demand sectors
excluding foreign trade

The model's input side is expressed as:

$$\sum_{i=1}^n X_{ij} + \sum_{p=1}^s V_{pj} + m_j = X_j \quad j = (1, \dots, n) \quad (2)$$

Where: X_j = total production in industry j
 V_{pj} = value added by factor-of-production
sector p in industry j
 m_j = imports by industry j
 s = number of factors of production

The coefficient that expresses the amount of input i required to produce a unit of j is given as a_{ij} and is derived by:

$$a_{ij} = \frac{X_{ij}}{X_j} \quad (3)$$

Substituting the above equation into (2), the I-O accounting system can be represented in matrix notation by:

$$AX + Y + E = X \quad (4)$$

Where: the elements of the Y vector are given as the equation:

$$Y_i = \sum_{f=1}^t Y_{if}$$

Solving the system for X gives:

$$B (Y + E) = X \quad (5)$$

Where: B equals the inverse matrix $(I - A)^{-1}$, and b_{ij} , as an element of the B matrix, is the direct and indirect purchases of industry i from industry j in order to produce an additional unit of final demand.

Although the I-O model has made its most significant contribution to economic studies at the national economic planning level, the model is also very useful for researching the impact of growth of a particular sector on the rest of the economy and for regional planning (Polenske, 1980).

While the static I-O model represents a powerful analytical tool, it is nonetheless not without criticisms. The most serious criticism is the stability of the technical coefficients (i.e., the assumption that there is no technical change). This assumption is difficult to justify on empirical and theoretical grounds because it implies that a doubling of inputs will

lead to a doubling of outputs. Thus, economies of scale are not permitted under this condition.

The introduction of a new industry, which represents a change in the economic structure also poses a challenge, although not insurmountable, to the I-O model. This is the equivalent to adding a row and a column to the I-O matrix, which requires calculating new technical coefficients. While this may be merely a technical setback, it nevertheless imposes an additional burden on the researcher. That is, if additional data are not available, the I-O table cannot capture the effects of a new industry, even though we know the industry exists.

The I-O model does not appear to be appropriate for the present research because of two reasons. First, the data are not available to implement the model. Second, I-O models are more concerned with national aggregates at a particular point in time, as represented by the accounts for a given year, rather than over time.

Simulation Models

Simulation models of transportation are similar to the LP model discussed above in that both models may be concerned with the spatial distribution of future economic activities and the resulting demand for transport. The two models are also similar in that they analyze the transport network and exogenously specify additions to the transport network. Addi-

tionally, both models utilize minimum-path routines in the analysis of the network as well as linear-programming routines to distribute the flows of goods by applying the least-cost criterion. Despite these similarities, there are fundamental differences between the two models. First, while the economic projections for the LP model are estimated exogenously and are independent of the transport network, the simulation model typically interacts with the economic model in order to influence the geographical distribution of economic activity. Second, a time-stage transport investment program can be evaluated by macroeconomic measures using a simulation model. That is to say, the simulation model can estimate the impact of the transport sector on national aggregates over time.

The economic-simulation model provides the transport-simulation model with national (regional) annual data of supplies and demands for commodities as well as other macroeconomic data on the performance of the economy at both the national and regional levels. Typically, economic-simulation models are based on an input-output table. The annual inputs to the transport model are the spatial distribution of supplies and demands from the economic model combined with any additions specified exogenously to the transport network for that particular year.

Physical changes to the transport network are incorporated into the transport model. Because investments in transportation facilities often take several years before physical improvements

to the system are noticeable, these changes can be accounted for in the economic model as a component of total transport investment. This permits the simulation of investments in the economy to show up as construction activity. The physical changes are exogenous inputs into the transport model, while the financial changes are inputs to the economic model.

The use of sub-models to simulate the operation of a particular transport mode represents another significant difference from other transport models. The primary function of such models is to simulate the cost performance characteristics of each link or node in the transport network.

The transport model provides an annual summary of the transport simulation by indicating the amount of transport purchased by each industry in each region. At the national level, the amount of transport purchased is placed in the domestic-flow matrix of the input-output table. This table is then reinverted and the economic model continues the simulation for the next time period.

Simulation models can expand and improve the predictive capabilities of the researcher in the analysis of policy. The models assume that the rationale governing the operations of a transport system can be captured if essential physical and behavioral relationships can be defined, supported on theoretical grounds, and, more importantly, if these relationships can be quantified. The usefulness of simulation models depends the validity of the relationships assumed and the possibility,

as well as the practicality, of being able to represent these relationships empirically.

Research with simulation models by Roberts and Kresge (1965, 1967, 1971), Holland (1972), and Holland and Harral (1972) have confirmed the importance and interdependence between the transport system and economic growth. While theoretical objections regarding macroeconomic transport models remain, the main difficulty in operationalizing such a model in low-income countries is primarily one of data availability. The data requirements for a transport simulation model exceed the normal inputs for most national planning efforts. Typically, data (such as historical data for the economic model, an input-output table, sectoral data on capital-output ratios, wages and profit, time-series on the components of final demand, as well as an investment flow matrix) are not readily available. The regional distribution of output by sector is the minimum requirement for any regional research application. Whether the LP, I-O or the simulation model is used, the transport model requires data on the physical characteristics of the transport network by each link and node. The model also requires specific traffic counts and origin-destination data for each commodity. These data requirements are costly, time consuming, and require an experienced research staff; each of which negatively affects the usefulness of simulation models as a research tool in low-income countries. In the context of the present study, data availability is the primary obstacle to implementing a simulation model.

Econometric Models

The next analytical technique to be reviewed under Part III is the econometric model. Virtually all of the conclusions of economic theory are presented in the form of relationships between variables. Thus, the main focus of this section is the application of the econometric technique to the analysis of economic relationships. Econometric models test whether hypotheses of certain theoretical relationships are supported by empirical evidence. Once a clear economic relationship is hypothesized, the procedure then is to determine the form and strength of that relationship. Specifically, what is then required is to determine the strength of the relationship, the magnitude of the parameters, and whether the relationship is linear or non-linear. Ordinary least-squares regression analysis is one of the principal statistical tools used in econometrics to estimate economic relationships.

The basic model in econometrics is the two-variable linear-regression model where the dependent variable is expressed as a function of some independent variable. This single-equation model can employ either time-series or cross-sectional data to explain the relationship between the dependent and the independent variable.

Typically, econometric models are built using theoretical propositions such as, for example, the macroeconomic formulation where total output (the dependent variable) is a function of consumption, investment, government expenditure, exports, and

imports (the independent variables). Assuming a linear relationship between the dependent and independent variables, a rule can be specified that determines the best straight line that fits the empirical data. This procedure is called the ordinary least-squares regression method, because it minimizes the sum of the square of each estimated deviation from the straight line.

The econometric model can be represented in a single equation; for example, the relationship between accessibility and agricultural output. The single equation can be fitted to empirical data using the ordinary least-squares regression technique. Consider the general form of the equation as:

$$\ln Y_i = f(\ln T_i)$$

Where: Y_i is the agricultural output in region i and T_i is the transport cost in region i .

The specific functional form of the model, as proposed by Liang (1981), is:

$$\ln Y_i = \ln c + \lambda \ln T_i \quad i = (1, \dots, n)$$

Where: Y_i is the agricultural output in region i , c is a constant parameter, λ is the elasticity of agricultural output with respect to the transport cost in region i and T_i is the total transport cost of all agricultural goods, factor inputs, and people in region i .

The above single-equation regression model, while simple in its application, may overstate some very important theoretical

assumptions. The theoretical basis for the model rests on the notion that a decrease in transportation costs and, as a result, improved transport accessibility has a definite influence on agricultural production. The model assumes that agricultural producers behave rationally and are profit maximizers; that perfect competition exists, and that there are constant returns to scale. However, in the absence of these assumptions, monopolistic competition may exist in the transport market such that transport costs may be unusually high in spite of governmental efforts to improve transport conditions. Reductions in transport costs may simply be consumed as additional profits by the transport firms rather than being passed on to the producers and consumers. Additionally, it is unclear whether all agricultural producers are profit oriented. For example, some small estate holders may produce only enough for subsistence beyond which they may engage in leisure activities, as some researchers suggest (Levi and Havinden, 1982).

The econometric models, particularly the single-equation models, are confronted with methodological problems when they are implemented with time-series data. First, time-series data may produce autocorrelation if the equations are misspecified or if lagged endogenous variables are used in the model. Misspecification and use of time-series data may also result in problems of multicollinearity. Multicollinearity results in biased parameter estimates. The problem of multicollinearity comes from not being able to determine which explanatory vari-

able(s) is having what effects on the dependent variable. Remedial measures can be used to overcome the problem of autocorrelation, while the problem of multicollinearity requires a respecification of the model.

The problem of data, as was the case with the other models discussed above, may be difficult to overcome if primary data are required. However, should primary data not be required, the models can be implemented using published time-series or cross-sectional data; thus, making it less costly for research application. The theoretical issues and methodological problems can also be made less encumbering if the model explicitly states all of its underlying assumptions, and if its stated hypothesis is based on sound economic theory.

Because of its flexibility, both in terms of data requirements and in terms of analytical strength, the econometric model was found more appropriate than other research methods for the present research.

PART IV. EMPIRICAL FINDINGS OF ECONOMETRIC MODELS

Transportation economists have used a variety of techniques and applications for the ex post and ex ante assessment of transport and development. Principal among these, as discussed in the previous section, are cost-benefit analysis, input-output, linear programming, simulation, and econometrics. Many of the problems that burden these models, as we indicated above, are methodological in nature. A large body of the empirical

literature consists of highway impact studies conducted by universities, international development agencies, and private firms using cost-benefit analysis as the principal analytical tool.

The empirical research surveyed here covers only those studies employing econometrics as the research technique. These studies broaden the focus of the transport and development research from an analysis of project-specific effects to sector-wide or, in some instances, economy-wide changes in production. Additionally, the econometric studies are more comparable to the models proposed in the present study. Many of the studies undertaken to date were conducted for a particular country involving several transport projects. The intent of this survey is to discuss some of the strengths and weaknesses of these studies and to suggest ways in which they might be improved.

Many of the econometric studies focused on testing the empirical relationship between changes in production and changes in transportation, using linear-regression techniques. The hypothesis of these studies was that the causality runs from transportation to output. The main purpose of these studies has been to estimate and compare the sector- or economy-wide (regional) economic effects resulting from improvements in the transportation supply and to derive appropriate policy responses regarding future transport demand.

In their studies, Walters (1968), Liang (1981), Armano and Fujita (1970), Katzman (1977), and Coatsworth (1980) found significant increases in overall output from improved transport

conditions. Walters, extending the Ellet model put forth in 1836, used a model of transport and development. The Walter's model is a theoretical model and was implemented using data from Liberia and Borneo. Walters found that a 10% decrease in the ton-mile cost of transport resulted in a 10% increase in tonnage transported. He also found an inverse relationship between acreage of cash crops in relation to subsistence crops and distance from the primary market. These results suggest that the crop-production intensiveness is sensitive to the friction of distance.

Liang (1981), using a linear-regression approach, found a consistent tendency for the factor-inputs to increase with improved accessibility when the former were regressed against transport costs. This finding relates to the elasticity of demand with respect to cost for transport, whereby each percentage point decline in transport costs was found to result in a 0.3% increase in average farm output transported. These results were also consistent with the research findings of Walters, although the magnitude of the elasticities are different and are not directly comparable. The statistically significant results of these two studies strongly support the hypothesis of a positive relationship between market accessibility and farm output. The fact that agriculture producers respond favorably to improvements in the transportation supply is further evidence of producers responding to economic incentives with additional factor inputs and increased output. Hofmeir (1970)

in Tanzania, Katzman (1977) in Brazil, and Coatsworth (1979) in Mexico, also found significant increases in output with decreasing friction of distance, particularly when they examined the expansion of the railway and highway systems. In these empirical studies, a positive correlation was shown to exist between changes in economic output and transportation improvements, as profit-maximizing producers respond to economic incentives in a competitive environment.

While the empirical findings of the econometric studies presented above are impressive, several key issues were left unanswered. First, the analysts failed to consider what level of investment in transport infrastructure would be required to induce changes in agricultural production. Second, they also failed to consider how much time would elapse before the effects of improved transport accessibility are transmitted into additional output. Third, the analysts did not consider the role of producer prices along with improved transport conditions in stimulating additional output. Finally, they did not specify whether the responses of producers to economic incentives (e.g., reduced transport costs) are short-run or long-run responses and how these responses vary among different crops.

The present study incorporates the theoretical assumptions of the above empirical studies and improves upon the models by introducing additional model specifications, each of which will be discussed in Chapter III. These improvements are intended to address the issues that were neglected by other researchers.

SUMMARY AND CONCLUSIONS

This chapter presented a review of some of the theoretical, methodological, and empirical studies in the transport and development literature. Chapter II had three purposes in mind. First, to demonstrate that a theoretical basis exists to conduct the present inquiry. Second, to outline the principal analytical research methodologies used for policy analysis. Third, to show that rigorous analytical techniques are available to the researcher under certain circumstances to facilitate the research.

The discussion in Part I on the theory of transport and development revealed that no one theory adequately addresses all of the fundamental economic issues of how transport affects economic growth. Moreover, it was discovered that the theory of transport and development is derived from many areas of economic theory. Such theories as location theory, international and interregional-trade theory, spatial-price theory and factor-mobility theory have all made noteworthy contributions to our understanding of the relationship between transport and development.

The economic framework for analyzing transport and its impact on economic activities was presented in Part II. It was observed in the transport literature that the transport-demand approach was commonly used in impact analysis; although it was revealed that the producer-surplus approach offered a

broader research approach. The basic difference between the two analytical approaches is that the transport-demand approach emphasizes estimates of the demand for transport based on net reductions in road-user charges. The producer-surplus approach, on the other hand, focuses on estimating the net additions to agricultural output induced by transport investments or changes in transport capacity. The producer-surplus approach was found to be a stronger analytical approach than other methods for use in remote agricultural regions because it does not rely on traffic levels to estimate benefits or economic effects. As a result, the analytical framework adopted for the present study is the producer-surplus approach.

While there are many advantages to each of the analytical research techniques discussed in Part III, most of the analytical research methods presented were found to exhibit methodological problems that restrict their usefulness for the present study. A summary of their advantages and disadvantages are presented in Table II-1.

The empirical studies presented in Part IV offered evidence indicating that reduced friction of distance induced additional production in the areas surrounding the transport facility. These studies confirm the theoretical proposition that there is a positive relationship between transportation infrastructure and changes in economic activity (such as agriculture). The studies also presented empirical evidence showing that the changes in economic activities induced by changes in the trans-

TABLE II-1

ANALYTICAL RESEARCH TECHNIQUES:
THEIR ADVANTAGES AND DISADVANTAGES

TYPE	ADVANTAGES	DISADVANTAGES
SOCIAL COST-BENEFIT ANALYSIS	<ul style="list-style-type: none"> • Measures primary impact of specific project • Can incorporate a social welfare objective 	<ul style="list-style-type: none"> • Use of shadow prices • Use of discount rate • Cannot measure secondary effects • Cannot aggregate across projects
INPUT-OUTPUT (STATIC) MODELS	<ul style="list-style-type: none"> • National & regional application • Fulfill resource consistency check • Strong analytical capability • Can be linked to simulation & LP models 	<ul style="list-style-type: none"> • Instability of technical coefficients • Technical coefficients must be recalculated for new industries • Requires large data base • No substitution of inputs
LINEAR PROGRAMMING MODELS	<ul style="list-style-type: none"> • Fulfill resource consistency check • Strong analytical capability • Computational feasibility • Reliability 	<ul style="list-style-type: none"> • Does not permit cross-hauling • Instability of programming solution • Ignores joint products • Requires large data base
SIMULATION MODELS	<ul style="list-style-type: none"> • Strong analytical capability • Can model behavior relationship • Can incorporate sub-models such as I-O model 	<ul style="list-style-type: none"> • Requires an input-output matrix • Costly to implement • Requires experienced researchers • Requires large data base
ECONOMETRIC MODELS	<ul style="list-style-type: none"> • Can model behavior relationships • Strong analytical capability • Can use pooled time-series & cross-sectional data • Strong forecasting and simulation capability 	<ul style="list-style-type: none"> • Requires strong theoretical foundation • Solutions for missing data relies on subjective judgement • Autocorrelation problems with time-series data • Misspecification of model produces biased parameters

portation system can be traced through to the factor markets, such as specific increases in labor and land cultivation. However, the empirical studies discussed above did not go far enough as we discovered in examining the relationship between transport and economic development because they neglected several important behavior issues in their analyses.

The next chapter will further explore the transport and development models developed by Liang (1981) and suggest ways in which these models can be improved. The chapter will outline the Liang models and describe three additional empirical models that can be used to analyze the relationship between net additions to agricultural production and improvements in transport conditions. The models that will be proposed are extensions of the Liang models and are used to examine the effects of transport investment and transport accessibility on production and on factor utilization.

CHAPTER III

A MODEL OF TRANSPORT AND AGRICULTURAL DEVELOPMENT

PART I. INTRODUCTION

Brown and Harral (1966) and Carnemark et al. (1976) in a more recent World Bank paper suggested a different analytical framework than the usual transport-demand approach that has guided transport investment policies in low-income countries for the last twenty-five years. As we discussed in Chapter II, the widely-applied transport-demand approach is concerned with estimating the direct primary benefits that accrue to users of an improved transport facility (e.g., roads, railway links, bridges, etc.) through reduced transport costs. We referred to such benefits as savings in vehicle-operating costs (e.g., fuel, maintenance, tires, etc.).

While the reduction in transport costs is still an important consideration for transport investment policy, the analytical approach suggested by Carnemark et al. (1976) does not consider transport cost reductions as the primary objective of transport investment policy. They proposed, instead, a general analytical framework that is production oriented, as we demonstrated in the previous chapter. Their production-ori-

ented approach to transport investment policy treats savings to road users as only one of the derived benefits of improving transport conditions. Their primary focus is on estimating the changes in production, as in the case of agriculture, and other economic impacts, such as those on employment, on land cultivation, rural-to-urban migration, etc.

Transport economists fully recognize the intimate relationship between transportation and the agricultural sector in low-income countries. However, very little applied research has been done to date to formulate transport investment policies within the producer-surplus framework suggested by Carnemark et al. (1976). One notable exception is a recent study by Liang (1981). He attempted to estimate the economic effects on the agricultural sector that emanate from improvements in transport conditions. The author used econometric models to demonstrate the empirical relationships between railway construction and changes in agricultural production and the use of factors of production. He showed, apart from changes in production, how the benefits from investments in the transport sector can be measured in terms of specific impacts on such factors of production as employment, changes in capital stock, land cultivation, fertilizer usage, irrigated and nonirrigated cropped area, etc.

Although a statistically important connection between the performance of the agricultural sector in terms of produc-

tivity and growth and the expansion of the railway system was clearly exposed by Liang, at least four important issues were overlooked. These are: 1) what is the time lag before the effects of improved transport access are transmitted into additional output; 2) is there a specific magnitude of investment in transport infrastructure required to induce a certain level of agricultural output; 3) what is the impact of producer prices on agricultural output; and 4) how does the short-run and long-run responses of producers to better transport access and producer prices vary among different crops and for a particular crop. Three econometric models are proposed in this chapter to demonstrate how such issues can be specified for empirical analyses.

The present chapter is presented in two parts. Part I is devoted to a brief discussion of the empirical specifications of Liang's (1981) model of transport accessibility and agricultural production and his model of transport accessibility and factor utilization. The section focuses on the hypothesis of the models; their descriptive and functional forms; their estimation techniques, and data employed.

In Part II, three empirical models are proposed. The models are production oriented and follow the general econometric approach suggested by Liang (1981), but, as a departure, additional explanatory variables using time-series data are proposed. The first model relates a distributed-lag func-

tion of transport investments to the production of rubber, coffee, cocoa, and palm kernels. The second model examines the relationship of transport accessibility to different export crops. The final model is concerned with factor-input utilization and assesses the disaggregated effects of transport accessibility on such factors of production as employment and land cultivation. The extensions to Liang's models are designed to represent a more dynamic response of producers to economic incentives induced by better market accessibility as well as to set forth a methodology that is more consistent with observed economic behavior.

LIANG'S MODELS OF TRANSPORT AND DEVELOPMENT

The first transport model by Liang (1981) is presented below. The model describes the relationship between transport accessibility and agricultural growth. The model is an econometric model that uses cross-sectional data from China. The data consisted of average farm output, factor inputs, and an index of accessibility defined as the total cost of transporting a ton of farm products from the local market to the regional market.

The hypothesis of Liang's accessibility model is that farm productivity, which he defined as total farm income from agricultural production, is positively related to the accessibility of (or negatively related to the total cost of trans-

fer from) the farm to the nearest (economic distance) regional market. This, he reasoned, results from increases in accessibility, which tend to induce both higher levels of factor-input employment and a more efficient utilization of resources in farm production, as measured by factor-input intensities.

This empirical relationship was estimated by fitting an equation to the empirical data using the ordinary least-squares regression technique. The model is expressed in natural logarithmic form as:

$$\ln Y^* = \ln c + \lambda \ln T$$

Where: $\ln Y^*$ = average farm output for rice and wheat (1933)

λ = elasticity of farm output with respect to total transfer cost

$\ln T$ = total transfer cost to market

$\ln c$ = a constant parameter

Carnemark et al. (1976) suggested in their producer-surplus model that improved transport facilities and, as a result better market access, effectively raise prices to producers through savings on output transported and factor inputs, such as fertilizers, tree plantings, farm equipment, etc. The second model by Liang (1981) of the disaggregated effects of improved accessibility on individual factor inputs showed that the elasticity of the factor input to accessibility was positive. The functional form of the model was specified in natural logarithmic form as:

$$\ln X_i = \ln c_i + \beta_i \ln T \quad i = (1, \dots, 7)$$

Where: $\ln X_i$ = ith factor input (cropped area; labor; cultivated land; irrigated cropped area; nonirrigated cropped area; fertilizers, and value of farm buildings)

$\ln c_i$ = a constant term

β_i = the elasticity of the factor input use with respect to transport cost

$\ln T$ = transfer cost (transport cost variable)

The factor-input and accessibility model is represented by an equation that shows how producers respond to economic incentives (e.g., reduction in transport costs and reduced factor-input costs, etc.). The model is specified by Liang (1981) in this manner to determine whether there is a consistent tendency of factor inputs to respond positively to improved transport facilities and whether this tendency reflects an increase in the factor inputs. The model was fitted to an equation of empirical data using the ordinary least-squares regression technique. The factor inputs were specified as the dependent variables in the model. The independent variable was specified as the transport costs in each of the two regions. The regression results indicated that factor-input levels rose with improved transport accessibility and revealed that the estimated coefficients were significantly different from zero at the usual levels of significance.

As we observed in Chapter II, it is generally accepted in the transport and development literature that the effect of lowering unit transport costs can be traced through the product and factor markets. Under a system of perfect competition, lowered factor-input costs are passed on to producers as savings such that profit-maximizing producers adjust their factor-mix to increase production, Schultz (1964) and Wharton (1970). This increase in output provides additional income because the price per unit of output has increased. The models presented above by Liang attempted to capture the responses of producers to improved transport access by measuring the change in production and factor utilization.

It should be kept in mind that it is possible that technological changes or factor intensities may not be large enough to affect changes in agricultural output significantly in all cases. Factor inputs, such as new seed varieties, fertilizers, higher yielding species (e.g., rubber trees, coffee plants, etc.), and better farm tools and equipment may be imported and, thus, they may be too costly to be offset by reduction in transport costs. Additionally, the scale of production (i.e., limited land area) may be too small for additional factor inputs to increase production significantly. Should these conditions exist, better market access as a result of transport infrastructure improvements may not cause producers to increase their

output significantly, because the reduction in transport margins may be too small even in a competitive market to have a noticeable effect on production.

PART II. A MODEL OF TRANSPORT AND AGRICULTURAL DEVELOPMENT

The existence of a positive correlation between transport accessibility and agricultural output was clearly demonstrated in the studies by Liang. The models suggested by Liang because of their focus on changes in output and factor inputs represent an improvement over the traditional transport-demand approach. The functional forms of the Liang models, in terms of how the models were specified, indicate areas where the models can be improved. The models, particularly the accessibility and agricultural production model, omitted some key issues from the inquiry. These issues are: 1) the absence of an appropriately lagged transport variable to represent short- to long-term time adjustments by agricultural producers as they adjust their factor mixes to changing transport conditions;¹ and 2) the omission from the model of the extent to which producer prices affected output. A model using time-series data that incorporates these and other features is proposed below.

¹/ Bateman (1970) in his survey article indicated that three different producer responses with respect to economic incentives are distinguishable for perennial crops. The first is the farmer response at harvest time to the current prices. This response occurs over a time period too short for new plantings to come into bearing. The second response is to lagged prices. The third response is a long-run response which allows for adjustment lags.

The analytical framework adopted for the present research follows the producer-surplus approach suggested by Carnermark et al. (1976) and the cross-sectional econometric models introduced by Liang (1981), but departs by introducing several improvements and extensions. The improvements are designed to capture the behavior responses of producers to transport accessibility and producer prices by setting forth a broader analytical framework for analyzing the economic effects of development impacts. These impacts are measured as additions to agricultural output.

The purpose of this inquiry is to estimate the economic effects of improvements in transport conditions and price changes on agricultural output. While cost-benefit analysis, as we indicated in Chapter II, has been the usual method used to estimate such effects, the econometric model is used in this study because it offers more flexibility than the cost-benefit method in the research design and in the analysis of broader development impacts.

In this chapter, three models that extend the accessibility and agricultural production model and the transport accessibility and factor-utilization model introduced by Liang (1981) are proposed. The models are the transport-investment model, the transport-accessibility model, and the factor-input model.

The main features of the proposed models are the following:

- 1) The transport-investment variable is introduced as an explanatory variable and is specified with a polynomial-distributed lag form in the transport-investment model.
- 2) The transport-accessibility variable represents physical units expressed as nonurban miles of roads.
- 3) The producer price variable of agricultural output is explicitly incorporated into the transport-investment and transport-accessibility models.
- 4) The models are implemented using time-series data. The transport-investment model will use annual data of transport investments, producer prices (both deflated), and total crop production for different crops. The transport-accessibility model will use annual data of nonurban road mileage, annual crop production data for different crops, and real producer prices. The factor-input model will use annual data of nonurban road miles, employment, and cultivated land.

These features improve upon Liang's (1981) models by addressing key issues overlooked by Liang and other re-

searchers. The first model to be presented is the transport-investment model.

BASIC ORGANIZATION OF THE TRANSPORT-INVESTMENT MODEL

As mentioned above, the basic structure of the proposed time-series transport-investment model follows the cross-sectional econometric model suggested by Liang (1981). The proposed model extends and improves upon Liang's model of accessibility and agricultural production in three of the areas that he neglected to consider. The first extension of the Liang model relates to the use of a distributed-lag function. The proposed model expresses agricultural production as a function of a polynomial-distributed lag of transport investments. The distributed lag is of the Almon (1965) type and is intended to capture the distributed effects of investments in transportation infrastructure over time and the behavior response of producers to improved transport conditions. The choice of the Almon distributed lag over other distributed-lag forms is discussed later in this chapter.

The second extension is the use of investments in transportation infrastructure as an explanatory variable rather than transfer cost as Liang did. The transport-investment variable is deflated by the Liberian implicit GDP price deflator to reflect investments in real Liberian dollars. The rationale for using transport investments to explain changes in agricultural

production is derived from the theory of transport and development. The rationale is based on the precept that the primary objective of transport investments is to relieve the friction of distance between spatially-separated markets for goods and services and to facilitate the convergence in space of the supply and demand for the factors of production and for new output. Economic theory holds that improved transport conditions, as a result of new investments, reduce the cost of transporting output and the factors of production. Reduced transport costs release investment capital for use in other economic activities.

Regarding the implications of transport investments for public policy, the level and location of investments in transportation, and maximizing social welfare is what is important in terms of resource allocation. There are no golden rules as to how much of the national budget should be allocated to the transport sector. The decision as to how much to invest in the transport sector is a complex function of the country's land mass and formulation, the social and economic organization, the location of resources, the stage of economic development, previous investments, dependency on foreign trade, and other factors (Kaufmann, 1962). However, several studies of public expenditures indicate that developing countries allocate between 20 to 35 per cent of their national budgets to the transport and communications sector (Owen, 1959; Lall, 1969; and Bejakovic, 1970). The magnitude of such large budgetary shares

alone suggests the need to focus public-policy analysis on the economic impacts of transport expenditures. In spite of such large financial commitments to the transport sector, the literature is replete with ambiguities, as we indicated in Chapter I, regarding the specific policy role of transportation investment in the national economic development process.

A model that explicitly incorporates transport investments over time as an explanatory variable should inform policy by addressing the issue of the magnitude of investments and the short- and long-term impacts on the agricultural sector. The fact that transport-cost margins are usually between five and ten per cent of the production cost in many low-income countries poses an interesting challenge for policy research. Transport investment policy would have had to reduce these transport cost margins significantly to induce significant agricultural output. The main issues for policy are what are the economic consequences of transport investments and how are these impacts distributed over time?

The third extension is the explicit treatment of agricultural prices as a second independent variable in the transport-investment model. The responsiveness of agricultural producers to producer prices will be expressed as the supply elasticity or the proportional changes in real prices against changes in output. Because economic theory holds that quantity supplied is an increasing function of price, the expectations are that the supply elasticity will be positive. The price variable

is expressed in 1975 constant U.S. cents and combined with current and past investments in transport infrastructure to represent economic incentives to which rational producers are believed to favorably respond.

The descriptive form of the transport-investment model is:

$$Y_t = f \left(\sum_{j=0}^s T_{t-j}, P_{it} \right) \quad \begin{array}{l} t = (1, \dots, 31) \\ i = (1, \dots, 4) \end{array}$$

- Where:
- Y_{it} = agricultural production in year t of the ith crop
 - $\sum_{j=0}^s T_{t-j}$ = transport investment as a polynomial distributed-lag type to account for adjustments by producers to improved transport access
 - P_{it} = the producer price of the ith crop in year t
 - i = crops (rubber, coffee, cocoa, and palm kernels)
 - t = year
 - j = number of periods over which the lag is distributed
 - s = end period of the lag

The functional form of the model is expressed in natural logarithmic form as:¹

$$\ln Y_{it} = \ln c_i + \lambda_i \sum_{j=0}^s \ln T_{t-j} + \ln P_{it} + \epsilon_t$$

¹/ The model is assumed to be linear in the parameters c_i and λ_i and linear in the logarithms of the variables, Y_t , T_{t-j} and P_t . Ln equals the natural log to the base e, where $e = 2.718$.

Where: $\ln c_i$ = a constant parameter to be estimated
 λ_i = elasticity of the i th crop with respect to transport investments
 ϵ_t = an error term assumed to be normally distributed over the time horizon

The transport-investment model will be estimated using annual data from Liberia and the ordinary least-squares regression technique. The data will consist of agricultural production statistics of rubber, coffee, cocoa, and palm kernels from 1950 to 1980. The transport-investment data are deflated by the Liberian GDP price deflator. The data series include both public and private investments in the transport sector for non-urban primary, secondary, and rural roads plus port and terminal facilities. The price of each crop is the producer price in constant 1975 U.S. cents for all tree crops in the study for a given year. The time-series data used in this study are presented in Appendix C.

Hypothesis of the Model

The transport-investment model is based on a reformulation of the hypothesis discussed earlier in Liang's transport accessibility and agricultural growth model. The model focuses directly on changes in agricultural output and the level of transport investments instead of farm income and accessibility.

While the availability of data accounts for some of the revision, the more fundamental issues relate to measurable changes in agricultural output for different crops and the dynamic response of producers induced by transport investments and agricultural prices. However, it might be possible that international commodity price fluctuations cause farmers to increase output due to falling prices. Thus, incremental increases in production could have occurred but the net income to farmers may have fallen. Therefore, as profit-maximizers, farmers would have to produce more to maintain their net income. If such were the case, it would have been reasonable for the research focus to be on farm income. This research approach is beyond the scope of the present study.

The hypothesis of this research is that agricultural production, measured as changes in agricultural output, is positively correlated with a distributed lag of investments in transportation infrastructure and of producer prices.¹ This result tends to induce additional agricultural production that can be measured over time as the transport investment impacts take effect. Such economic effects can be measured both for short- and long-run producer responses.

1/ This hypothesis does not consider the case when the elasticity of supply of a crop is influenced by crop substitution or alternative uses of resources, such as growing rubber instead of coffee or food production for home consumption.

Assumptions of the Transport-
Investment Model

As we discovered in Chapter II, unless markets are competitive, savings from improved transport conditions may not be passed on to producers and consumers. Because of this, the transport-investment model incorporates the normal neo-classical assumptions of perfect competition, of constant returns to scale, and that agricultural producers and transportation providers are profit-maximizers.

Because the price elasticity of supply, although positive, may vary according to the type of crops involved, the various tree crops examined in this study are assumed to be affected differently by improved transport conditions, such as new roads, and by producer prices. The transportation of low-value export crops are normally affected by the crop's weight content, distance to market, and production cost. The price of these export commodities are assumed to be influenced primarily by the equilibrium price conditions in international competitive markets and are unaffected by local supply.

A final assumption of the model is that the structure of the lag is of a polynomial-distributed lag type, whose length can be approximated by some suitable-degree polynomial of the lag coefficients. Although the shape of the lag is not known, it is assumed to be of the Almon (1965) type whereby the lag structure follows an inverted U-shape with small initial invest-

ments response, then increasing and finally, decreasing. While there are several forms that the distributed lags can take, as will be discussed later in this chapter, the Almon distributed-lag is assumed to approximate the effects of how transport investments are distributed over time.

The basic model will be tested using rubber production as the dependent variable and producer prices of rubber and an Almon-lag of transport investments as the independent variables. Separate models of the same specification will be tested for coffee, cocoa, and palm kernels. Each of the models assumes that there is a time lag between the response of agricultural producers for each crop and when the transport investments are made.

Testing of Significant Relationships

The transport-investment model is concerned with determining whether the relationship between current and past investments in transportation and of producer prices on agricultural production are statistically significant. Specific measures will be undertaken to test the strength of this relationship. The relationship will be estimated by fitting an equation to the empirical data using the ordinary least-squares regression technique. Testing of the model will be in the form of parametric tests of statistical significance (e.g., t-statistic, R^2 , F-statistic) and the Durbin-Watson statistic for serial correlation.

Distributed Lags and
Transport Investments

The relationship of investments in transport infrastructure to increases in agricultural output has been consistently misspecified in other econometric studies of transport and development. Few researchers, if any, took the time to incorporate time lags in their description of the behavior of profit-maximizing producers and transport providers. Time lags are important because they represent a dynamic response of producers to changing market conditions and production requirements. Unless they are first accounted for and then properly specified, the coefficients of the independent variables in the model may bias the effects of transport investments on output by overstating the distributed effect over a number of time periods.

The single-equation model of transport investments and producer prices of agricultural output proposed in this study extends the current methodological approaches by setting forth an explicit treatment of time lags as a distributed lag of the Almon type. A brief introduction to the concept of distributed lags and how the effects are distributed over time is presented next.

It is well understood in transport economics that time is required for producers to adjust their production functions to the changing realities of reduced transport costs (improved accessibility), higher producer prices for their products, and

improved market conditions. By way of illustration, if the time lag is taken as some constant, namely θ , the agricultural output that responds to transport investment can be represented as a lag θ (Johnston, 1972). Consider the following reduced-form model, as previously discussed, where agricultural output (Y_t) is a function of some lagged transport-investment function ($T_{t-\theta}$):

$$Y_t = f(T_{t-\theta})$$

The relationship can then be written as the following equation:

$$Y_t = \alpha + \beta T_{t-\theta} + \epsilon_t$$

However, the above relationship assumes that the effects of the transport variable ($T_{t-\theta}$) appears only within period t and is fully exhausted within that period. Such an assumption is unrealistic for large-scale, capital-works projects because it is known that capital expenditures for transport infrastructure (i.e., roads, port facilities, etc.) normally require several years to be fully disbursed. Such expenditures are often disbursed on a construction schedule that seems to approximate an inverted U-shape. For example, in the case of road maintenance or road rehabilitation, as investments are disbursed, the condition of the facility improves up to a particular point and, as traffic increases, the facility declines.

By way of further introduction to the distributed lag, consider the fact that Johnston (1972) thinks of the time relationships in terms of a causal force T_t producing a component $\beta_0 T_t$ in Y_t , a component $\beta_1 T_t$ in Y_{t+1} , and so on up to $\beta_s T_t$ in Y_{t+s} where Y_{t+s} is the end period of the lag. If this system remains constant over time, then the value of Y in any period may be expressed as a linear function of current and past values of T . This function can be expressed mathematically as:

$$Y_t = \alpha + \beta_0 T_t + \beta_1 T_{t-1} + \dots + \beta_s T_{t-s} + \epsilon_t$$

This equation can be rewritten as:

$$Y_t = \alpha + \sum_{i=0}^s \beta_i T_{t-i} + \epsilon_t$$

The second expression on the right-hand side of the model represents the usual distributed lag which, in this study, is a finite s -period lag. That is to say, the length of the lag period can be predetermined based on agronomic information about the tree crops involved. The structure of the lag is assumed to be of the form of some n -degree polynomial-distributed lag with no end-point restrictions (Almon, 1965).¹ The Almon distributed lag will commonly produce an inverted U-shape of the lag structure because the end-points are restricted

¹/ End-point restrictions are the assumed values of the first and last lag weights in the polynomial functions. In the Almon distributed-lag model, the choice of whether to restrict the end-points is optional. Restricting the end-points in the polynomial function involves setting the first and last lag weights to zero.

(Pindyck and Rubinfeld, 1981). The lag coefficients first show an increasing and then a decreasing trend.

The Almon lag appears to be more consistent with the practical experience of capital-works projects. However, it should be pointed out that distributed lags can take on several different shapes, as Solow (1960) and Griliches (1967) indicate. The shape of the lag structure can take the form of a geometrically declining weights of the Koyck (1954) type. They can also take the form of a Pascal distribution as Solow (1960) discovered or they can take the form of an inverted V-shape of the De Leeuw type (1962). Additionally, the lag distribution can take the form of a rational distributed-lag function of a two-ratio polynomial type, suggested by Jorgenson (1966). Griliches (1967) argues that most distributed lag models have almost no or only a very weak theoretical underpinning. He further suggests that the form of most lags are assumed a priori rather than derived as an implication of a particular behavioral hypothesis.

One advantage, however, of the Almon polynomial-lag structure over other distributed lags is that it provides a more flexible method of incorporating a variety of lag structures. Another advantage is that we do not have to worry about the presence of the lagged dependent variables as an explanatory variable in the model and the problems it creates of biased parameter estimates.

Because serial correlation is likely to be a problem as is often the case with distributed-lag models, the above model makes the classical linear-regression assumption of independence of T and ϵ and that the ϵ 's are normally distributed. Hence, the least-squares estimate will give the best linear unbiased estimate.

It is also well known (Pindyck and Rubinfeld, 1981), however, that if the ϵ 's are serially correlated, the least-squares estimate of T will be biased. Should serial correlation present a problem, Griliches (1967) has surveyed several remedial measures for overcoming this difficulty and has devised expressions for the asymptotic bias of least-squares estimates caused by the serial correlation of the ϵ 's.

The technique for estimating a polynomial distributed-lag model is based on Weierstrass' theorem that a function continuous in a closed interval can be approximated over the whole interval by a polynomial of suitable degree, which differs from the function by less than any given positive quantity at every point of the interval (Johnston, 1972). The mathematical procedure for estimating the Almon distributed lag is illustrated in Appendix A.

THE TRANSPORT-ACCESSIBILITY MODEL

As discussed earlier in this chapter, the main concern of this study is with the economic effects of transport investments on agricultural activities. Another way of approaching this problem is to assess the extent to which improved trans-

port facilities (e.g., roads, ports, etc.) have a direct influence on productive activities. It is generally believed that new investments in transportation infrastructure resulting in increased accessibility or decreasing friction of distance lead to measurable economic changes such as those occurring in agriculture. This is evidenced by the fact that the development of transport facilities reduce appreciably the unit transport cost of crop production and expands the market for such goods. Studies have shown that improved accessibility to agricultural markets increases average farm output (Wilson, 1965; Carnemark, 1976; and Liang, 1981).

Additionally, an inverse relationship between acreage of cash crop and distance from the primary market was found by Walters (1968). This result suggests that crop production is sensitive to the friction of distance.

The discussion that follows presents an empirical model of the impact of accessibility and agricultural prices on output. The model is based on Liang's model of transport accessibility and agricultural production (1981). The proposed model is consistent with the producer-surplus approach because it emphasizes the additions to agricultural production. Additionally, the model addresses the issue of the effects of producer prices on agricultural production when it is combined with improved market access. Liang's model is modified for present purposes to take into account the producer's response to both producer-

price changes and accessibility, measured in additional miles of roads. The model is formulated to test the strength of this relationship and to set forth a more consistent behavior model of the responses of agricultural producers when conditions for marketing production improve. This would be the case when roads are built or improved.

The descriptive form of the model is as follows:

$$Y_{it} = f(NR_t, P_{it}) \quad \begin{array}{l} t = (1, \dots, 31) \\ i = (1, \dots, 4) \end{array}$$

Where: Y_{it} = agricultural production in year t of the i th crop, million lbs.
 NR_t = the number of miles of nonurban roads in year t
 P_{it} = the producer price of the i th crop in year t , cents per lb.
 i = crops (rubber, coffee, cocoa and palm kernels)
 t = year

The functional form of the model is expressed in natural logarithmic form as:

$$\ln Y_{it} = \ln c_i + \lambda_i \ln NR_t + \ln P_{it} + \epsilon_t$$

Where: $\ln c_i$ = a constant parameter to be estimated
 λ_i = the elasticity of the i th crop with respect to nonurban roads
 ϵ_t = an error term assumed to be normally distributed over the time horizon

The transport-accessibility model hypothesizes that improved transport access stimulates producers to increase their output such that decreasing friction of distance positively influences production activities. The extent of this economic effect, as measured by additions to output, is a direct function of the degree of accessibility.

The hypothesis of the transport-accessibility model will be tested with the ordinary least-squares regression method using annual data of agricultural production statistics of rubber, coffee, cocoa, and palm kernels. The data profile consists of officially-published secondary data from Liberia and covers the period from 1950 to 1980. The transport-accessibility variable will be based on annual nonurban road mileage of primary, secondary, and rural roads. The price variable represents the real producer prices for each crop based on the annual volume and value of production.¹ The data series and sources of data are contained in Appendix C. Testing for statistical significance will be in the form of parametric tests using the F-statistic, t-statistic, R^2 , and the Durbin-Watson statistic for serial correlation.

THE FACTOR-INPUT MODEL

Liang (1981) in his factor-input and accessibility model found that improved transport conditions, which resulted

¹/ The effects of producer prices on agricultural supply were disregarded in Liang's (1981) model of transport accessibility and agricultural production.

in decreasing friction of distance, induce the use of additional production inputs. He tested the extent to which increased accessibility causes additional factor inputs to be used in production. A decrease in transportation cost in El Salvador of 20 per cent was found to make 20 per cent more land available and increased employment by 38 per cent (Churchill, 1972). Such factor-augmenting effects of improved accessibility on factor utilization are represented in the following model based on the model suggested by Liang (1981):

$$\ln X_{jt} = \ln c_j + \lambda_j \ln NR_t + \epsilon_t \quad \begin{array}{l} j = (1 \text{ and } 2) \\ t = (1, \dots, 31) \end{array}$$

Where: $\ln X_{jt}$ = the j th factor input in year t
 $\ln c_j$ = a constant term to be estimated
 λ_j = elasticity of the j th input with respect to road mileage in year t
 $\ln NR_t$ = number of miles of nonurban roads in year t
 ϵ_t = an error term assumed to be normally distributed over the time horizon
 j = factor inputs (cultivated land and agricultural employment)
 t = year

The factor-input model hypothesizes that there is a consistent tendency of agricultural producers to utilize additional factors of production as transport conditions improve.

The factor inputs (X_j 's) are the dependent variables in the model and consist of cultivated land and agricultural employment. The independent variable in the model is the number of nonurban miles of roads.

In the present study, the effects of accessibility on individual factors of production will be fitted to an equation of empirical data using the ordinary least-squares regression technique. The data that will be employed to implement the model are from Liberia and consist of annual data of employment in rubber production and land cultivated for rubber production. The data cover the period from 1950 to 1964 and are presented in detail with a source list in Appendix C.5.

Testing of significant relationships of the factor-input model will be in the form of parametric tests of statistical significance using the F-statistic, t-statistic, R^2 , and the Durbin-Watson statistic for serial correlation.

SUMMARY

Part I presented two empirical models of the relationship between: transport accessibility and agricultural growth, and accessibility and factor-input intensity. These models were formulated by Liang (1981) and applied to cross-sectional data of rice and wheat production in China. The models were fitted to empirical data using the ordinary least-squares regression method. The empirical regression results revealed

that the strength of the relationships was statistically significant at the usual levels of significance in each of the models. The importance of Liang's findings to the present research is that they demonstrated that an empirical model can be specified to measure specific economic changes in the product and factor markets as rational producers respond to improved transport accessibility.

Part II discussed how the Liang models could be improved by introducing additional explanatory variables and setting forth a more consistent behavior model of the interaction of transport and agricultural development. Liang (1981) measured the resulting effects in terms of changes in total output and utilization of additional factor inputs.

A polynomial distributed-lag transport-investment model that incorporated both accepted theoretical knowledge and methodological practice for analyzing the relationship between past and current transport investments and of producer prices on agricultural output was presented in Part II. The model will be used to test the strength and functional form of this relationship.

Economic theory holds that, under perfect competition, the effects of reducing transport costs and price effects are traceable through the factor and product markets, which, in turn, stimulate producers to increase their output. As unit transport costs decline, assuming appropriately high transport

demand elasticities, lower transport rates are expected to benefit agricultural producers and transport providers in a perfectly competitive market. In practice, however, several important considerations must be taken into account when modeling such behavior effects. The first of which is the time lag between the time the transport investments are made and when producers increase their output. Time lags represent the short-run and long-run behavior of producers. They allow producers to adjust their production factors on the basis of current and future market expectations and transport conditions. Second, the functional form of the model must be properly specified such that specification bias is absent and the relevant independent variables (e.g., prices, transport investments, etc.) are incorporated into the model based on an informed behavior hypothesis. Both producer prices and the distributed lag of transport investments are consistent with the economic theory that they exert an influence on output. Finally, sufficient empirical data must be available to model and test the strength of the empirical relationships.

What distinguishes the proposed transport-investment model from the more recent empirical studies of Liang (1981) and Coatsworth (1980) is that it satisfies the above considerations and further extends the models by addressing four research issues that others neglected in their research. First, is there a particular magnitude of transport-cost reductions required

to induce producers to increase output? Second, how should the time lags of producer response be represented in the model in terms of their structure and length of the lag? Third, if producer prices are represented in the models, what impact does this have on output? Finally, what are the short-run and long-run supply responses of producers of different crops?

The transport-investment model will be implemented in Chapter V using the ordinary least-squares regression technique and applied to annual production and price data of rubber, coffee, cocoa, and palm kernels from Liberia. Other econometric models of this relationship have represented the transport variable directly as unit transport costs rather than as transport investments, as the proposed model does. Because of this, additional assumptions such as the shape of the transport-investment function and the length of the lag distribution were explicitly incorporated into the model.

The second model proposed was the transport-accessibility model. The model will focus on the impact of the physical development of road infrastructure and the producer price effects on agricultural output. The model derives its inspiration from the transport-investment model, but it is concerned with how investments in transport infrastructure expressed as physical units of road mileage affect output. The model departs from previous empirical models by explicitly incorporating producer price changes for agricultural goods as an independent variable

into the model. The accessibility model will be implemented in Chapter V as an econometric model that uses the ordinary least-squares regression method.

The factor-input model was proposed to assess the disaggregated effects of accessibility on individual factors, such as employment and cultivated land, in the production of rubber in Liberia. These factors are specified as dependent variables in the model. The model is consistent with previous empirical studies of this type but, as a departure, uses physical units expressed in road miles as the independent variable instead of transport cost. The factor-input model will be implemented by fitting an equation of empirical data using the ordinary least-squares regression method. The model will employ time-series (annual) data from Liberia.

The next chapter discusses the historical development of the Liberian economy over the period from 1950 to 1980. The chapter assesses the growth of Liberian Gross Domestic Product (GDP) and examines the specific contributions that the agricultural and transport sectors made to the GDP during the period under study.

CHAPTER IV
TRANSPORTATION, AGRICULTURE AND
THE ECONOMY: AN OVERVIEW

PART I. INTRODUCTION

Chapter IV reviews the historical development of macro-economic trends and sectoral growth patterns in Liberia over the period from 1950 to 1980. The primary focus of this chapter is to analyze the main sectors of the economy in terms of their impact on the Liberian Gross Domestic Product. The chapter is concerned with the evolution of the transport and agricultural sectors with a view towards determining what impact these sectors have had on national income.

This chapter is intended to serve as the link between the theoretical models of transport and development in Chapter III and the empirical studies that will be conducted in Chapter V. This is accomplished by introducing real world economic phenomenon such as the historical changes to the transport system and changes in the agricultural sector. Good public policy must be formulated within the constraints imposed by objective reality. As such, it is essential to provide, as the present chapter does, the historical development context within which public policy decisions were made in order to devise ways in which these policies can be analyzed and improved.

The chapter is divided into three parts. Part I presents a brief background discussion of the geographical features, people, political economy, and political history of Liberia. It then goes on to outline the structure of the Liberian economy with a focus on the national income and product accounts.

Part II examines the multimodal transport sector of Liberia and seeks to determine which mode(s) of transport were more critical than others to the development of the economy. The section describes the historical development of the transport system and assesses the trends in transport investment policies, transport revenue, and transport financing.

Part III analyzes the agricultural sector. Its purpose is to determine which export crop or crop mix was more important than others to Liberia's export-earning capacity and to assess the relative importance of both commercial and subsistence agriculture to national income. The chapter will examine changes in agricultural production for each of the primary export crops. It will also examine agricultural employment and land cultivation in order to explore how these two factors of production affected the production of rubber.

The data presented in this chapter on the historical development of the agricultural and transport sectors and the data presented in Appendixes B and C will be used in Chapter V to determine if meaningful statistical relationships of these two sectors can be estimated empirically and the extent to which policy inferences can be discerned.

BACKGROUND

Geography

The Republic of Liberia (see Figure IV-1) is situated on the west coast of Africa, north of the equator. It is bounded by the Republics of: Sierra Leone on its northern border; Guinea to the northeast and east, and Ivory Coast to the south, with the Atlantic Ocean to the west. Liberia has a land area of 43,000 square miles of rolling, low bush and forest-covered land and is within Africa's tropical rainbelt. The country receives up to 200 inches of rain each year during the rainy season which lasts from about June to October. Liberia's climate is suitable for growing a variety of tropical crops. It is endowed with considerable natural resources of timber, iron ore, and other minerals in its Nimba, Bomi Hills and Bong ranges.

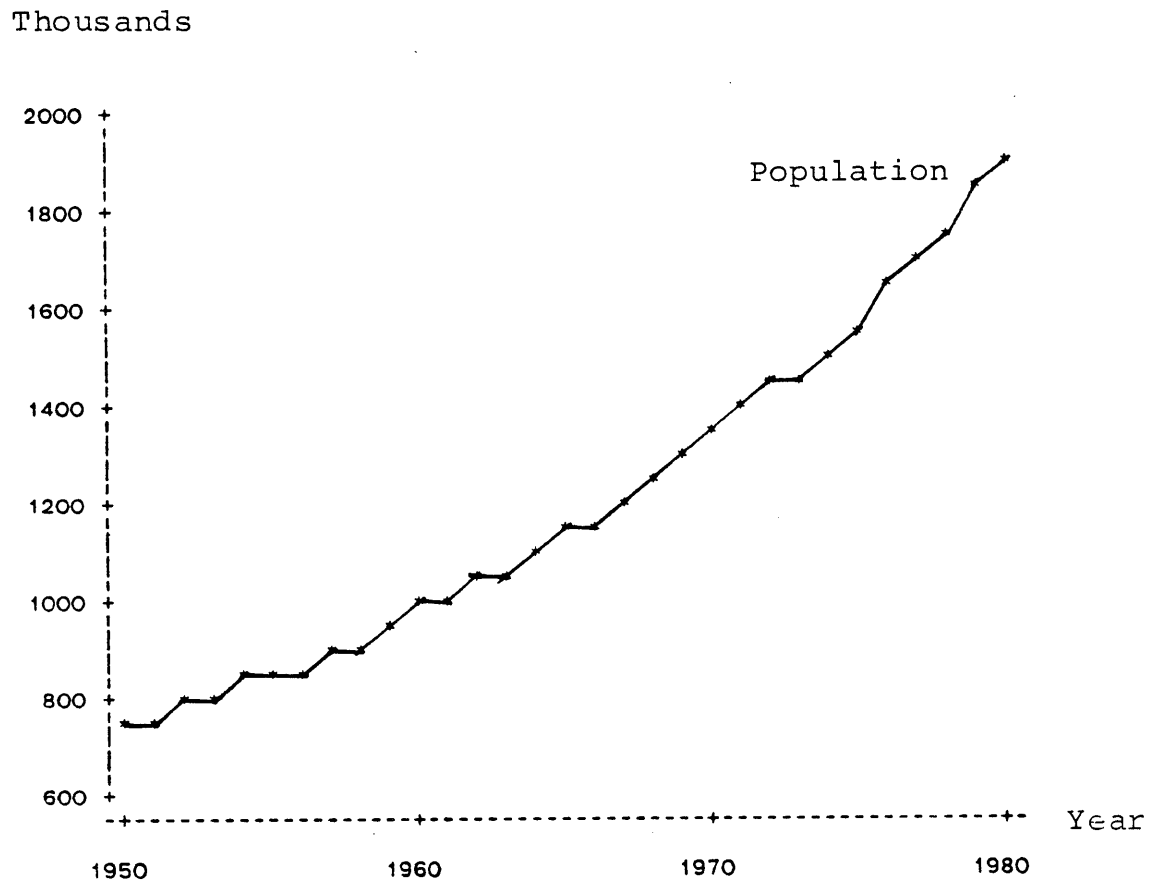
People

A population census was first carried out in 1962 and revealed a population of about one million people. The census showed that the population density was approximately 25 persons per square mile or about 1,075,000 people. In 1980, the population was estimated at 1.88 million people. Figure IV-2 presents the distribution of the population over a thirty-year period.¹

Despite its low population density, Liberia is a country of diverse ethnic, religious, and linguistic groups. The major-

¹/ Figures IV-2 through IV-16 are derived from data contained in Appendixes B and C.

FIGURE IV-2
POPULATION OF LIBERIA, 1950-1980



Source: I.B.R.D. (1980). World Tables, Second Edition, The Johns Hopkins University Press, Baltimore, pp. 124-125.

ity of its population is distributed among sixteen major tribes with each possessing its own tradition, custom, laws, religion, language, and philosophy. The tribes are divided into four groups: the Mande-Fu group; the West-Atlantic group; the Mandetan group, and the Kru group.

In addition to the tribes, there is a minority population of repatriated Africans (known as Americo-Liberians) whose ancestors immigrated during the early nineteenth century to Liberia from the United States under the aegis of the American Colonization Society.¹ These immigrants were freed-American slaves who, in 1847, set up the Republic of Liberia ostensibly with the consent of the indigenous tribal leaders and certainly at the encouragement of the American Colonization Society.

Political Economy

For almost 100 years after colonization had begun, most of the Liberian economy remained untouched by the capitalist economic sphere of influence and most of the territory remained outside of euro-centric political and social organizations and administrative institutions. Wrubel (1971) termed this period one of segmental, intermittent, social segregation--a period in which the colonists (settlers) remained largely segregated from the indigenous population, but occasionally entered into practical relations for trade and defense purposes.

¹/ This was one of several organizations established in the United States in the 1800's to resolve the problem of racism by repatriating people of African descent to Africa.

By the turn of the century, this situation began to change due, in large measure, to external threats by neighboring European colonial powers. Because of these threats, the United States Government became a close ally and later provided military assistance to the Liberian Government.

In 1926, the Firestone Rubber Company became the first multinational corporation to penetrate the country by setting up a large-scale commercial rubber plantation.¹ During the Second World War, the United States built an airbase at Robertsfield and the Port of Monrovia which began operation in 1948. These two events served as the first major impetus that began the process of incorporating Liberia into the web of international capitalism. The discovery and subsequent exploitation of rich iron ore deposits became even more of an important development than the establishment of the Port of Monrovia and Firestone's plantation. The exploitation of iron ore greatly characterized Liberia's path towards a "dual economy."² The production

1/ The Firestone Company of Akron, Ohio was granted in 1926 the exclusive rights (known as a concession) by the Government of Liberia to develop a commercial rubber plantation. The concession agreement entitled Firestone to tax and duty-free privileges, repatriation of profits, tax abatements, etc. Land tenure was for 99 years on a million square acres of land. In return, the Liberian Government was to receive infrastructural development in the concession area and technical assistance for Liberian-owned rubber estates.

2/ Liberia's economy has been characterized as "a double enclave one of an extreme kind, with iron ore and rubber accounting together, for over 50 per cent of monetary gross domestic product." See: Maynard, G. (1970). "The Economic Irrelevance of Monetary Independence: The Case of Liberia", Journal of Development Studies, Vol. VI, No. 2, January, p. 111.

of iron ore and rubber expanded dramatically over the next several decades and together these two resources became the largest contributors to the Gross Domestic Product (GDP).

Political History

The political system of Liberia, up until the establishment of the People's Redemption Council following a military coup in 1980, closely resembled that of the United States.¹ The President, as head of the executive branch of government, was elected to an eight-year term by popular vote. Legislative authority was vested in a bicameral congress representing each of Liberia's nine counties. The judicial system consisted of lower courts and a supreme court, which adjudicated based on a constitution modeled after that of the United States. Although the constitution had provided for a multiparty system, in point of fact, Liberia had been, since its colonization, only a one-party state. The True Whig Party led by the Americo-Liberians dominated the political arena of Liberia from about 1870 to 1980. W.V.S. Tubman was Liberia's "charismatic leader" from 1944 to his death in 1971. William Tolbert was President from 1971 until his overthrow in 1980.

Trade unions were permitted, but the right to strike was illegal and collective bargaining arrangements did not exist.

¹/ In April, 1980, noncommissioned officers, led by Sergeant Samuel Doe staged a military coup and overthrew the Government of William Tolbert. See The Washington Post, April 12, 1980.

A minimum wage law was in force, but did not cover eighty per cent of the workforce of domestic and agricultural workers.

Former President Tubman was the architect of Liberia's "policy of unification" which reflected, in the main, a lessening of the discriminatory treatment of indigenous peoples by Americo-Liberians. Expropriation of tribal lands, without compensation, and compulsory labor, for example, experienced a noticeable decline during the early years of Tubman's Administration.¹

The second major policy enunciated by Tubman upon his assumption of office in 1944 was the so-called "Open Door Policy." The policy welcomed foreign investments and operations to Liberia with complete freedom of management, and full repatriation of capital and withdrawal of profits plus tax abatements and import duty concessions.² Miller and Carter (1972) assert that Liberia has been "enjoying", since 1944, the advantages of colonization. They go on to argue that:

1/ For a fuller discussion of this issue, see: Dalton, G. (1965). "History, Politics and Economic Development in Liberia", Journal of Economic History, Vol. 25, pp. 582-586.

2/ For a lucid evaluation of this policy, see: Miller, R.E. and P.R. Carter. (1972). "The Modern Dual Economy: A Cost-Benefit Analysis of Liberia", The Journal of Modern African Studies, Vol 10, No. 1, pp. 113-21. This study concludes that the "Open Door Policy" has worked to Liberia's disadvantage . . . [with] even more significant long-run drawbacks to Liberia's economic development through the persistence of the dual economy and continuance of present arrangements.

. . . Liberia has been exchanging her resources--notably rubber and, more recently, several massive mountains of iron ore - for some roads, schools, clinics, public buildings, and individual fortunes, with only a little spill-over into domestic investment and general economic activity.

Miller and Carter (1972) furthermore agree with Clower et al. (1966) and posit that Liberia has the classic dual economy--"growth without development".¹

THE STRUCTURE OF THE LIBERIAN ECONOMY

The authors of the first indepth and authoritative survey of the Liberian economy (Clower et al., 1966) summarized their findings by the following statement:

The rate of expansion of the economy of Liberia during the decade preceding 1961 surpassed that of almost any other country in the world. Gross domestic money income more than quadrupled between 1950 and 1960, government receipts increased more than eightfold, tonnage of goods imported nearly quadrupled, rubber exports rose by one-third from an already high base, iron ore exports increased from nothing to nearly three million long tons per year, the money sector labor force nearly tripled, net money income of tribal households more than quadrupled, and mileage of all-weather roads quadrupled.

Other economic surveys of Liberia by the World Bank (1963, 1966) confirmed the phenomenal expansion of the Liberian economy.

¹/ Clower et al. (1966), in Growth Without Development: An Economic Survey of Liberia, Northwestern University Press, Evanston, concluded that while Liberia had experienced impressive economic growth in primary commodities produced by foreign concessions for exports, this rapid growth had little developmental impact on Liberia or Liberians.

The basis of the Liberian economy over the period from about 1950 to 1980 has been primarily the production for export of commercial agriculture (e.g., rubber, coffee, cocoa, palm products, etc.), iron ore for export, and subsistence agriculture. As Table IV-1 of the national income of Liberia reveals, the most important economic sectors are agriculture and mining of iron ore, based on the Gross Domestic Product.

As noted above, Liberia experienced unprecedented economic growth during the 1950's and 1960's. It has been estimated that the nominal Gross Domestic Product (GDP) of Liberia increased by almost 3 times over the 1950-1960 period. This represents an increase from a base of \$58 million to \$172.8 million in current market prices. The 1960-70 period was not any less dramatic; nominal GDP increased from \$172.8 million to \$408.4 million in current market prices. The nominal GDP increased to \$1,116.8 million in 1980, 273% of the 1970 level.

These profound and impressive results are in sharp contrast to the state of the Liberian economy that had existed throughout the first one hundred years after the country formally became a republic and when the economy was not linked to the international capitalist system to any large degree. The development of the enclave sector, particularly iron-ore mining, and the continued rise in the international price for rubber, accounts for much of this phenomenal growth.

The performance of the Liberian economy during the 1950-60 period can be best understood in terms of its growth rate

TABLE IV-1

GROSS DOMESTIC PRODUCT
BY SECTORAL ORIGIN IN CURRENT PRICES
(in U.S. \$ Million)

ITEM	1950	1960	1970	1980
AGRICULTURE	\$45.0 ^{2/}	\$68.3 ^{2/}	\$40.4	\$159.0
Rubber	21.0	39.9	23.0	61.5
Forestry	-	10.3	4.1	47.0
Other	-	18.1	13.3	50.5
MINING	0.1	39.5	120.3	153.0
Iron Ore	-	36.8	109.3	133.0
Other	-	2.7	11.0	20.0
MANUFACTURING	-	-	15.2	77.0
CONSTRUCTION	7.4	29.0	16.2	32.5
WHOLESALE, RETAIL TRADE, & HOTEL & RESTAURANT	-	-	42.5	79.0
ELECTRICITY & WATER	-	-	5.5	19.1
TRANSPORT, STORAGE, & COMMUNICATIONS	-	23.5	31.8	61.0
FINANCIAL INSTIT. & BUSINESS SERVICES	2.6	-	23.7	76.0
COMMUNITY, SOCIAL, & PERSONAL SERVICES	-	-	12.4	31.5
GOVERNMENT SERVICES	3.0	12.5	23.0	123.6
IMPUTED BANK CHARGES	-	-	-3.4	-11.5
MONETARY GDP (F.C.) ^{1/}	-	122.5	323.1	800.8
TRADITIONAL ECONOMY (F.C.)	-	34.6	55.3	200.2
TOTAL GDP (F.C.)	-	157.1	378.4	1,001.0
INDIRECT TAXES (NET)	2.8	15.7	30.0	115.8
TOTAL GDP (MARKET PRICES)	\$58.1	\$172.8	\$408.4	\$1,116.8

1/ F.C. = Factor Cost

2/ Note: 1950 and 1960 GDP account items are expressed in market prices only.

Sources: IBRD. (1979). Liberia Current Economic Situation and Prospects, Report No. 2662-LBR.
 IBRD. (1982). Liberia Recent Economic Developments and Medium-Term Prospects, Report No. 4178-LBR.
 Clower et al. (1966). Growth Without Development: An Economic Survey of Liberia, Northwestern University Press, Evanston, p. 238.
 Dalton, G. (1965). "History, Politics and Economic Development in Liberia", J. Economic History, Vol. 25, p. 573.

in nominal GDP presented in Figure IV-3. Clower et al. (1966) estimated that between 1954 and 1960 alone, the annual rate of growth of leading Liberian production and income accounts averaged about 15 per cent; a rate that would double output every five years, if it were sustained. Nominal GDP growth during the 1960's was estimated by Clower et al. at about 5.8 per cent a year.

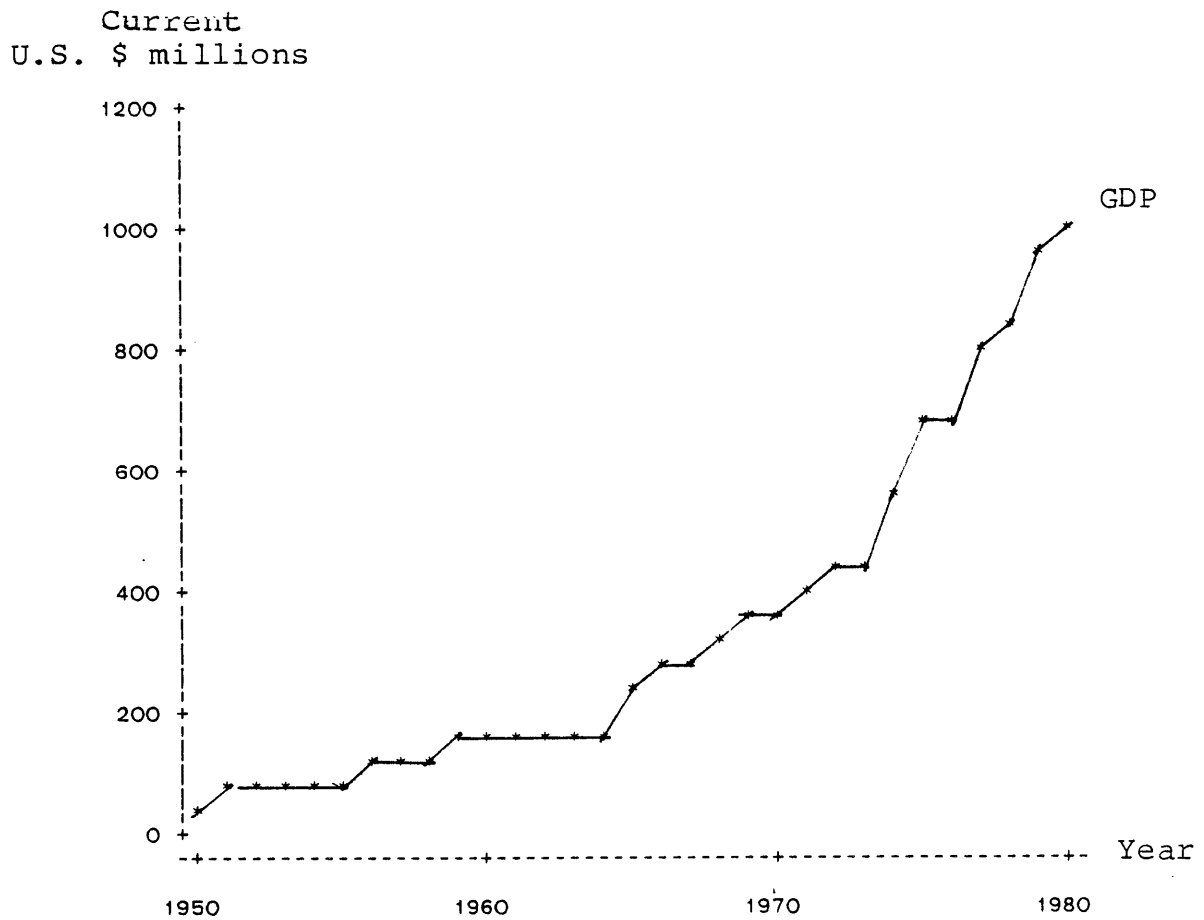
Mehmet (1975) states unequivocally that "the impressive economic growth of Liberia since the 1950's is largely attributable to external factors, reflecting a substantial inflow of foreign investments in the enclave sector."

For a clearer understanding of the structure of the Liberian economy, the economy was disaggregated into two categories of production and income in order to determine the sectoral components of the country's national income. Because of the double enclave nature of the Liberian economy, the productive sectors were further broken down into the monetary sector and the traditional or subsistence sector.

The Monetary Economy

One of the striking features of the Liberian monetary sector is the fact that major ownership and control is in the hands of foreign-owned companies. Monetary GDP in 1960, at factor cost, was estimated at \$122.5 million. Over a period of twenty years, as shown in Figure IV-4, it increased to \$800.8 million, or about 654%. This increase represents an annual

FIGURE IV-3
LIBERIA'S GROSS DOMESTIC PRODUCT

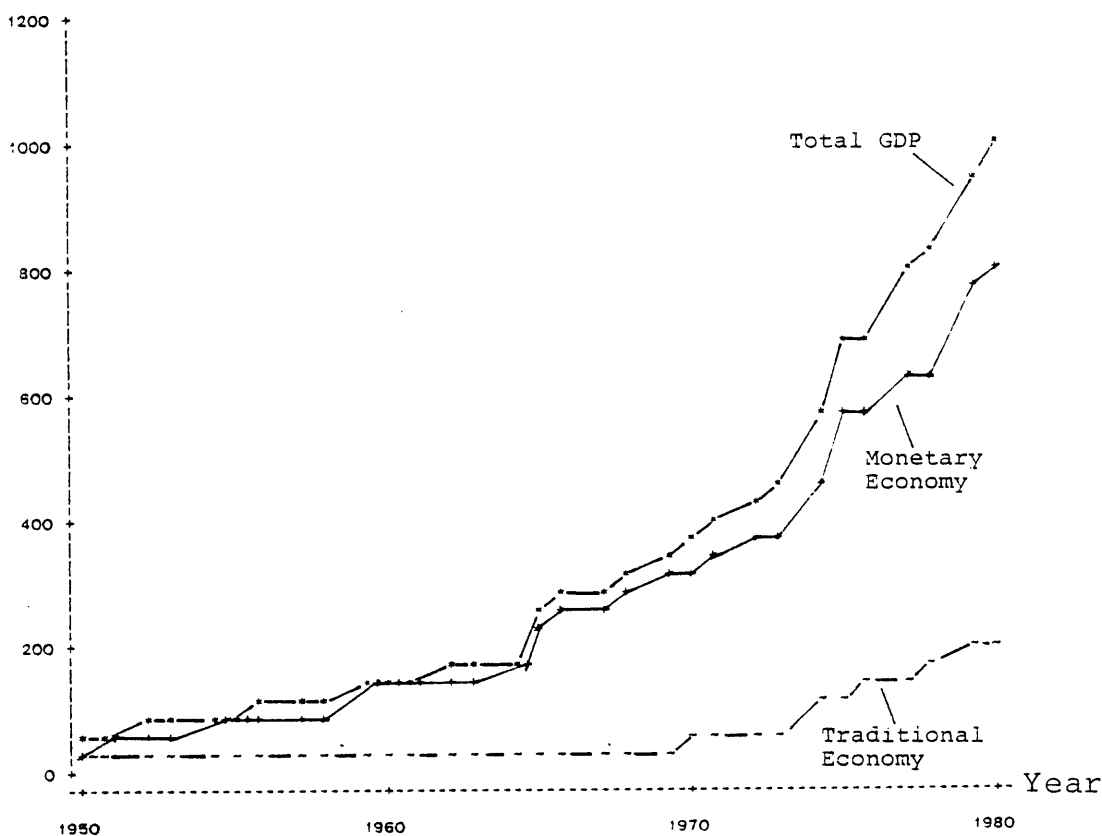


Sources: I.B.R.D. (1963). The Economy of Liberia, Report No. AF-10a, September.
I.B.R.D. (1969). The Current Economic Situation and Prospects of Liberia, Report No. AW-5a, May.
I.B.R.D. (1979). Liberia: Current Economic Situation and Prospects, Report No. 2662-LBR, December.
I.B.R.D. (1982). Liberia: Recent Economic Developments and Medium-Term Prospects, Report No. 4178-LBR, December.

FIGURE IV-4

TOTAL GDP DISAGGREGATED INTO
MONETARY ECONOMY AND TRADITIONAL ECONOMY

Current
U.S. \$ millions



Sources: I.B.R.D. (1963). The Economy of Liberia, Report No. AF-10a, September.
I.B.R.D. (1969). The Current Economic Situation and Prospects of Liberia, Report No. AW-5a, May.
I.B.R.D. (1979). Liberia: Current Economic Situation and Prospects, Report No. 2662-LBR, December.
I.B.R.D. (1982). Liberia: Recent Economic Developments and Medium-Term Prospects, Report No. 4178-LBR, December.

average growth of \$34 million in current dollars in the monetary sector. Rubber and iron ore production were principally responsible for this phenomenal output as Table IV-1 reveals. These sectors will be detailed below under the section on Sectoral Growth Patterns.

The Traditional Economy

Total transactions in the traditional economy are presented in Table IV-1.¹ It is estimated that about 71.6% of the population was employed in 1980 in the traditional economy. The traditional economy accounted for 22 per cent of the nominal GDP at factor costs in 1960 and declined to about 20% in 1980. As Figure IV-4 shows, this sector of the economy grew to \$200.2 million in 1980 from \$34.6 million in current dollars in 1960. This contribution to the GDP represents an average growth of approximately \$8.5 million per year.

Akpa (1981) observes that fully three out of every four working Liberians are employed in agriculture and, of this amount, 83 per cent are employed in the traditional sector. Because of the relative size and importance of the traditional economy, it is instructive to provide some details of its composition.

The traditional economy is made up primarily of agriculture. As such, the crop mix consists mainly of rice, cassava,

¹/ By traditional or subsistence economy, we refer to an economy in which production or services are primarily for home consumption and the standard of living yields little more than the basic necessities such as food, clothing, shelter, etc.

TABLE IV-2

LIBERIA: RESOURCES AND EXPENDITURES
(in current U.S. \$ million)

ACCOUNT	1950	1960	1970	1980
GROSS DOMESTIC PRODUCT	\$58.1	\$172.8	\$408.4	\$1,116.8
RESOURCE GAP (M-X)	17.0	0.8	-51.9	0.5
Imports (G+NFS)	10.6	83.8	159.0	614.0
Exports (G+NFS)	27.6	84.6	210.9	613.5
TOTAL EXPENDITURES	4.9	154.7	567.4	1,117.3
CONSUMPTION	N.A.	95.	259.2	811.7
General Government	N.A.	16.9	45.1	182.0
Private	N.A.	79.0	214.1	629.7
INVESTMENT	N.A.	50.0	80.0	305.1
Fixed Investment	N.A.	-	-	196.1
Changes in Stocks	N.A.	8.0	10.6	49.1
DOMESTIC SAVINGS	N.A.	13.5	149.2	305.1
Net Factor Income	N.A.	34.6	-	-139.6
Current Transfers	N.A.	15.7	-	35.7
NATIONAL SAVINGS	N.A.	11.0	37.9	201.2

N.A. = Not Available

Sources: Clower et al. (1966). Growth Without Development, Northwestern University Press, Evanston, p. 41-63.
 I.B.R.D. (1963). The Economy of Liberia, Report No. AF-10a, September.
 I.B.R.D. (1982). Liberia Recent Economic Developments and Medium Term Prospects, Report No. 4178-LBR, December.
 I.B.R.D. (1979). Liberia Current Economic Situation and Prospects, Report No. 2662-LBR, December.

yams, sweet potatoes, fruits and vegetables, and palm and coconut products. Of these crops, rice is the crop that is most widely grown. About 89 per cent of the agricultural households grow rice, according to Akpa (1981). Considerably smaller percentages, ranging between 2 and 46 per cent of the households, based on the National Rice Production Estimates of 1974, are involved in growing other crops.

Information on the non-agricultural components of the traditional sector of Liberia is largely impressionistic. Such activities are mainly based in the urban areas and consist of labor services and small-scale production by micro-enterprises. Clower et al. (1966) estimated the value of the non-agricultural traditional sector in 1960 to be about \$4.7 million in current dollars based on household budgets and import statistics. On the basis of this estimate, the non-agricultural traditional sector accounted for about 3.0% of the total nominal GDP at factor costs in current dollars in 1960. There are no present estimates available of the non-agricultural components of the traditional economy.

SECTORAL GROWTH PATTERNS

The Liberian economy, as a small open-economy, was based until the early fifties primarily on subsistence farming and the production of rubber for export. Iron ore only became a major contributor to the GDP after the 1950's. While the export of rubber remains an important contributor to Liberia's domestic

product, the production of iron ore exceeded the value of rubber production in 1970 by about 475% and declined to about 216 per cent in 1980. Some of the main sectoral growth components of the Liberian economy and their contributions to GDP are indicated in the following section and are presented graphically in Figure IV-5.

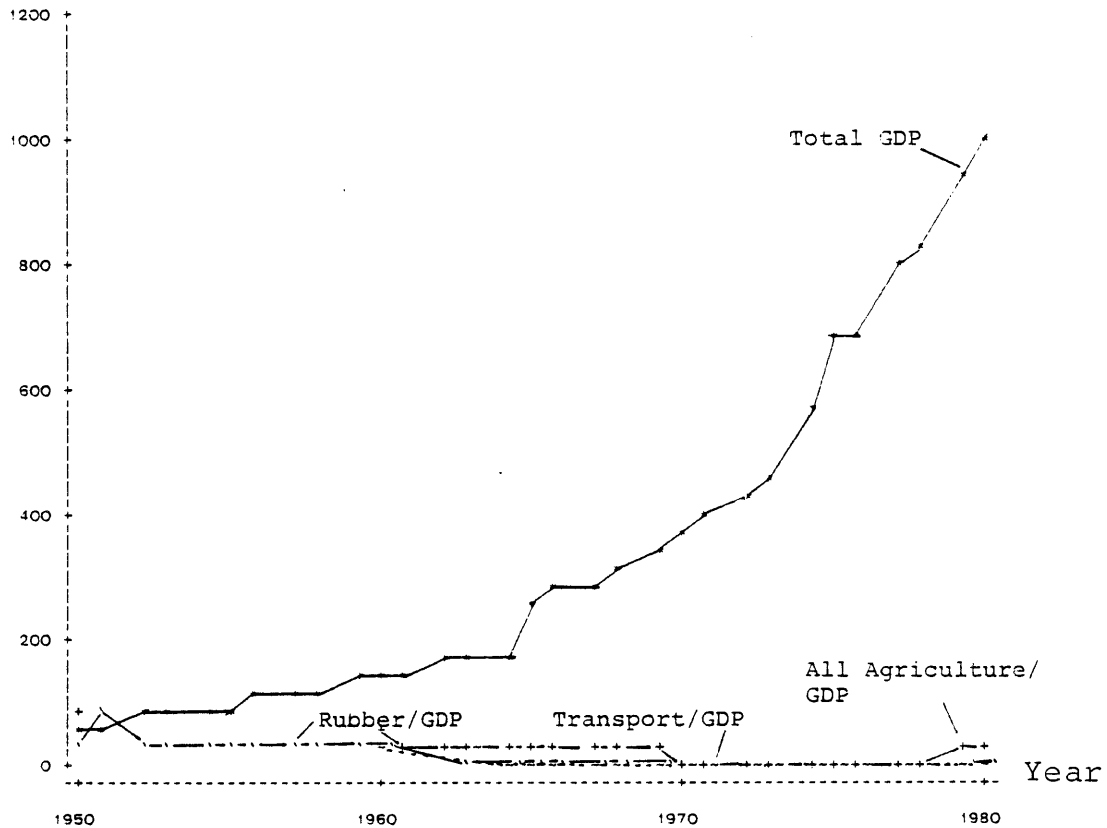
Mining

Although diamonds and gold are mined in Liberia, iron ore production is the most significant mineral mined. Diamonds, which are mostly of industrial grades, are mined in several parts of the country, but are confined primarily to small-scale surface mining. The production of iron ore outpaced rubber in value exported in the late sixties as the most important sector of the economy. Table IV-1 reveals that the value of iron-ore exports increased from \$36.8 million in current market prices in 1960 to \$133 million at factor cost in 1980. Rubber exports, on the other hand, increased from \$39.9 million in current market prices to \$61.5 million at factor cost over the same twenty-year period.

Between 1950 and 1980, four mines made up the iron-ore sector with only one iron-ore mine in operation by 1962. The mine was operated by the Liberia Mining Company (LMC), a U.S.-based firm affiliated with the Republic Steel Corporation. The mine was located at Bomi Hills, 40 miles northwest of Monrovia. The ore was mined open-cast and shipped by private rail-

FIGURE IV-5
SECTORAL ORIGINS OF GDP BY SELECTED SECTORS

Current
U.S. \$ millions



Sources: I.B.R.D. (1963). The Economy of Liberia, Report No. AF-10a, September.
I.B.R.D. (1969). The Current Economic Situation and Prospects of Liberia, Report No. AW-5a, May.
I.B.R.D. (1979). Liberia: Current Economic Situation and Prospects, Report No. 2662-LBR, December.
I.B.R.D. (1982). Liberia: Recent Economic Developments and Medium-Term Prospects, Report No. 4178-LBR, December.

way to the Port of Monrovia. LMC started its production in 1951 after being granted a concession in 1946. LMC ceased operations in 1977 after exhausting its iron-ore body.

The National Iron Ore Company (NIOC) was the second foreign-controlled iron ore mining concern to be established in Liberia. This mining concern received a concession from the Liberian Government in 1958. It is located in the Mano River area to the northwest of Monrovia near the Sierra Leone border. Production did not start until after 1962 and the iron ore was shipped by a branch railway that links up to the LMC railway line.

The largest iron-ore mine in Liberia is the Liberian American Swedish Minerals Company (LAMCO), which began production in mid-1963. This mining concession is located in the Nimba Range northeast of Monrovia near the Guinean border. Its ore is shipped by a 170-mile railway to the Port of Buchanan, south of Monrovia.

The fourth mining concern in Liberia is the Bong Mining Company (BMC) located in the Bong Range, about 50 miles northeast of Monrovia. BMC began production in 1971 and ships its ore also via railway to the Port of Monrovia.

Iron-ore production statistics are presented in Table IV-3. The table reveals that the production of iron ore increased by about 635% from 1959 to 1978. Such a rapid expansion had a profound impact on the GDP over this period; although in recent years the impact has begun to moderate considerably.

TABLE IV-3

LIBERIA: IRON ORE PRODUCTION, 1959-1978
(million long tons)

FIRM	1959	1960	1961	1962	1963	1964	1974	1975	1976	1977	1978
LAMCO-JV	-	-	-	-	2.3	7.2	12.9	11.2	9.4	8.6	8.2
Bong Mining Co.	-	-	-	-	-	-	1.5	5.7	6.3	6.2	7.1
National Iron Ore Co.	-	-	0.6	0.6	2.3	3.1	3.4	2.8	2.7	2.7	2.5
Liberia Mining Co.	<u>2.8</u>	<u>2.9</u>	<u>3.1</u>	<u>3.1</u>	<u>3.0</u>	<u>3.0</u>	<u>2.1</u>	<u>1.8</u>	<u>1.6</u>	<u>0.4</u>	<u>-</u>
TOTAL	2.8	2.9	3.7	3.7	7.6	13.3	19.9	21.5	20.0	17.9	17.8

Sources: IBRD. (1969). Report No. AW-5a.
IBRD. (1979). Report No. 2662-LBR, Annex I.

This moderation began after 1975 when production fell from almost 22 million long tons to about 18 million long tons in 1978.

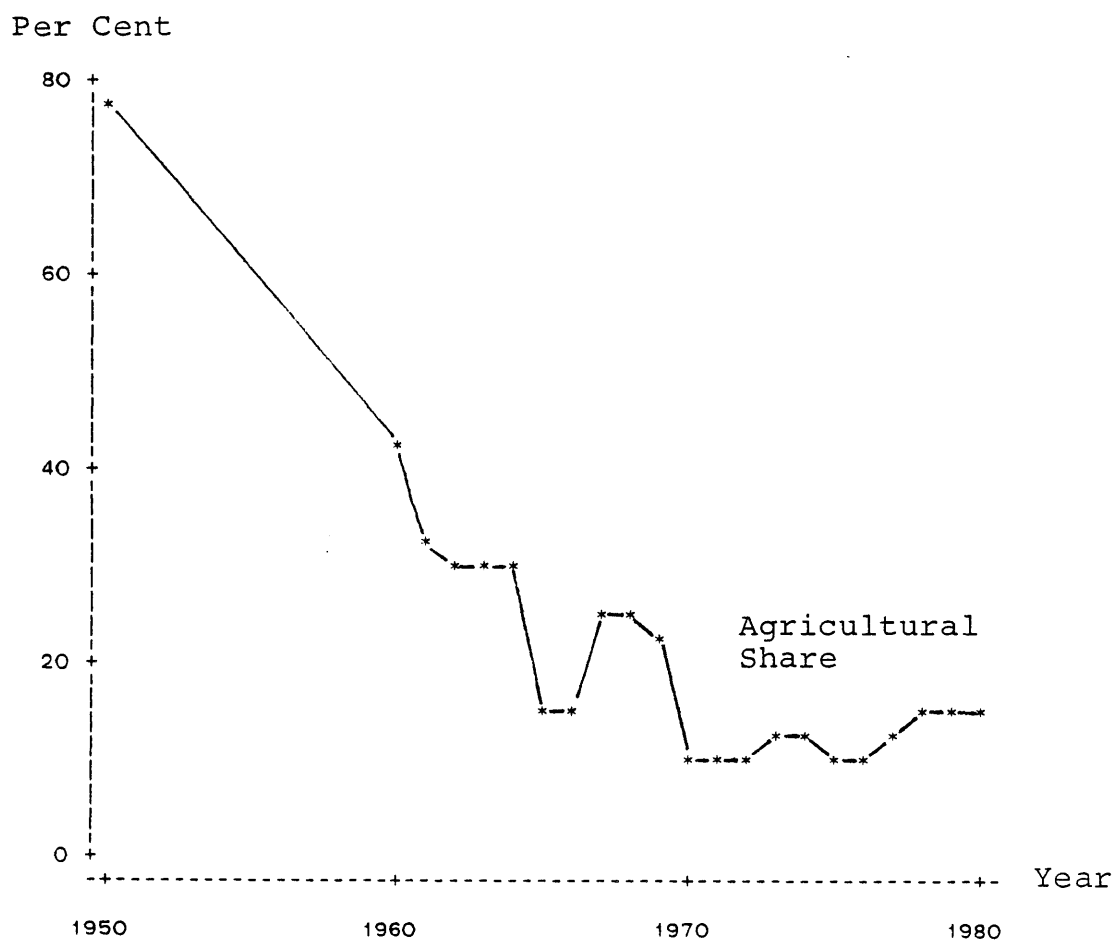
The most recent estimates by the World Bank (1982) on the structure of Liberian exports show that iron ore accounted for 63.9 per cent of total exports in 1970 and 51.7 per cent in 1980. During the mid-1970's, iron-ore exports peaked at a high of 74.4 per cent of exports, which is an indication of how important iron-ore production is to the Liberian economy.

Agriculture

Like iron-ore mining, agriculture has been one of the most important sectors of the Liberian economy, as represented by its share of GDP in Figure IV-6. The agricultural sector is separated into two types: traditional or subsistence agriculture and commercial estate agriculture. Subsistence agriculture in Liberia, as in most developing countries, are activities where produce or services are mainly consumed by the family household; although some crops are also sold in markets in the major urban centers. Commercial agriculture is largely made up of foreign-owned and managed estates; although Liberian-owned farms have emerged with increasing frequency after about 1960. The commercial estates produce primarily rubber; however, some, particularly Liberian firms, have ventured into producing such crops as coffee, cocoa, and palm products.

As indicated elsewhere in this chapter, in excess of 70 per cent of the population of working age are employed in

FIGURE IV-6
AGRICULTURE'S SHARE OF GDP



Sources: I.B.R.D. (1963). The Economy of Liberia, Report No. AF-10a, September.
I.B.R.D. (1969). The Current Economic Situation and Prospects of Liberia, Report No. AW-5a, May.
I.B.R.D. (1979). Liberia: Current Economic Situation and Prospects, Report No. 2662-LBR, December.
I.B.R.D. (1982). Liberia: Recent Economic Developments and Medium-Term Prospects, Report No. 4178-LBR, December.

the agricultural sector. This group contributed on the order of \$45 million in current market prices to the GDP in 1950 and about \$159 million at factor cost in 1980. These figures show that agriculture's share of the value added amounted to 78% of the total GDP at current market prices in 1950 and declined to about 14.2 per cent in 1980. Agriculture, particularly rubber production, dominated the economy in the late 1940's and throughout the 1950's, as revealed in Table IV-1.

No other primary crops in Liberia have experienced growth comparable to that of the rubber industry. The Liberian low-value export crop-mix has been tempered by wide fluctuations in international prices and a lack of adequate internal transportation and marketing arrangements (Qureshi et al., 1964). Other cash crops produced for export include coffee, cocoa, and palm kernels. Each of these crops are discussed separately under Part III of this chapter and data are presented that show their production trends.

PART II. THE TRANSPORT SECTOR

Most of what has evolved as the transport system of Liberia was developed primarily to accommodate the transportation needs of foreign-owned rubber, mining and, in recent years, timber concessions.¹ The railroads, for example, are primarily

¹/ For a detailed discussion of the historical development of the transport system of Liberia, see two studies by Stanley, W.R. (1966). "Changing Patterns of Transportation Development in Liberia", Ph.D. thesis, University Microfilms International, Ann Arbor, MI. and Stanley, W.R. (1970). "Transport Expansion in Liberia", The Geographical Review, Vol. 60, pp. 529-547.

owned by the foreign mining concessions under their concession agreements and are used almost exclusively for transportation of iron ore to the Ports of Monrovia and Buchanan. The mining concessions also used the railroads to transport imported equipment and supplies for their operations and to meet their foreign staff's needs.

Roads, which historically have formed the basis of Liberia's internal transportation system, continue to be the most important system for transporting goods and passengers today. Stanley (1966), in a study of transport development in Liberia, found that bulk transportation on the few roads that were in existence during the early twentieth century did not begin until after the Firestone Plantation was constructed in 1926. Significant transportation by road did not begin in earnest until about 1932 when the shipping of rubber products began. Prior to this, the few roads that did exist during the late eighteen hundreds were located near the coastal settlements with no interconnections.

In contrast to road development which started in the 1920's, port facilities development did not get started until the mid-1940's, when the United States undertook the construction of a port in Monrovia as a result of a military assistance agreement. The Firestone Plantation Company had considered the idea in the 1920's, but abandoned it because of cost considerations. Similarly, airport facilities were not developed until the late 1940's when a U.S. military airfield was built

at Robertsfield, south of Monrovia near the Firestone rubber plantation. An airport was later built for Monrovia in about 1953. Stanley (1970) makes the following points regarding transport expansion:

. . . Liberia has been transformed from a series of disconnected coastal settlements to what is essentially a politically unified country noticeably throbbing with economic activity and social progress. This change can be attributed primarily to the impact of port and road development which began toward the end of World War II.

Stanley (1970) goes on to argue that the expansion of transport facilities in Liberia approximated the Taaffe, Morrill and Gould model of the ideal-typical sequence.¹

The development of the transport sector will be further detailed on a mode-specific basis later in this section. However, it is instructive to point out the significance of the transport sector in relationship to its contribution to the GDP. The share of the transport sector in nominal GDP has been relatively high and averaged about 7.2% from 1964 to 1980. The country's economy, as previously indicated, has been and is still essentially based on the foreign-enclave sector, which contributes well in excess of 60% to the GDP. By comparison,

¹/ The model developed by Taaffe, Edward J., Richard L. Morrill, and Peter R. Gould and presented in their 1963 article, "Transport Expansion in Underdeveloped Countries: A Comparative Analysis", The Geographical Review, Vol. 53, pp. 503-529, sets forth six sequential categories of transport development. The categories consist of 1) scattered ports, 2) penetration lines and port concentration, 3) development of feeders, 4) beginnings of interconnection, 5) complete interconnection, and 6) the emergence of high-priority "main streets".

the traditional economy, made up principally of traditional agricultural production, contributes about 20% to the Liberian nominal GDP.

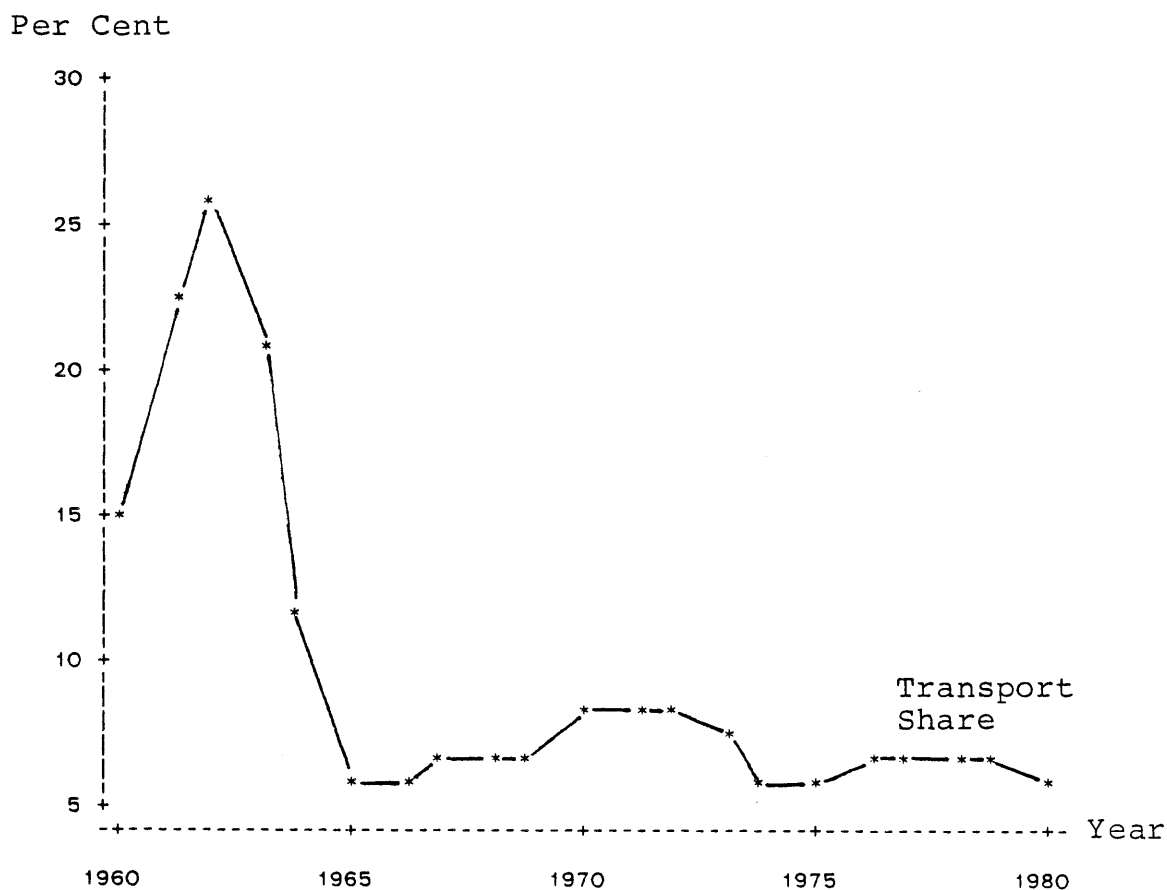
The various transport modes have had differential impacts on the country's economy during its most profound economic period--the 1950 to 1980 era. While the transport sector, as a whole, contributed about 7.2% to the GDP as Figure IV-7 shows, the transport share of Gross Domestic Capital Formation (GDCF), found in Table IV-4, grew from about a modest 2% in 1960 to 13.5% in 1980, with an average investment of about \$11.9 million in current dollars over a thirty-year period. These results, however, should be viewed in their proper context, because there was virtually no transport system to speak of prior to 1950. As would be expected, any investments in the transport sector, because of no previous contributions, would represent a significant amount both in absolute terms and on a percentage basis.

THE ROAD NETWORK

The development of roads in Liberia did not get started with any degree of intensity or public coordination until about 1953, when the Government embarked upon a construction program (Stanley, 1966). Prior to this, except for a few roads in the Monrovia area, almost no roads existed (see Figure IV-8). What roads did exist were low-volume rural roads located near the coast and around Monrovia and in the foreign-owned concession

FIGURE IV-7

THE TRANSPORT SECTOR'S SHARE OF GDP



Sources: I.B.R.D. (1963). The Economy of Liberia, Report No. AF-10a, September.
I.B.R.D. (1969). The Current Economic Situation and Prospects of Liberia, Report No. AW-5a, May.
I.B.R.D. (1979). Liberia: Current Economic Situation and Prospects, Report No. 2662-LBR, December.
I.B.R.D. (1982). Liberia: Recent Economic Developments and Medium-Term Prospects, Report No. 4178-LBR, December.

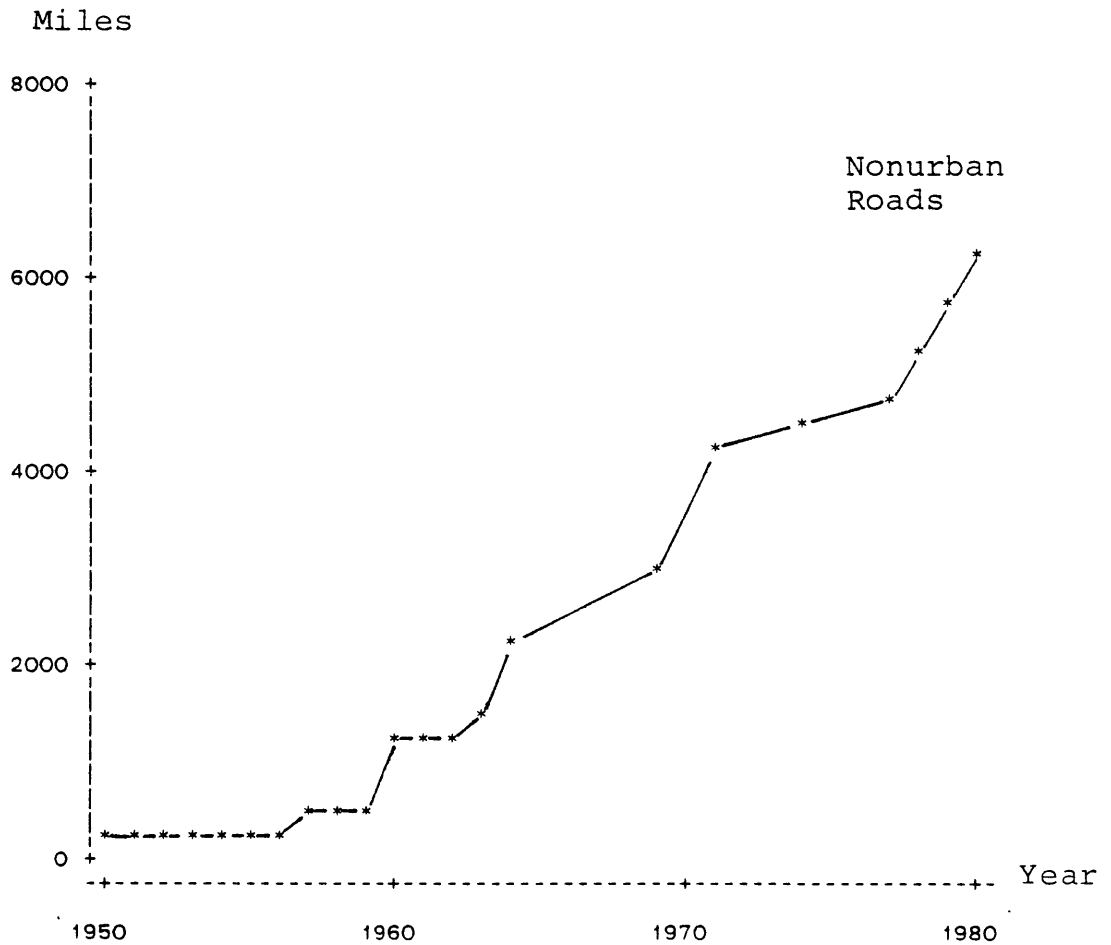
TABLE IV-4
 INVESTMENTS IN THE TRANSPORT SECTOR
 (in current U.S. \$ million)

	1950	1960	1965	1970	1980
TRANSPORT INVESTMENT	\$1.24	\$1.0	\$7.1	\$7.7	\$41.2
GROSS DOMESTIC CAPITAL FORMATION	N.A.	50.0	56.0	80.0	305.1
TRANSPORT SHARE OF GDCF (%)	N.A.	2.0%	12.7%	9.6%	13.5%
AVERAGE ANNUAL TRANSPORT INVESTMENT (TEN YEARS)	N.A.	2.87	3.06	5.65	24.3

N.A. = Not Available

Sources: Clower et al. (1966). Growth Without Development: An Economic Survey of Liberia, Northwestern University Press, Evanston.
 I.B.R.D. (1969). The Current Economic Situation and Prospects of Liberia, Report No. AW-5a, May.
 I.B.R.D. (1979). Liberia: Current Economic Situation and Prospects, Report No. 2662-LBR, December.
 I.B.R.D. (1982). Liberia: Recent Economic Developments and Medium Term Prospects, Report No. 4178-LBR, December.

FIGURE IV-8
NONURBAN ROADS IN LIBERIA



Sources: Stanley, W.R. (1966). Changing Patterns of Transportation Development in Liberia, Ph.D. Thesis, University of Pittsburgh.
Clower et al. (1966). Growth Without Development: An Economic Survey of Liberia, Northwestern University Press, Evanston.
I.B.R.D. (1978). Liberia: Proposed Fourth Highway Project, Staff Appraisal Report, Report No. 1827-LBR.

areas. Many roads were the result of U.S. aid during World War II in cooperation with the Firestone Company. Table IV-5 shows the development of the road system from 1950 when there were only 230 miles of unsurfaced public roads to 1977 when almost 5,000 miles of roads were in existence.

The history of Liberian road development has been one whereby foreign-owned concessions, principally rubber and iron-ore concessions, undertook the primary responsibility for opening up the country to facilitate the export of their products. Stanley (1966, p. 21) notes that, by 1964, roads built by concessionaires totalled 530 miles or 20 per cent of the total road mileage constructed in the country. As Table IV-5 indicates, the road system of Liberia has been significantly influenced by private concessionaires whose own road construction output reached about 30 per cent of all roads constructed in Liberia up to 1977. Although these roads were built and are maintained by the concessionaires, most of the roads, unlike the railways, have always been open for use by the general public.

Transport Investment Policy

Notwithstanding the physical development of the transport network, the objectives for the transport sector in Liberia were first set forth officially in the 1946-1950 Five Year Plan for Overall Development. The plan allocated \$10.0 million for public works and improvements. The plan stated that primary

TABLE IV-5
DEVELOPMENT OF THE HIGHWAY SYSTEM
(in miles)

	1950	1964	1971	1974	1977
I. PUBLIC ROADS					
A. Primary Roads					
Asphalt Surface	-	160	203	208	230
Gravel	<u>230</u>	<u>650</u>	<u>941</u>	<u>968</u>	<u>946</u>
Subtotal	230	810	1,144	1,176	1,176
B. Secondary Roads					
Gravel Surface	-	330	487	707	823
Earth	<u>-</u>	<u>610</u>	<u>1,270</u>	<u>1,265</u>	<u>1,432</u>
Subtotal	-	940	1,757	1,972	2,255
Subtotal (A+B)	230	1,750	2,901	3,148	3,431
II. PRIVATE ROADS					
Asphalt Surface	-	30	86	86	90
Gravel Surface	<u>-</u>	<u>500</u>	<u>1,184</u>	<u>1,308</u>	<u>1,354</u>
Subtotal	-	530	1,270	1,394	1,444
TOTAL	230	2,280	4,171	4,542	4,875

Sources: Clower et al. (1966). Growth Without Development: An Economic Survey of Liberia, Northwestern University Press.
Stanley, W.R. (1966). "Changing Patterns of Transportation Development in Liberia", Ph.D. Thesis, University of Pittsburgh, p. 24.
I.B.R.D. (1978). Liberia Proposed Fourth Highway Project: Staff Appraisal Report, Report No. 1827-LBR.

consideration should be given to road construction and as such \$7.0 million were budgeted for roads and bridges, Richardson (1959). The country would have to wait almost twenty years before any clear statements would be made regarding transport policy. In its 1967-1970 Development Plan, the Liberian Government adopted a policy of targeting 60 miles of secondary roads a year for construction and rehabilitation, and 25-30 miles per year of feeder roads, partly to be constructed through local self-help. The plan envisaged that project financing would be largely supported through foreign borrowing and grants. In order to implement the policy, about \$3.4 million in capital expenditures were budgeted during the planned period. The 1967-1970 Plan was never fully realized because of insufficient funding.

Using multi-donor assistance, the Liberian Government adopted its Five-Year Road Maintenance and Development Program of 1973-1977. The program was estimated to cost about \$12.0 million and represented the first comprehensive policy for construction and rehabilitation of roads in Liberia that was eventually implemented.

However, the most explicit statement of policy for the transport sector did not come until the 1976-1980 Four-Year Development Plan. The plan called for: i) improved road maintenance; ii) improved road access to the Port of Monrovia; iii) upgrading key primary roads and extending the secondary road system to centers of agricultural development; iv) provision of

feeder roads to support rural development; v) increased port capacity in Monrovia and Greenville, and vi) modernization of the international airport at Robertsfield. Under the 1976-1980 Plan, total investment in the transport sector was to amount to \$153 million or about 42 per cent of all public investments. Although it was not achieved, the road construction output was anticipated to produce 325 miles of asphalt-paved roads and an additional 355 miles of gravel roads.

Investments in the transport sector by modal share are presented in Table IV-6. A detailed profile of investments in road development from 1950 to 1980 are shown in Table IV-4 as they relate to Gross Domestic Capital Formation. The policy implications of investments in the transportation sector will be discussed in Chapter VI.

Road Financing and Transport Investments

Apart from the significant investments in road construction by foreign concessionaires, intensive public activity in new road construction and road improvements, made possible by foreign grants and credits, did not get underway until about 1952 as revealed in Figure IV-9. Loan funds mainly from the U.S. Export-Import Bank (EXIM Bank) and an Italian private contractor provided the bulk of foreign financing for road construction during the 1950's.¹ The World Bank began its program of

¹/ Vianini (Liberia Ltd.) undertook the construction of several miles of roads in Liberia on a pre-financed basis.

TABLE IV-6

INVESTMENTS IN TRANSPORT SECTOR BY MODE
(in current U.S. \$ '000)

TRANSPORT SECTOR		Actual Investments in 1972-75			
		1972	1973	1974	1975
1. <u>Roads</u>					
Construction	Foreign	\$2,610	\$186	\$4,026	\$3,798
	Government	708	1,050	738	1,870
	Other <u>1/</u>	48	2,213	2,335	1,845
	Total	<u>3,366</u>	<u>3,449</u>	<u>7,099</u>	<u>7,513</u>
2. <u>Airports</u>					
	Foreign	1,900	762	596	1,730
3. <u>Ports</u>					
	Foreign	220	-	130	260
	Government	-	-	20	-
	Total	<u>220</u>	<u>-</u>	<u>150</u>	<u>260</u>
	Grand Total	<u>\$5,486</u>	<u>\$4,211</u>	<u>\$7,845</u>	<u>\$9,530</u>
Investments Envisaged in 1976-1980 Plan					
		<u>Projects A</u>	<u>Projects B</u>	<u>Total</u>	
1. <u>Roads</u> <u>2/</u>					
Construction	Foreign	\$40,040	\$53,020	\$93,060	
	Government	11,390	18,430	29,820	
	Other <u>1/</u>				
	Foreign	11,190	510	11,700	
	Government	4,370	1,965	6,335	
	Total	<u>66,990</u>	<u>73,925</u>	<u>140,915</u>	
2. <u>Ports</u>					
	Foreign	5,200	-	5,200	
	Government	3,650	-	3,650	
	Total	<u>8,850</u>	<u>-</u>	<u>8,850</u>	
3. <u>Airports</u>					
	Foreign	-	-	-	
	Government	3,250	-	3,250	
	Grand Total	<u>79,090</u>	<u>73,925</u>	<u>153,015</u>	
	Foreign	(\$56,430)	(\$53,530)	(\$109,960)	
	Government	(\$22,660)	(\$20,395)	(\$ 43,055)	

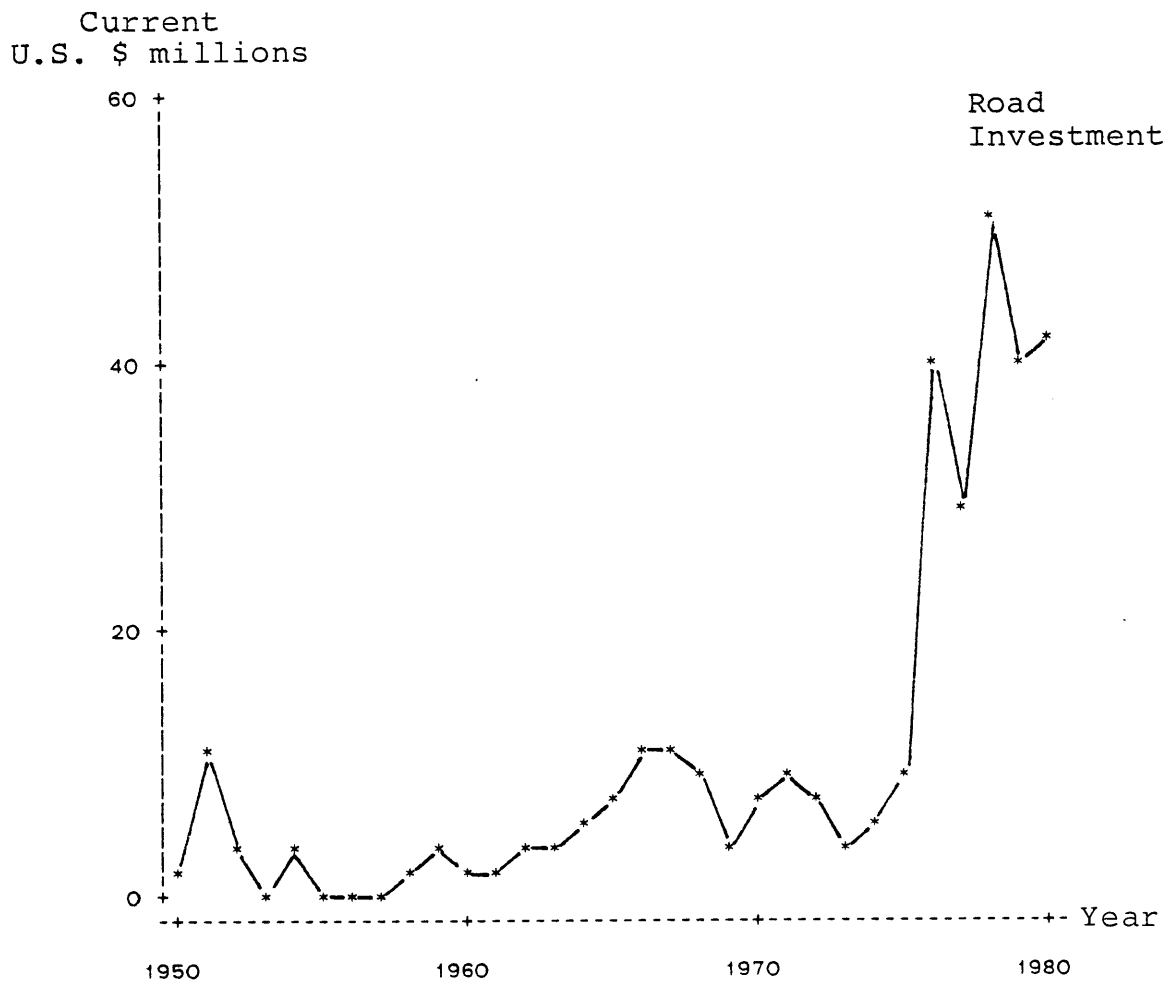
1/ Maintenance equipment, spare parts, street reconstruction, etc.

2/ Original figures were adjusted because of revised cost estimates and road design standards.

Source: I.B.R.D. (1978). Liberia Proposed Fourth Highway Project: Staff Appraisal Report, West African Projects Department, Report No. 1827-LBR.

FIGURE IV-9

INVESTMENTS IN THE TRANSPORT SECTOR FOR ROADS



Sources: Stanley, W.R. (1966). Changing Patterns of Transportation Development in Liberia, University of Pittsburgh.
Clower et al. (1966). Growth Without Development, Northwestern University Press, Evanston.
I.B.R.D. (1966). Report No. AF-45a, June.
I.B.R.D. (1969). Report No. AW-5a, May.
I.B.R.D. (1979). Report No. 2662-LBR, December.
I.B.R.D. (1982). Report No. 4178-LBR, December.

financing construction and improvement of roads in 1963, about the same time that the German Government undertook a road construction program under a bilateral assistance agreement. The U.S. Agency for International Development (U.S.A.I.D.) funding for the transportation sector in 1962 represented 14.6% of the aid allocated to Liberia in 1962. Foreign economic and technical assistance to Liberia for road construction and road improvements through bilateral assistance programs was relatively small before the 1960's. The only foreign government with any significant aid program to Liberia at that time was the various programs (e.g., the EXIM Bank, Military Assistance Programs, U.S. A.I.D., etc.) of the United States. Total U.S. assistance, including grants and loans, to Liberia amounted to about \$146 million in current dollars from 1951 to 1961 (Clower et al., 1966).

Table IV-6 presented some recent statistics on foreign contributions to the transport sector. Foreign assistance for road development was about 78 per cent of total investments in roads in 1972 and declined to about 51 per cent in 1975. These results are in sharp contrast to the investments in road development by the foreign concessionaires in the late 1940's and 1950's, when significant efforts were made to develop the road system in pursuit of their own private interests. It is somewhat ironic that foreign bilateral and multilateral assistance programs became so prominent in the 1960's and 1970's.

Such assistance was a reversal of the situation in the 1940's and 1950's, when private firms played the dominant role in road development.

Of particular interest in Table IV-6 is the Liberian Government investments in roads. During the 1972-1975 period, the Government investments were about 21 per cent of the total investment in 1972 and peaked to about 30.4 per cent the following year. Annual expenditures by the Liberian Government for highway operations has shown an increasing trend from 1971 to 1976. Expenditures for highway operations including maintenance, although comparable figures are not available for prior years, improved substantially in 1975 and 1976, as Table IV-7 indicates.

As a result of both foreign and domestic transport investments, highway construction in general has increased dramatically since the 1950's from about 230 miles of unimproved earth roads to almost 5,000 miles of roads in 1977--including asphalt-surfaced, all-weather, and feeder roads. Such increases averaged about 27 per cent annually.

Vehicle Registration

The number of registered vehicles is a measure of the extent to which road motorization affects user mobility. Although the composition of the vehicle population is not known, the total number of vehicles registered in 1950 was 650 and by 1960 had increased to 7,800. Between 1960 and 1970, the

TABLE IV-7

LIBERIAN EXPENDITURES FOR HIGHWAYS, 1971-76
(in current U.S. \$ '000)

YEAR	RECURRENT MAINTENANCE EXPENDITURES			TOTAL MAINTENANCE EXPENDITURES <u>1/</u>
	PERSONNEL	OPERATIONS	TOTAL	
1971	\$875	\$689	\$1,564	\$2,607
1972	899	973	1,872	2,983
1973	620	716	1,336	2,951
1974	310	1,822	2,132	3,185
1975	358	2,246	2,604	8,019
1976	428	4,882	5,310	10,974

1/ Including foreign assistance and capital expenditures.

Source: I.B.R.D. (1978). Liberia: Proposed Fourth Highway Project, Staff Appraisal Report, West African Projects Department, Report No. 1827-LBR.

total vehicle population averaged about 8,500 vehicles, although these data are incomplete. From what is known, however, the vehicle population in the decade up to 1970 had been increasing at about 11 per cent annually. Table IV-8 shows the composition of the vehicle fleet based on the most recent information available.

Petroleum Products Consumption

Another indication of the degree of road motorization, apart from vehicle registration, is the consumption of petroleum products. Data on petroleum consumption in Liberia are incomplete. However, the most recent data as revealed in Table IV-9 indicate that gasoline and oil consumption fluctuated widely. These fluctuations appear to be consistent with the change in the number of registered vehicles over the same period.

Road-User Taxes

Tax revenues generated by road users provide an indication of the impact of the road system on the economy. Revenues from road-user charges have since about 1966 played an important role in financing Government expenditures. Road revenues are shown in Table IV-10. Although earmarking road-user taxes for road development was official policy between 1955 and 1964, it never functioned as intended in that taxes were treated as ordinary revenues. Road taxes as a percentage of total government revenues have shown a fluctuating trend from 1966 to 1976 as Table IV-11 reveals. In 1950, road taxes contributed about

TABLE IV-8
VEHICLE REGISTRATIONS

YEAR	PASSENGER CARS	TAXIS	TRUCKS <u>1/</u>	BUSES	TOTAL
1970	9,377	4,735	5,234	3,864	23,210
1971	8,996	4,103	5,454	2,521	21,074
1972	10,607	3,384	4,730	2,575	21,295
1973	10,769	3,507	5,384	3,135	22,795
1974	9,875	4,576	5,841	1,800	22,092
1975	10,375	2,421	5,466	2,497	20,759
1976	11,800	1,967	4,770	2,600	21,134

1/ Including pick-ups.

Source: See Table IV-9.

TABLE IV-9
TOTAL CONSUMPTION OF PETROLEUM PRODUCTS
(in '000 U.S. gal.)

YEAR	GASOLINE	KEROSENE	GAS-OIL
1971	19,987	3,695	51,181
1972	16,098	3,144	48,688
1973	21,374	3,823	58,046
1974	18,891	3,616	61,614
1975	21,078	3,139	54,676
1976	23,728	3,251	48,140

Source: I.B.R.D. (1978). Liberia: Proposed Fourth Highway Project, Staff Appraisal Report, West African Projects Department, Report No. 1827-LBR.

TABLE IV-10
 REVENUES FROM ROAD-USER CHARGES
 (in current U.S. \$ '000)

YEAR	FUEL TAXES	IMPORT DUTIES <u>1/</u>	LICENSING/& REGISTRATION <u>2/</u>	TOTAL
1966	\$1,383	N.A.	\$720	\$2,100
1967	1,436	N.A.	642	2,080
1968	1,451	N.A.	699	2,150
1969	N.A.	N.A.	N.A.	N.A.
1970	N.A.	N.A.	N.A.	N.A.
1971	2,057	\$5,243	781	8,081
1972	1,682	4,906	985	7,573
1973	1,538	5,045	1,684	8,267
1974	1,861	2,027	1,762	5,650
1975	1,923	3,533	1,897	7,353
1976	2,421	3,544	2,256	8,221

N.A. = Not Available

1/ Import duties are duties paid on private vehicles and parts.

2/ Licensing and registration taxes are paid on all classes of private vehicles.

Sources: Shoup et al. (1970). The Tax System of Liberia: Report of the Tax Mission, Columbia University Press, pp. 138-43.
 I.B.R.D. (1978). Liberia: Proposed Fourth Highway Project, Staff Appraisal Report, Report No. 1827-LBR.

TABLE IV-11

ROAD-USER TAXES AS A PER CENT OF TOTAL REVENUES
(Revenues in current U.S. \$ million)

YEAR	ROAD-USER REVENUES	TOTAL CURRENT REVENUES	USER TAXES AS A % OF TOTAL REVENUES
1966	\$2.10 <u>1/</u>	\$46.26	4.5%
1967	2.08 <u>1/</u>	48.09	4.3
1968	2.15 <u>1/</u>	51.60	4.2
1969	N.A.	N.A.	N.A.
1970	N.A.	66.50	-
1971	8.08	69.50	11.6
1972	7.57	78.10	9.7
1973	8.26	89.80	9.2
1974	5.65	108.60	5.2
1975	7.35	125.30	5.9
1976	8.22	132.10	6.2

N.A. = Not Available

1/ Represents estimates; data on import duties for vehicles and spare parts are not available.

Sources: I.B.R.D. (1969). The Current Economic Situations and Prospects for Liberia, Report No. AW-5a, May.
I.B.R.D. (1982). Liberia Current Economic Situations and Prospects, Report No. 2662-LBR, December.

4.5 per cent of total revenues and peaked to 11.6 per cent in 1971; thereafter, a declining trend evolved. Road-user taxes as a per cent of total revenues averaged about 6 per cent a year between 1966 and 1976.

RAILROADS AND RAIL TRANSPORT

Similar to the development of the road network, the railroads in Liberia were built between 1951 and 1964 for the purpose of evacuating iron ore from the various mines in the country. The railroads were constructed by foreign-owned mining companies under agreements with the Government. As Table IV-12 shows, the largest system is the LAMCO railroad which runs 167 miles from Mt. Nimba in the north to the Port of Buchanan to the southeast.

The four railroads that do exist are used exclusively for the transportation of iron ore and mining equipment, supplies and personal consumption items. Because of this, these railroads have had no impact on the agricultural sector or on the general population in terms of movement of products or people. Railroad's contribution to the Liberian economy has been important only with respect to iron-ore mining.

PORTS AND SHIPPING

Unlike the limited freight access on the railway lines, virtually all of Liberian exports and imports are handled through its four ports on the Atlantic coast. Although trading stations existed as far back as 1821, modern port development did not

TABLE IV-12
RAILROADS IN LIBERIA

COMPANY	YEAR COMPLETED	LENGTH	LOCATION
Liberia Mining Co.	1951	42 miles	Bomi Hills to Monrovia
National Iron Ore Co.	1961	49 miles	Mano River to Bomi Hills Line
LAMCO	1963	167 miles	Mt. Nimba to Buchanan
Bong Mining Co.	1964	47 miles	Bong Range to Monrovia

Source: Stanley, W.R. (1966). "Changing Patterns of Transportation Development in Liberia", Ph.D. thesis, University of Pittsburgh, p. 148.

get started until about a hundred years later. In 1926, the Firestone Company, as part of its concession agreement with the Liberian Government, was obligated to spend \$300,000 towards port construction in Monrovia. Firestone withdrew from the project when it concluded that the cost for a deep-water port was well in excess of several million dollars. As a result, the Town of Marshall, twenty-five miles south of Monrovia, became the principal place for rubber exports.

As part of its agreement to station troops in Liberia in 1944, the U.S. Government undertook the construction of a deep-water facility at Monrovia. Twelve years later, the construction of a port facility at Greenville began following an agreement in 1953 between Liberia and the African Fruit Company, a German-owned company who planned to use the port to ship bananas from its concession plantation. The German Government funded the construction of the port with a \$10.5 million loan to the Liberian Government.

In 1959, a protected anchorage was developed in the south of Liberia at Harper to facilitate export of rubber from Firestone's plantation at Harbel and timber from the region. The newest, and perhaps one of the most modern, deep-water port was constructed at Buchanan in 1963 by the LAMCO mining concern for the purpose of exporting iron ore.

Ports, unlike railroads, were more integrated into the country's economy in terms of its spread effects. The most recent data on port traffic indicate that Monrovia and Buchanan,

as the deep-water ports, handle over 90% of the foreign trade. Greenville and Harper, which are shallow ports, handle the remainder--mainly timber products.

Stanley (1971) concludes that "port concentration and growth have led to major penetration routes into the interior, beginning with Monrovia, followed by Buchanan, and ending with Greenville and Harper." He goes on to argue that, "... the beginning of road interconnection had to wait until more modern port facilities were available..."

Table IV-14 presents some recent data on port traffic. Port traffic in 1973 was at 27.0 million tons up from 16.1 million tons in 1965; representing about 7 per cent growth annually. General cargo and transshipment traffic has been declining since about 1974 due to world economic conditions and restrictive import policies, according to the World Bank studies.

Three of the major facilities are operated by the publicly-owned National Port Authority. The fourth port at Buchanan is operated by the mining company, LAMCO.

AIRLINES AND AIR TRANSPORT

Since about the mid-1940's, aircrafts have been in operation in Liberia, when Firestone started using them to service their two plantations. Under a military assistance agreement, the U.S. Government constructed an airstrip at Robertsfield. Scheduled airline service began in 1948 as a venture by U.S. investors. The company they founded was the Liberian Interna-

TABLE IV-13
MAIN PORTS FACILITIES IN LIBERIA

PORT	BREAKWATER	QUAYS	DEPTH OF CHANNEL
MONROVIA	Two; 6,500 - 7,000 ft. each	General cargo; 2,000 ft. petroleum tanker pier; 3 iron ore loading piers	30 ft.
BUCHANAN	Two; 6,700 & 2,000 ft.	General cargo; 2,000 ft. commercial; 1,041 ft. Iron ore loading	33 ft.
GREENVILLE	One; 1,350 ft.	Commercial; 590 ft.	24 ft.
HARPER	One; 1,500 ft.	Pier; 180 ft.	15 ft.

Source: Stanley, W.R. (1970). "Transport Expansion in Liberia", The Geographical Review, Vol. 60, p. 536.

TABLE IV-14
PORT TRAFFIC BY MAJOR FACILITIES
(in '000 long tons)

PORTS	1971	1972	1973	1974	1975	1976
MONROVIA	12,410	12,370	13,744	13,312	11,082	11,673
BUCHANAN	10,340	11,608	12,956	13,104	8,957	N.A.
GREENVILLE	166	161	204	123	153	254
HARPER	<u>54</u>	<u>38</u>	<u>54</u>	<u>37</u>	<u>35</u>	<u>57</u>
TOTAL TRAFFIC	22,970	24,177	26,958	26,576	20,227	11,984

Source: Government of Liberia. (1975). Economic Survey of Liberia, Ministry of Planning and Economic Affairs.

tional Airlines. After one year, the Liberian Government took control of the company and concentrated on providing domestic air service. Scheduled service was made available to every part of the country beginning in 1953. Spriggs-Payne Airfield, the second major airport, was constructed about 1953 in the suburbs of Monrovia. Apart from Robertsfield and Spriggs-Payne Airport, there are numerous airfields throughout the country. Twelve of these airfields are served by scheduled flights.

Airline passenger traffic, even though it fluctuated a great deal between 1952 and 1964, showed an increasing trend. Passenger traffic went from a low of 339 passengers carried in 1952 to 688 in 1960 to a high of 1,748 in 1964. Similar results are available for air cargo which went from 10,721 pounds in 1952 to 37,475 pounds in 1961 to 50,209 pounds in 1964. Over the 1952-1964 period, air cargo traffic peaked to 79,266 pounds.

As the most recent data in Table IV-15 indicate, international passenger traffic has increased at a rate of 8% annually since 1971, climbing to about 83,000 passengers in 1976. Air cargo has achieved a similar percentage increase over the same period, reaching about 3,000 tons in 1976.

Domestic air transport of the Liberian-owned Air Liberia and two non-scheduled chartered services has been declining during the late 1970's due to system inefficiencies. Domestic air service continues today to provide an important function by opening up remote areas of the country not yet served by

TABLE IV-15
COMMERCIAL AIR TRAFFIC IN LIBERIA

	1971	1972	1973	1974	1975	1976
Number of Passengers	51,797	53,652	58,753	68,270	70,387	82,927
Cargo (tons)	1,746	1,576	1,940	1,668	2,628	3,053
Mail (tons)	174	195	244	245	274	N.A.

Source: Government of Liberia. (1975). Economic Survey of Liberia, Ministry of Planning and Economic Affairs.

roads. However, domestic air service does not appear to be very significant, in terms of transportation impacts on the agricultural sector.

PART III. THE AGRICULTURAL SECTOR

In contrast to the transport sector discussed in Part II, agriculture, as the second largest sector in the Liberian economy, contributed about 15.9 per cent of GDP at factor cost in 1980. The agricultural sector is characterized by separate and distinct types of farming operations. The first is commercial estates, mainly foreign-owned concessions that produce rubber and palm products for export, and Liberian-owned farms which produce rubber as the primary crop but also produce coffee, cocoa, and palm products. The second is traditional farms that produce such food crops as cassava, rice, yams, sweet potatoes, tropical fruits, and vegetables, primarily for home consumption. Commercial estates accounted for over two-thirds of cultivated area in 1980 and represented only 7 per cent of the farming population. Traditional farmers, on the other hand, represent more than 80 per cent of the farming population but cultivate only about a third of the land.

In spite of the fact that Liberia has one of the more favorable agricultural environments in Africa, the country is basically a one-crop country in terms of its main export earnings, with rubber as the principal crop.

COMMERCIAL ESTATE AGRICULTURE

Rubber

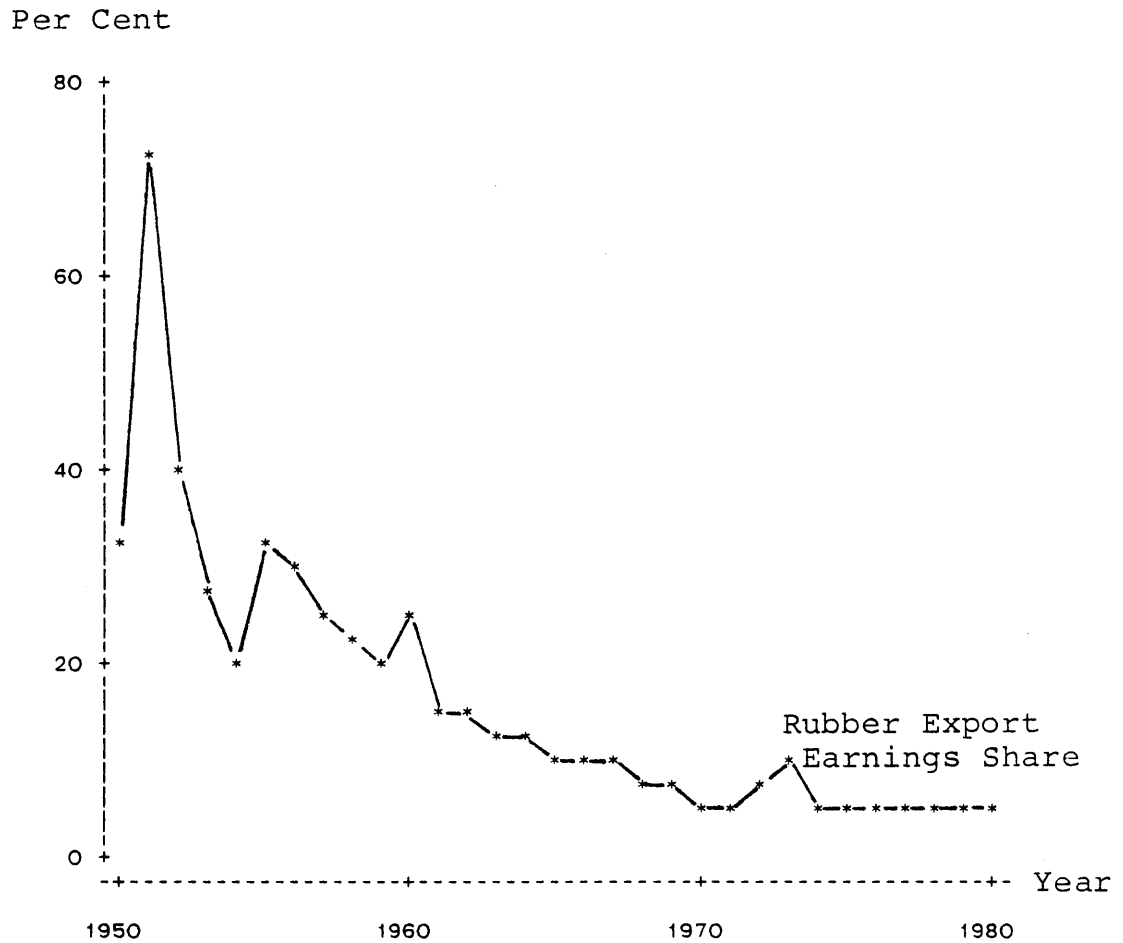
Before 1950, rubber was produced almost entirely on commercial estates, such as the Firestone Plantation. In later years, the B.F. Goodrich, the African Fruit Company, the Salala Rubber Co., and the Liberian African Company started large-scale rubber plantations under concession agreements with the Liberian Government. Independent rubber farmers, mainly Liberian-owned commercial estates, with the assistance of the Firestone Company, began production in the late 1950's. The Firestone Company provided independent producers with seedlings, technical assistance, and working capital.

Data on total output of rubber production are presented in Figure IV-11. Independent growers produced about 17 per cent of the total output in 1961, while the remainder was produced by Firestone. See Table IV-16 for a review of the number of independent rubber farmers and their output.

Rubber's contribution to the nominal GDP in the 1950's was impressive as shown by its share in Figure IV-10. In 1950, the export earnings from rubber accounted for 36% of the GDP in current market prices and declined in 1960 to about 23 per cent. The decline was even more dramatic in the following decades, with rubber accounting for only 6.1 per cent of GDP at factor cost in 1970 and 1980. Although there is a declining trend in rubber's export earnings compared to the total GDP, rubber's performance in the economy, in terms of the pattern

FIGURE IV-10

RUBBER EXPORT EARNINGS AS A SHARE OF GDP



Sources: Clower et al. (1966). Growth Without Development: An Economic Survey of Liberia, Northwestern University Press, Evanston.
I.B.R.D. (1966). The Current Economic Position and Prospects of Liberia, Report No. AF-45a, June.
I.B.R.D. (1982). Liberia: Recent Economic Developments and Medium-Term Prospects, Report No. 4178-LBR, December.

TABLE IV-16
LIBERIAN-OWNED RUBBER FARMS

YEAR	NO. OF FARMS	RUBBER PRODUCTION *	TOTAL OF ALL RUBBER PRODUCTION *	% OF TOTAL
1950	477	2.7	66.7	4.0
1951	777	4.4	79.3	5.5
1952	866	5.4	78.0	6.9
1953	888	5.9	78.8	7.5
1954	912	6.4	82.8	7.7
1955	991	7.6	87.5	8.7
1956	1,192	8.3	88.5	9.4
1957	1,520	8.9	83.9	10.6
1958	1,734	11.3	94.8	11.9
1959	2,066	12.6	96.2	13.1
1960	2,312	14.4	106.7	13.5
1961	2,700	15.8	90.8	17.4
1962	2,991	17.0	100.1	16.9
1963	3,154	17.0	88.5	19.2
1964	3,200	16.5	95.5	17.3

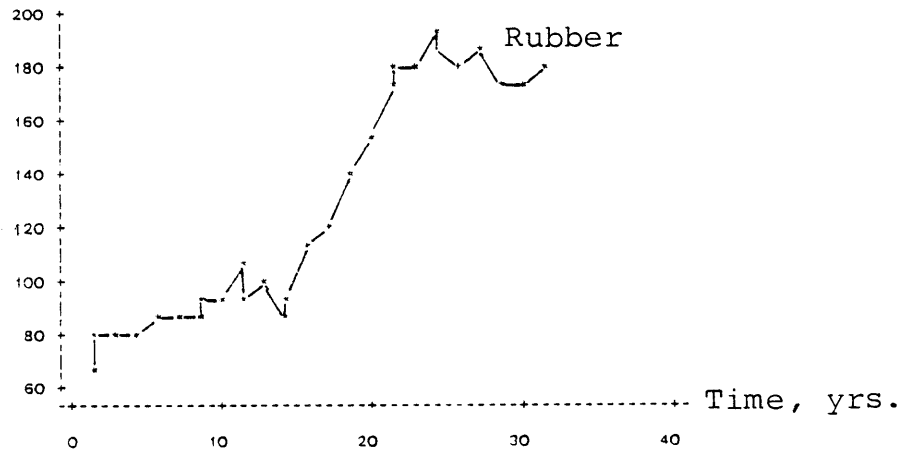
* in million lbs.

Sources: Clower et al. (1966). Growth Without Development: An Economic Survey of Liberia, Northwestern University Press, Evanston, p. 168.
Stanley, W.R. (1968). "The Cost of Road Transport in Liberia: A Case Study of Independent Rubber Farmers", The Journal of Developing Areas, Vol.II, July, p. 498.
I.B.R.D. (1963). The Economy of Liberia, Report No. AF-10a, September.

FIGURE IV-11

DOMESTIC RUBBER PRODUCTION, 1950-1980

Thousand lbs.

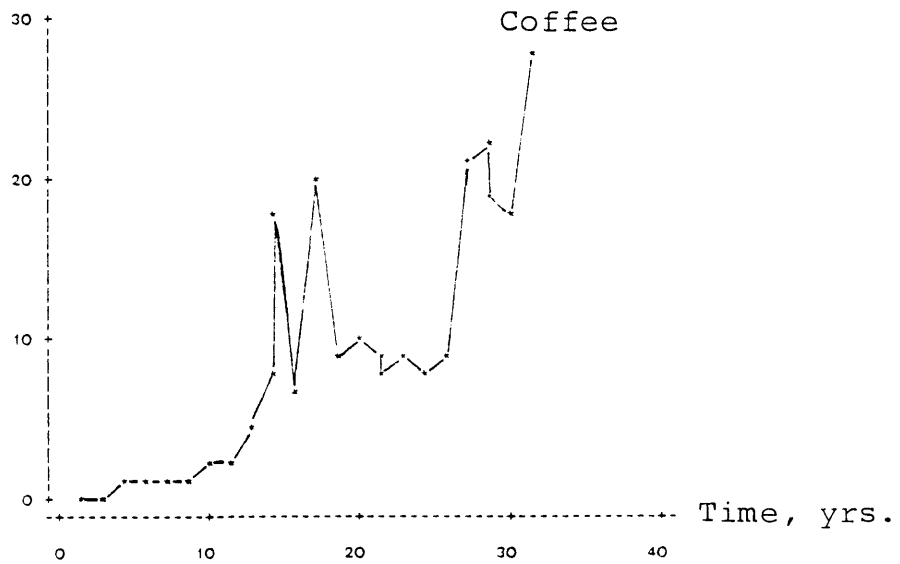


Source: See Figure IV-12.

FIGURE IV-12

DOMESTIC COFFEE PRODUCTION, 1950-1980

Thousand lbs.



Sources: Clower et al. (1966). Growth Without Development, Northwestern University Press.
I.B.R.D. (1966). Report No. AF-45a, June.
I.B.R.D. (1982). Report No. 4178-LBR, December.

of sector growth, was profound. In 1980, rubber exports were estimated at \$61.5 million at current factor cost, up from \$21.0 million in current market prices in 1950.

CASH CROP MIX AND PRODUCTION VOLUMES

While the importance of rubber production to the Liberian export-earning capacity has been demonstrated in the previous section, very little has been said about the relative importance of other cash crops such as coffee, cocoa, and palm products. The production of these three perennial crops for export has remained relatively small over the last forty years with wide fluctuations in recent years. The agency with responsibility for promoting agriculture is the Liberian Produce Marketing Corporation (LPMC). LPMC was established in 1962 by the central Government in partnership with the East Asiatic Company of Denmark to provide management, marketing, and overseas sales facilities. With the exception of rubber, LPMC has monopoly rights of purchase on all three primary export commodities.

Coffee

Coffee production in Liberia showed no definitive trend between 1950-1980 except that of wide fluctuations. Between 1950 and 1960, the variation in production ranged from a low of 166,000 pounds to a high of about 2.0 million pounds. The period between 1960 and 1970 is not any less dramatic with a high of 19.6 million pounds in 1966 from a low of 2.0 million pounds in 1960. The 1970 to 1980 period was even more extreme

in that coffee production increased to 28.0 million pounds in 1980 from a low of 7.3 million pounds in 1972. Such wide variations in the volumes of production over this thirty-year period can, to some extent, be attributed to international market prices for coffee and the fact that since 1967 Liberia has been a member of the International Coffee Agreement (ICA). The ICA imposes basic quotas on member countries and since Liberia joined, its quota was set at 3,600 tons in the first year and increased only by 10% per year. In addition to the impact of international prices on production, poor access to markets, credit, and technology by smallholders appears also to have contributed to low production volumes. Figure IV-12 shows the production for coffee.

Cocoa

The contribution of cocoa to Liberia's agricultural exports, although it is relatively small, has shown a rather consistent tendency towards growth. Between 1950 and 1960, cocoa production increased by 100 per cent. By way of comparison, from 1960 to 1970 the production of cocoa doubled. The 1970-1980 period showed the same results as the previous decades with production volumes doubling. Cocoa production is shown in Figure IV-13. Cocoa production, like coffee, is undertaken primarily by smallholder-estate owners.

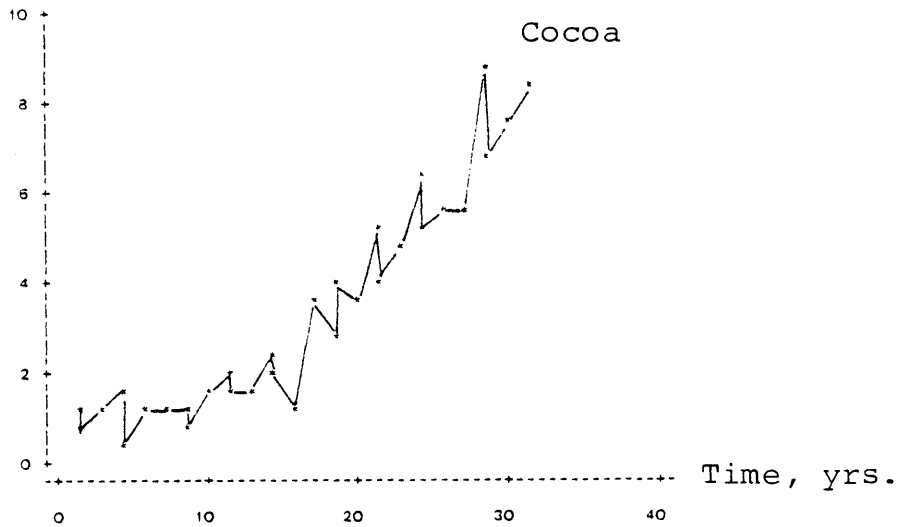
Palm Kernels

The production of palm kernels satisfies some of Liberia's local consumption needs for oils and fats, while the remainder--

FIGURE IV-13

DOMESTIC COCOA PRODUCTION, 1950-1980

Thousand lbs.

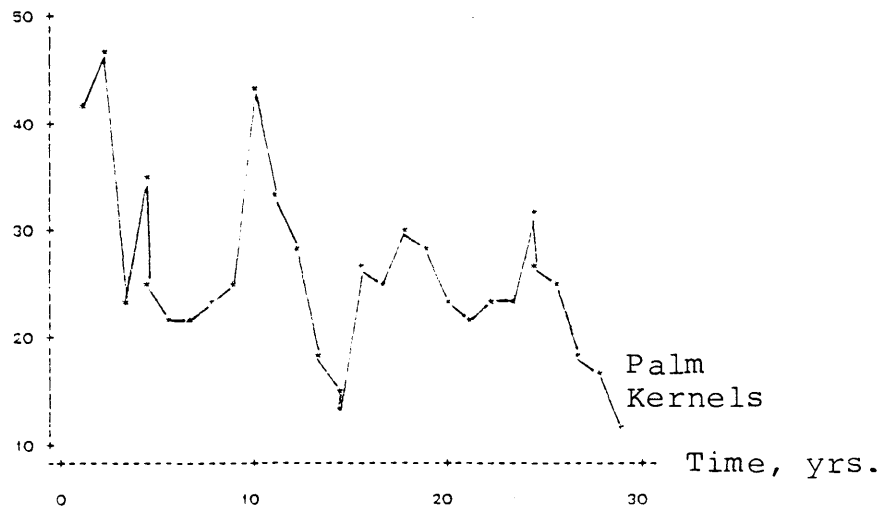


Source: See Figure IV-14.

FIGURE IV-14

DOMESTIC PALM KERNELS PRODUCTION, 1950-1980

Million lbs.



Sources: Clower et al. (1966). Growth Without Development, Northwestern University Press.
I.B.R.D. (1966). Report No. AF-45a, June.
I.B.R.D. (1982). Report No. 4178-LBR, December.

or the majority of it--is exported. The production of palm kernels, which became one of the most important crops other than rubber, declined steadily over a number of years up to about 1963, as Figure IV-14 indicates. This decline, which was experienced not only in volume but also in prices, reflected a decrease in volume from 43.0 million pounds in 1950 to 13.2 million in 1963. Qureshi et al. (1964) note that palm kernels, as a wild crop in Liberia, may have declined during this period in part due to falling prices and/or alternative employment opportunities which compete with the gathering of palm kernels. A notable increase in edible oil consumption is also believed to have been a contributing factor to declines in production exported. In fact, between 1964 and 1978, no specific trends regarding exports of palm kernels were noticeable. An average of about 23.0 million pounds per year were produced over this period and, in some years, wide variations were experienced. Palm kernel production, unlike coffee and cocoa, are not cultivated as a plantation or large-scale agricultural crop.

AGRICULTURAL EMPLOYMENT

It has been noted elsewhere in this chapter that in excess of 70 per cent of working Liberians are employed in the agricultural sector. About 83 per cent of these workers are employed in the traditional economy, producing mainly for subsistence. As Table IV-17 indicates, the agricultural sector is not only important to the Liberian economy in terms of its

TABLE IV-17
PERCENTAGE EMPLOYMENT IN LIBERIA
BY MAJOR SECTOR, 1977-1980

SECTOR	1977	1978	1979	1980
AGRICULTURE	76.0	75.6	74.1	79.3
Monetary Agriculture	11.3	11.3	11.5	7.7
Non-Monetary Agriculture <u>1/</u>	64.7	64.3	62.6	71.6
INDUSTRY	8.7	8.7	9.1	6.6
SERVICES	<u>15.3</u>	<u>15.6</u>	<u>16.8</u>	<u>14.1</u>
TOTAL EMPLOYMENT (PER CENT) <u>2/</u>	100.0	100.0	100.0	100.0

1/ Includes Forestry and Fishing

2/ Percentage totals may not add to 100.0 because of rounding.

Source: Government of Liberia. (1979). Economic Survey of Liberia, Ministry of Planning and Economic Affairs.

export-earnings capacity but also in terms of its employment absorption. The monetary agricultural economy represents only about 15 per cent of total agricultural employment. Of those workers employed in the monetary agricultural economy, foreign-owned rubber concessions are the largest employers.

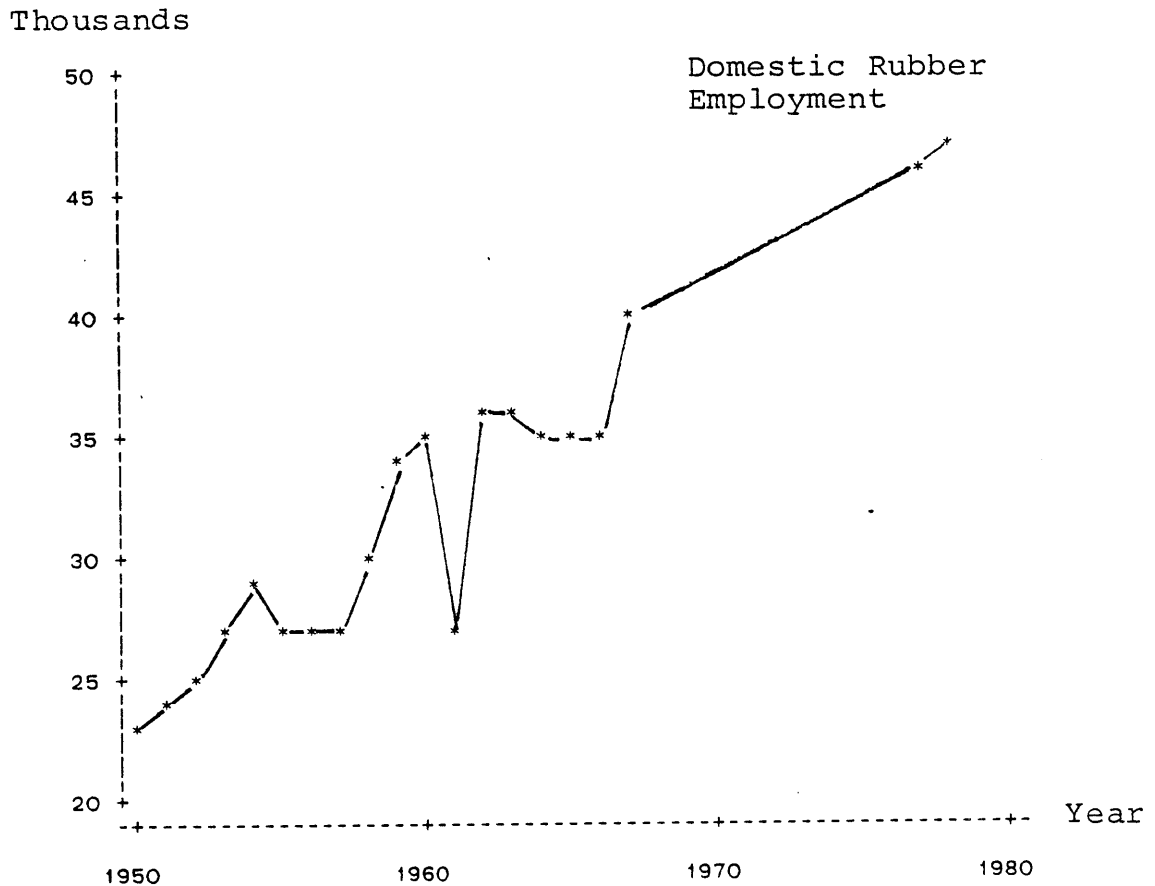
Total employment in the production of rubber, as shown in Figure IV-15, shows a trend of increasing growth. In 1950, there were about 23.1 thousand workers engaged in producing rubber and by 1980 that figure has increased to 52.0 thousand. This is expected particularly in light of the fact that many of the foreign-owned rubber concessions did not start cultivating rubber until the late 1950's and early 1960's, which is the period when the largest expansion occurred.

LAND CULTIVATION

Like employment in rubber, the intensiveness of land utilization for agricultural activities is demonstrated by the rapid growth in commercial rubber farms. Figure IV-16 presents the number of acres of cultivated land from 1950 to 1970. As the figure shows, Liberia went from about 71,000 acres of rubber plants in 1950 to about 218,000 acres in 1970. The increase in cultivated land for rubber production experienced its most dramatic rise in 1964 when it went to 191,000 acres from 90,290 acres in 1961--a rise of 212 per cent. Such a phenomenal increase is attributed to two factors. First, the growth in the number of Liberian-owned commercial rubber farms which increased by

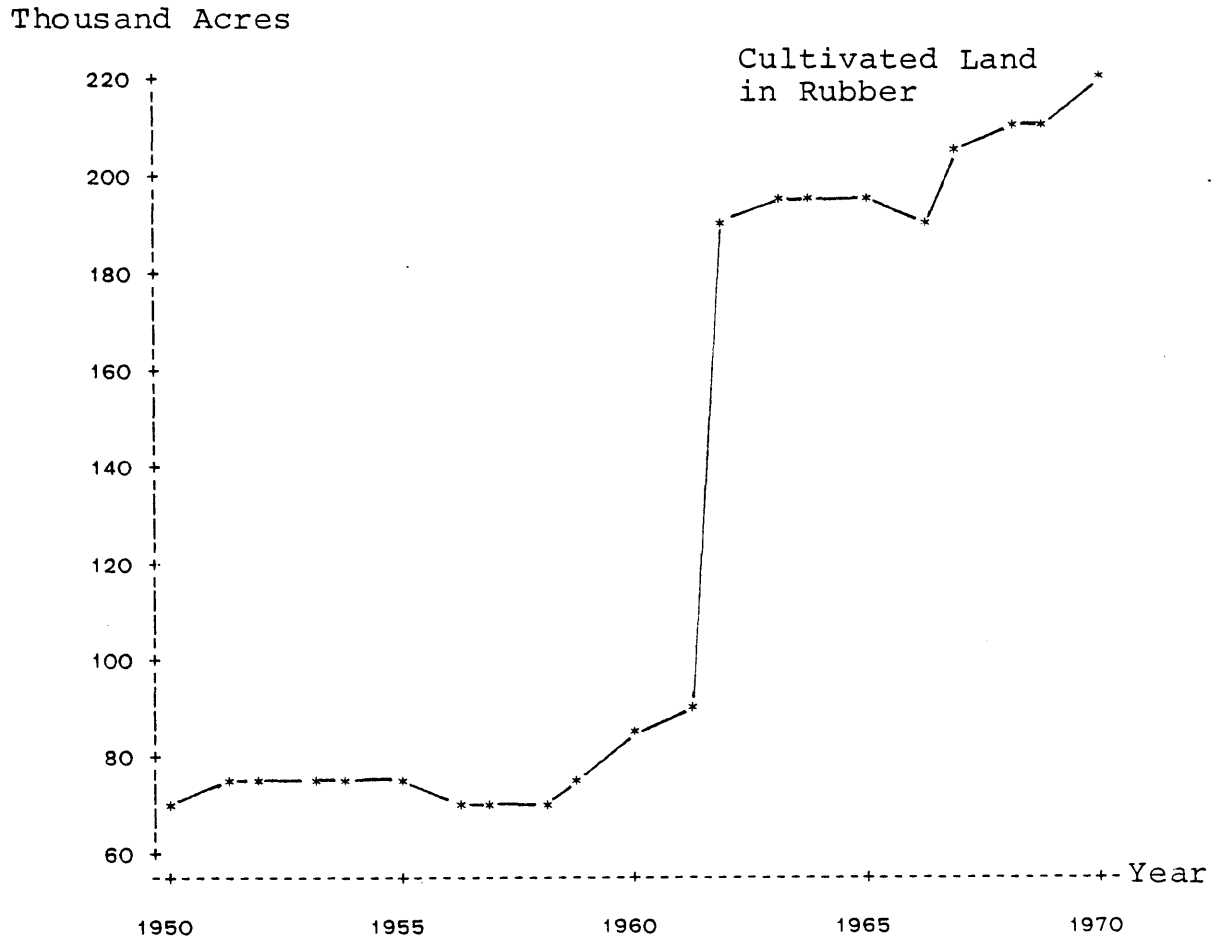
FIGURE IV-15

DOMESTIC EMPLOYMENT IN RUBBER PRODUCTION,
1950-1967



Sources: Clower et al. (1966). Growth Without Development: An Economic Survey of Liberia, Northwestern University Press, Evanston.
I.B.R.D. (1966). The Current Economic Position and Prospects of Liberia, Report No. AF-45a, June.
I.B.R.D. (1982). Liberia: Recent Economic Developments and Medium-Term Prospects, Report No. 4178-LBR, December.

FIGURE IV-16
LAND CULTIVATED FOR RUBBER PRODUCTION,
1950-1970



Sources: Clower et al. (1966). Growth Without Development: An Economic Survey of Liberia, Northwestern University Press, Evanston.
I.B.R.D. (1966). The Current Economic Position and Prospects of Liberia, Report No. AF-45a, June.
I.B.R.D. (1982). Liberia: Recent Economic Developments and Medium-Term Prospects, Report No. 4178-LBR, December.

almost 300 farms over the same period is partly responsible for this increase. Second, three foreign-owned commercial estates came into the market. Both the locally-owned and foreign-owned estates accounted for more than 100,000 acres of new land coming into cultivation. The Firestone Plantation dominated rubber production in Liberia with about 75,000 acres planted in 1969, which at that time represented the largest rubber estate in the world.

In the early 1960's, the total acreage of the reserve areas of the six foreign-owned rubber concessions was just over 3 million acres or about 11 per cent of Liberia's total land area. This may imply that the Liberian Government expected that earnings from rubber exports would play a significant role in the economy well into the 1970's and 1980's. However, as we have seen, such was not the case. Rubber production began to decline in the 1970's as prices fell and synthetics became widely used in manufacturing.

SUMMARY

This chapter presented the key economic sectors of the Liberian economy over the period from 1950 to 1980. Its main focus was to outline the sectoral growth patterns and components of the economy in terms of their contribution to Liberian GDP. It was also to provide the historical context from which the present research emerges.

The profound growth of the Liberian economy by sectoral compositions revealed how important both agriculture and trans-

portation have been with regards to national income. The transportation sector contributes in excess of 7 per cent to the GDP. Agriculture, in addition to mining, has been one of the two most important sectors of the economy. Agriculture contributed 78 per cent of the Liberian GDP in 1950. It declined to about 16 per cent in 1980 and was replaced by iron-ore mining as the dominant sector around 1970.

The economy was further disaggregated to determine what crop-mix or crop, in the agricultural sector, accounted for this impressive economic expansion. The results indicated that despite the export of coffee, cocoa, and palm kernels, commercial production of rubber was almost singularly responsible for agriculture's contribution to GDP. Rubber production in 1950 was 36 per cent of nominal GDP, 23 per cent in 1960, and 6.1 per cent in 1980. Rubber increased from \$21.0 million in current market prices in 1950 to \$61.5 million at factor cost in 1980.

The transportation sector was also disaggregated by mode to determine which modes were most critical to the development of the Liberian economy. Liberia has a multi-modal transport sector of various classes of roads, ports, airports and airfields, and railways. A survey of the transport sector revealed that the most important modes to the country's economy were railroads, roads, and ports. The impact of the railway system was limited to the mining sector. The railway system is used exclusively for transportation of ore, mining equip-

ment, and consumer items for the mining concessions. The impact of roads, both those publicly and privately built, was ubiquitous in that all sectors of the economy, including mining, were affected by passenger and goods movements. The development of the road network went from 230 miles of gravel roads in 1950 to almost 6,200 miles of asphalt-surfaced, gravel and all-weather roads in 1980. The impact of roads was also measured in terms of taxes collected from road-user charges. Road-user taxes, as a per cent of total Government revenues, averaged about 6 per cent each year between 1966 and 1976.

Port development was also found to have had a significant impact on the country's economy by facilitating the export of its primary commodities, rubber products and iron ore. The importation of essential equipment and machinery and other essential import items were also made possible by the development of deep-water ports.

From the data presented in this chapter on the Liberian economy, whether measured in national aggregates, sector components, or sectoral growth patterns, Liberia experienced unprecedented growth between 1950 and 1980. In the next chapter attempts will be made to analyze the relationship between the transport sector and agricultural development to determine if meaningful statistical relationships can be established and the extent to which policy inferences can be drawn from these relationships.

CHAPTER V

EMPIRICAL APPLICATIONS AND ESTIMATED RESULTS

PART I. INTRODUCTION

The preceding chapter discussed the historical development of macroeconomic trends, sectoral components, and sectoral growth patterns of the Liberian economy from 1950 to 1980. In Chapter IV, it was clearly shown that the agriculture and transportation sectors made substantial contributions to the Liberian Gross Domestic Product. However, the interrelationship and specific impact that the two sectors had on each other were not revealed. The underlying assumption throughout the chapter was that an important connection existed between the two sectors, and some evidence was offered, based on studies by Stanley (1966), to support this proposition. However, the specific nature of the relationship was left unclear. This chapter addresses the issue of the relationship between the transportation sector and agricultural development. The chapter examines available empirical evidence and employs statistical techniques to measure and determine the strength of this relationship.

The chapter is organized around three empirical models and is presented in three parts. Part I briefly outlines the transport-investment model. It also presents the empirical findings and interpretations of the model as they relate to

changes in production of four Liberian primary export commodities. Part II is concerned with the effects of transport accessibility and of producer prices on agricultural production. An empirical model of transport accessibility is outlined and estimated results are discussed under this section. Part III discusses the factor-input model and presents the results and interpretations of the empirical studies of cultivated land for rubber production and agricultural employment as they relate to transport accessibility. Chapter V concludes with a section that summarizes the main findings of the study.

DESCRIPTION OF THE VARIABLES AND DATA USED IN THE STUDY

The variables to be employed in the transport investment, transport accessibility, and factor-input models were outlined in Chapter III. Table V-1 presents a description of the variables and their relevant unit measurements. The table also indicates whether the variables appear in the models as dependent or independent variables. A further description of the data is presented below.

Agricultural Production

The empirical data used to implement the models are derived from the 1950 to 1980 agricultural production statistics of Liberia and other data published by various official sources of the Government of Liberia and international agencies, such as the World Bank. These data are detailed in Appendix

TABLE V-1

VARIABLES USED IN THE MODELS

DEPENDENT VARIABLES	
VARIABLE NAME	VARIABLE DESCRIPTION*
RU	RUBBER PRODUCTION, in thousand lbs.
CF	COFFEE PRODUCTION, in thousand lbs.
CC	COCOA PRODUCTION, in thousand lbs.
PA	PALM KERNELS PRODUCTION, in million lbs.
AE	AGRICULTURAL EMPLOYMENT: RUBBER, in thousands
CL	CULTIVATED LAND: RUBBER, in thousand acres
INDEPENDENT VARIABLES	
VARIABLE NAME	VARIABLE DESCRIPTION*†
TI	TRANSPORT INVESTMENTS, in U.S. \$ million
NR	NONURBAN ROADS, in miles
RUP	RUBBER PRICES, in U.S. ¢/kilogram
CFP	COFFEE PRICES, in U.S. ¢/pound
CCP	COCOA PRICES, in U.S. ¢/pound
PAP	PALM KERNEL PRICES, in U.S. ¢/pound

* Note: Each of the variables were transformed into their natural logarithmic equivalents in the models.

† All variables in units of U.S. dollars are expressed in 1975 prices.

C.1 for each of the primary commodities used in the models. The data series on crop production covers rubber, coffee, cocoa, and palm kernels.

Producer Prices

The data on producer prices represent the prices paid from 1950 to 1980 in the international market for the commodities under study. The price for rubber is the New York spot market price. The price series for coffee is that quoted on the New York spot market for Angolan coffee. The series for cocoa is the price quoted for Ghanaian cocoa on the New York spot market. The series for Malayan palm kernels is the price quoted on the international market. The price series for each of these commodities are expressed in 1975 prices. The data are taken from the World Bank's Commodity Trade and Price Trends and are fully detailed in Appendix C.2.

Transport Investments

The data series and sources of transport investments are detailed in Appendix C.3. The transport investment series were deflated by the Liberian GDP implicit price deflator to eliminate the effects of changes in the general price level over the period under study. The resulting investment series are expressed in constant U.S. dollars using 1975 as the base year. The transport investment series includes capital stock in addition to road maintenance and repair expenditures.

Transport Accessibility

The transport accessibility data that will be used to implement the models are contained in Appendix C.4. The data series represent the total road miles, excluding urban roads, in Liberia from 1950 to 1964.

Cultivated Land

The data series for cultivated land is for land used in the production of rubber from 1950 to 1964. The data represent both foreign- and locally-owned rubber estates. The series and sources of data are presented in Appendix C.5.

Agricultural Employment

The agricultural employment series used in this study represents domestic employment on rubber estates for the years 1950 to 1964. The data series does not include expatriate employees who were mostly middle- and senior-level managers of commercial rubber estates. The data series and sources of data are presented in Appendix C.5.

THE TRANSPORT-INVESTMENT MODEL WITH A DISTRIBUTED LAG

The functional form of the transport-investment model was discussed in Chapter III. To summarize the model briefly, past and current investments in transport infrastructure and producer prices are hypothesized to be positively correlated with changes in agricultural output. The transport-investment variable as an independent variable is assumed to be a distrib-

uted lag of the polynomial type. The price variable, as an independent variable represents the real producer prices for the agricultural commodities. The two variables are hypothesized to jointly exert a positive influence on agricultural production.

Procedures and Applications

Before implementing the transport-investment model, several decisions were made. First, it was decided that second-, third-, and fourth-degree polynomials would be tested to describe the pattern of the transport investments. Second, the length of the lag period would be tested for 5 through 12 years. This is consistent with the polynomial distributed-lag approach whereby the number of periods in the distribution should exceed the degree of the polynomial by at least one period. Additionally, the length of the lag periods are consistent with agronomic information for perennial tree crops. The third and final decision was to implement the model without endpoint restrictions. The intent of this decision was to examine the structure of the lag coefficients without forcing them into the inverted U-shape, as would be the case when both the head and tail of the lag coefficients are set to zero.

Criteria for Selecting the Best Distributed-Lag Model

Almon (1965) suggested that two criteria should be considered in order to select the best distributed-lag model. The

criteria consist of selecting i) the model with the highest coefficient of determination or R^2 , and ii) the model with the largest sum of the lag coefficients. These criteria will be applied in this study as the initial screening of the estimated equations. Additional tests such as the standard error of the estimate and ordinary least-squares tests of hypothesis (e.g., F-test, t-test, and Durbin-Watson test) will also be used to select the best distributed-lag model.

PRELIMINARY RESULTS AND EMPIRICAL IRREGULARITIES

As we indicated in the previous section, the transport-investment model would be tested for two-, three-, and four-degree polynomials for five through twelve year lag periods. The model was also respecified to explicitly take into account the cumulative stock of "transport investments" as an additional explanatory variable. This was done in order to strengthen the underlying theoretical basis of the transport-investment model. Recall that the model hypothesized that current and past investments in transportation infrastructure exert a positive influence on agricultural output. However, the existing stock of transport investments as a proxy for the physical stock was not explicitly incorporated into the model. The respecified model is presented below in the following functional form:

$$\ln Y_{it} = \ln c_i + \lambda_i \sum_{j=0}^s \ln T_{t-j} + \ln P_{it} + \ln \sum_{k=1}^t TS_k + \epsilon_t$$

Where the term: $\ln \sum_{k=1}^t TS_k$ = the natural log of the transport investment stock variable for k equals year 1 to t .

k = number of years

All other variables are as previously specified in Chapter III.

The model was tested on each crop for alternate lag periods and alternate degrees of polynomial. The empirical results revealed that the transport investment stock variable coefficient was negative for each of the crops tested. Comparing the results of the transport-investment model without the stock variable to the one with the cumulative investment stock variable, the variable lnTS increases the R^2 value as would be the case when an additional explanatory variable is added to an equation. But when the R^2 value is adjusted for the degrees of freedom and the explanatory variables, the adjusted R^2 value in some cases fell below the results found in the "without" model. Additionally, the stock variables tended to increase the standard error of the estimate while marginally reducing the Durbin-Watson statistic. Because of these empirical irregularities, no evidence was found to justify including this stock variable in the model even though the theory underlying the model seems to indicate that its addition to the model should increase the model's predictive capability.

The empirical irregularities suggest that the stock variable lnTS should not be included in the model because it reduces rather than enhances the predictive capability of the model. As a result, the empirical findings reported on below do not incorporate a stock variable in the model as an additional explanatory variable.

EMPIRICAL RESULTS OF THE
DISTRIBUTED-LAG MODELS

The results of the estimated equations to explain the influence of past and current investments in transport infrastructure along with producer prices on the production of rubber, coffee, cocoa, and palm kernels are presented in Table V-2. Because our primary objective was to estimate the best distributed-lag model for all of the crops, only the final regression results are summarized in this chapter. Complete results that include all parametric tests; the residual and fitted values; the lagged coefficients, standard errors of the estimate, and estimates of the variance-covariance of the coefficients are contained in Appendixes D.1.1 through D.1.4.

The final results of the best distributed-lag model of transport investment ($\ln TI$) and producer prices ($\ln P$) on the crops under study indicate that the model achieved reasonably good results as revealed in Table V-2. The estimated equations using Almon's criteria of a high coefficient of determination and a large sum of the lag coefficients revealed an adjusted R^2 of 0.971; 0.861; 0.861; and 0.520 for rubber, coffee, cocoa, and palm kernels, respectively. The sum of the lag coefficients were, respectively, 0.3874; 1.147; 0.9023, and -0.016. These results were selected from 24 regression tests for each crop, out of a total of 96 equations.

One of the most important findings of the final results is that the lag coefficients in each estimated equation exhibited stability. This is evidenced by the positive sign of the

TABLE V-2

FINAL REGRESSION RESULTS: AGRICULTURAL PRODUCTION
ON TRANSPORT INVESTMENTS AND PRODUCER PRICES

INDEPENDENT VARIABLES	DEPENDENT VARIABLES			
	lnRU	lnCF	lnCC	lnPA
Constant	3.9638 (8.1939)*	2.0415 (1.7299)	-1.3504 (-1.809)	2.2565 (2.4613)
lnP	0.0601 (0.6344)	-0.5877 (-2.0485)	0.2219 (1.0232)	0.2651 (0.9995)
lnTI Distributed Lag Coefficients, yrs.				
0	0.0235 (1.3071)	0.6306 (7.5748)	0.0176 (0.3109)	-0.0744 (-1.1707)
1	0.0117 (2.0394)	0.3223 (10.4323)	0.0709 (2.6426)	0.0269 (0.9775)
2	0.0158 (1.9060)	0.1135 (2.5416)	0.1003 (4.1515)	0.0601 (1.8584)
3	0.0284 (3.9955)	0.0040 (0.0839)	0.1107 (3.9713)	0.0544 (1.8574)
4	0.0436 (8.0726)	-0.0059 (-0.1573)	0.1065 (4.0618)	0.0328 (1.4048)
5	0.0567 (8.0029)	0.0835 (1.0642)	0.0925 (4.5605)	0.0115 (0.4995)
6	0.0643 (7.1224)		0.0733 (4.8085)	0.0002 (0.0065)
7	0.0644 (7.2504)		0.0536 (3.0498)	0.0019 (0.0836)
8	0.0561 (8.214)		0.0379 (1.6167)	0.0130 (0.6761)
9	0.0401 (7.3503)		0.0394 (1.1779)	0.0235 (1.024)
10	0.0182 (2.6911)		0.0374 (1.5781)	0.0164 (0.5865)
11	-0.0064 (-0.8947)		0.0618 (2.6334)	-0.0315 (1.2828)
12	-0.0291 (-2.834)		0.1089 (2.2866)	-0.1503 (-3.3801)
Sum of Lag Coef- ficients	0.3874	1.1479	0.9023	-0.0155
Mean Lag	5.1497	0.8319	5.8176	74.6
\bar{R}^2	0.971	0.861	0.861	0.519
Durbin-Watson	1.7204	1.5909	2.5772	2.1682
SEE	0.0431	0.4054	0.2127	0.1893
F-statistic	101.6023	40.4664	23.2301	4.2452
Degree Polynomial	4	2	3	4

* t-statistics are in parenthesis

lag coefficients for consecutive lag periods. Table V-2 shows that the best distributed-lag model for rubber (lnRU) is a fourth-degree polynomial with a twelve-period lag. The best distributed-lag model for coffee (lnCF) is a two-degree polynomial with a five-period lag. The best distributed-lag model for cocoa (lnCC) is a three-degree polynomial with a twelve-period lag and for palm kernels (lnPA), a fourth-degree polynomial with a twelve-period lag.

OUTPUT SUPPLY RESPONSES

The final results of the distributed-lag models of transport investments, presented in Table V-2, support the hypothesis of a distributed impact of transport investments on agricultural production. This is evidenced by the relative stability (i.e., positive sign) of the lag coefficients in the estimated equations, although rubber and palm kernels exhibited negative lag coefficients at the tail. This indicates that the distributed effect approaches zero in the eleventh and twelfth periods.

The structure of the lag coefficients revealed the inverted U-shape lag for rubber, cocoa and palm kernels, whereby the lag coefficients showed an increasing trend up to some point and then decreased. This was accomplished without restricting the head and tail endpoints to zero. The resulting shape of the lag revealed a more realistic picture of the lag structure.

The distributed-lag model indicates two responses by agricultural producers; a current or short-run response as measured by the current period, and a long-run response as mea-

sured by the sum of the lag coefficients. The single-year current supply response typically represents a harvesting response based on past plantings to current market conditions which occurs over a period of time too short for producers to adjust their factors of production. The current supply responses, as Table V-2 indicates, are 0.0234, 0.6306, 0.0176, and -0.0744 for rubber, coffee, cocoa, and palm kernels, respectively. The output response in the current period for palm kernels is negative. This is unexpected and inconsistent with the hypothesis of the research. However, a plausible explanation can be offered. The nature of palm kernels production as a wild tree crop does not appear to lend itself to quick adjustments to economic incentives. This is evidenced by the negative coefficient for palm kernels in the current period. In the production of palm kernels, no economies of scale in production are realized by producers. This means that producers would have had to utilize their factors of production (mainly labor) more intensively in order to increase their output in the short-run. However, producers may decide instead to increase their output for alternative crops, such as coffee or cocoa, in which economies of scale are possible and additional factor inputs may not be required.

It is instructive to note here how the long-run output responses vary among different crops. The results were expected because, while each of the tree crops require a long gestation period between planting and the first harvesting, their factor-mixes; market conditions; method of harvesting, and producer

prices were vastly different. Thus, it can be expected that the supply responses would vary among crops as the research assumed in Chapter III.

The long-run supply responses are intended to measure the effect of producers adjusting their factor-mixes (e.g., plantings, cultivating new land, etc.) in response to improved market conditions and better transport access. The long-run supply responses, as shown in Table V-2, are 0.387 for rubber; 1.148 for coffee; 0.9023 for cocoa, and -0.016 for palm kernels. Although the t-statistic on the sum of the lag coefficients, as shown in Appendixes D.1.1 through D.1.4, are statistically significant, the magnitudes of the long-run output elasticities exceed one only for coffee and approaches one in the case of cocoa. The remaining output elasticities were smaller.

The negative long-run supply response for palm kernels suggests that the producers of palm kernels do not respond to transport investments in the long-run. This implies that the response is more immediate, although it is not necessarily a current or short-run response as we have already discovered. Trying to isolate this response is further complicated, however, by the fact that palm kernels are joint products with palm oil and palm butter which are harvested from wild tree crops.

PRICE ELASTICITIES

The price variable (LRUP, LCFP, LCCP and LPAP) in each of the estimated equations, except coffee, indicates support for the hypothesis that prices exert a positive influence on

producer output. As revealed in Table V-2, the estimated price elasticities are 0.0601, -0.5877, 0.2219 and 0.2651 respectively for rubber, coffee, cocoa, and palm kernels. Although the signs are positive except for coffee, the t-statistics indicate that the elasticities are not statistically significant.

The price elasticities for palm kernels, cocoa, and rubber are consistent with the general survey results of the price elasticity for perennial tree crops reported by Bateman (1970, p. 251) and Helleiner (1975, p.41). The results for coffee are inconsistent with findings in other countries and the hypothesis of this research. Evidence of a positive price elasticity for coffee in most countries varies between 0.16 and 0.64 for the current response and 0.47 to 1.01 for the long-run response. Bateman (1970, p. 252) concludes that in most of the coffee producing countries, producers are relatively responsive to prices in the long run. In Liberia, where the tendency of smallholder estate owners is to intersperse coffee and cocoa plantings with rubber trees, the negative price variable may reflect a substitution effect. That is to say, if the expected price shows a downward trend, smallholder estate owners may switch their resources to harvesting other crops such as rubber or cocoa because of higher prices.

The existence of a gestation period for coffee further complicates the supply relationship. This is primarily because of the delay between planting and harvesting which generally

requires between 5 to 10 years for the plants to reach their bearing cycle; although it is expected that output supply would be related to the current or the expected prices. It is conceivable that production of coffee is more related to earnings than prices as has been found for cocoa (Helleiner, 1977). Real producer prices for coffee experienced wide fluctuations during the 1960's and 1970's with a generally downward trend. Levi and Havinden (1982) offered the following explanation for negative responses to producer prices. They argued that if the real producer prices had been downward over the analysis period, it is quite possible that improved transport infrastructure would have had very little effect in increasing export. Having said this, it is very difficult to know with any degree of certainty based on the existing evidence, why producers of coffee respond negatively to current prices.

As we indicated above, there was a downward trend in coffee prices. The net effect on local supply may have been only to produce enough to maintain the producer's net income while simultaneously allocating labor and capital to harvest other cash crops.

INTERPRETATIONS OF THE EMPIRICAL RESULTS

The distributed-lag model for rubber, coffee, cocoa and palm kernels, as measured by the coefficient of determination (\bar{R}^2), indicates that investments in transportation infrastructure and producer prices over the analysis period explains

97.1%; 86.1%; 86.1%; and 51.9% of the variation in production, respectively. The unexplained variation for each crop is attributable to variables not specified in the model. Agricultural production is sensitive to weather conditions, quality of land, historical price trends, institutional constraints, technological change, factor mix, supporting infrastructure, and other disturbances. The lack of available data explains why these factors were not incorporated into the model. In spite of the unexplained variation, the estimated equation revealed a high degree of correlation with crop production.

The estimated equations in Table V-2 show that the positive effects of transport investments are spread over a ten-year period for rubber, four years for coffee, twelve years for cocoa, and nine years for palm kernels.

The mean lag which measures the average length of time it takes for a unit change in transport investments to be transmitted into additional output is 5.2 years; 0.83 years; 5.8 years, and 74.60 for rubber, coffee, cocoa, and palm kernels, respectively.

One of the more curious findings of this study is the distributed-lag effect on coffee production which extended over a five-year period. While this result does not contradict agronomic information about a 5 to 10 year gestation period, it was expected that a longer lag period and a higher mean lag value would be found than what was obtained. This is because of the planting and fruit-bearing cycle which requires at least five years and thereafter, it bears coffee up to thirty years.

The Durbin-Watson statistics of 1.7204, 1.5909, 2.5772, and 2.1682 for rubber, coffee, cocoa and palm kernels, respectively, indicate that serial correlation is not a problem in the residuals of the estimated equations. The F-statistic tests the joint hypothesis that the independent variables are zero. The F-statistics, as revealed in Table V-2, are 101.6023, 40.4664, 23.2301, and 4.2452 for rubber, coffee, cocoa, and palm kernels, respectively. These values are significant at the 0.05 level of significance. Because of this finding, we must reject the null hypothesis.

In two of the four cases, the distributed-lag models appeared to have captured the impact of past and current transport investments on primary crop production rather well as evidenced by the parametric tests and the magnitude of the current and long-run producer responses. Except for palm kernels and coffee, the empirical results are generally consistent with the research hypothesis discussed in Chapter III, where it was hypothesized that transport investments and producer prices are positively correlated with agricultural output. This hypothesis was contradicted in the case of coffee production and in the current supply response for palm kernels; for rubber and cocoa, the models achieved reasonably good results.

PART II. THE TRANSPORT-ACCESSIBILITY MODEL: ESTIMATED RESULTS

The transport-accessibility model was estimated on annual production of four tree crops as a function of current producer prices and total annual miles of nonurban roads, from 1950 to

1964. The tree crops consisted of rubber, coffee, cocoa, and palm kernels. A summary of the results of the estimated equations are presented in Table V-3. Complete results of all parametric tests and the plot of the residuals and fitted values are contained in Appendix D.2. The data series on nonurban roads, which is the independent variable in the transport-accessibility model, were insufficient to construct a reliable empirical model of the distributed-lag type, as in the previous model.

Hypothesis Testing on Ordinary Least Squares Estimates

As Table V-3 indicates, the independent variable, natural logarithm of nonurban roads ($\ln NR$) has a positive sign as hypothesized for each of the tree crops except palm kernels. In addition to having the correct sign, the magnitudes of the coefficients for all crops, except palm kernels, are significant as indicated by their t-statistics in parentheses under the coefficients. Except for palm kernels, the t-statistic of $\ln NR$ exceeds the critical value of 3.055 for the 0.01 level of significance. These results confirm the hypothesis of the research that non-urban roads are positively correlated with crop production.

The price variable, $\ln P$ (natural logarithm of price), which measures the price elasticity of output with respect to crop production revealed a positive influence of producer prices on output for each of the crops analyzed. Although the price elasticities varied widely (0.002, 0.874, 0.63 and 0.961 for rubber, coffee, cocoa, and palm kernels, respectively), the results were encouraging because they confirm the hypothesis

TABLE V-3

FINAL REGRESSION RESULTS: AGRICULTURAL
PRODUCTION ON TRANSPORT ACCESSIBILITY
AND PRODUCER PRICES

INDEPENDENT VARIABLES	DEPENDENT VARIABLES			
	ln RU	lnCF	ln CC	ln PA
Constant	3.750 (5.656)	-15.081 (-3.516)	-6.423 (-3.361)	1.082 (0.277)
ln NR	0.112 (3.111)	1.820 (6.477)	0.630 (5.431)	-0.149 (-0.925)
ln P ^{1/}	0.002 (0.020)	0.874 (1.416)	0.630 (2.086)	0.961 (1.000)
R ²	0.539	0.870	0.760	0.358
\bar{R}^2	0.463	0.848	0.720	0.251
F-statistic	7.024	40.028	19.014	3.342
SEE	0.0837	0.4919	0.2236	0.3209
Observations	14	14	14	14
Time bounds	1950-1964	1950-1964	1950-1964	1950-1964

Note: t-statistics are in parenthesis.

^{1/}The independent variable lnP represents here the price elasticity of each commodity. It is labeled lnRUP, lnCCP, and lnCFP, etc. in each of the empirical models.

of a positive relationship between price and supply for each of the crops, as Table V-3 indicates.

The t-test on the price variable in each of the estimated equations was conducted to determine if the coefficients of $\ln RUP$, $\ln CFP$, $\ln CCP$, and $\ln PAP$ were statistically different from zero at the 0.05 level of significance. The results were not promising because the t-statistics did not exceed the critical value of 2.179. Therefore, we cannot accept the null hypothesis that the price coefficients are statistically significant in the models when the variable $\ln NR$ is held constant. The F-test was conducted on each of the models to test the joint hypothesis that the parameter estimates are zero. The F-statistics for all of the estimated equations except for palm kernels exceed the critical value of 6.93 for the 0.01 level of significance. For palm kernels production, the F-statistic was not significant. Therefore, in the case of rubber, coffee, and cocoa, we can reject the null hypothesis.

The coefficient of determination, or R^2 , was estimated to determine how much of the variation in crop production ($\ln RU$, $\ln CF$, $\ln CC$, and $\ln PA$) is explained by the independent variables, $\ln NR$ along with $\ln RUP$, $\ln CFP$, $\ln CCP$ and $\ln PAP$. The results, as shown in Table V-3, indicate that the estimated equations adjusted for the explanatory variables and the degrees of freedom explain 46.3%; 84.8%, 72.0%; and 25.1% of the variation for rubber, coffee, cocoa, and palm kernels, respectively.

The unexplained variation is attributable to variable(s) omitted from the transport-accessibility model. Other factors

such as institutional constraints, weather conditions, expected prices, factor-mixes, and factor-intensities, etc., combine to influence agriculture. However, no data were available to incorporate these factors into the model.

Interpretations of the Estimated Results

While the transport-accessibility model worked reasonably well for each of the crops, except palm kernels, additional interpretations of these results are warranted. To begin with, palm kernels production in Liberia for the period under study was found to be insensitive to decreasing friction of distance as measured by increases in road mileage. A plausible explanation as to why the model does not work as well on palm kernels is the following. As we have indicated in Part I, palm kernels unlike the other tree crops analyzed in this study, grow wild throughout Liberia and are not an estate crop. This means that the harvesting of palm kernels does not lend itself to economies of scale in production. This may further imply that the marginal cost of production, while it may be decreasing because of economic incentives such as transport-cost reductions, may not be decreasing at a sufficient rate to significantly induce additional production. Evidence of this is indicated by the positive sign of the price elasticity in the model which shows that the magnitude is not statistically significant.

Additionally, there is empirical evidence that suggest that positive producer price supply responses for palm kernels

are essentially that of a harvesting response rather than a planting decision (Helleiner, 1975, p. 38). It is also important to note that palm kernels are joint products with palm oil and palm butter, both of which are produced and consumed domestically in Liberia. This adds a further complication to the analysis because there is no way of knowing the total production of palm kernels, including both the share exported as palm kernels and the share used for local oils and fats consumption.

On the basis of the findings presented above, it must be concluded that during the period under study, palm kernels production in Liberia is not correlated with transport accessibility; and although producer prices were positively correlated with production, they were not statistically significant.

The coefficients of determination indicate that nonurban road mileage and real producer prices are highly correlated with coffee and cocoa production but less so for palm kernels and rubber production. Even though a positive correlation was indicated, the explained variations in crop production were unexpectedly low for both rubber and palm kernels. There are both striking similarities between these two crops, as well as important differences. Rubber is an estate crop in Liberia and requires a gestation period of about seven years before harvesting can begin. Thereafter, the producer can decide how much he/she wants to harvest based on current and future prices. Palm kernels, on the other hand, is a crop that grows wild in Liberia. Interestingly enough, both crops require tappers in

the case of rubber and laborers for palm kernels production to walk long distances during harvesting. This did not appear to have had any negative impact on transport accessibility in terms of rubber production, although palm kernels production was found to be insensitive to better access. The production of rubber lends itself more to economies of scale in production than does palm kernels and, therefore, one would expect rubber to be more highly correlated with transport access.

Finally, the empirical evidence for transport accessibility on rubber, coffee and cocoa were very promising as we have already shown. The coefficients of $\ln NR$ can be interpreted as follows. A 1 per cent change in miles of nonurban roads was statistically associated with a 0.11 per cent increase in rubber production; a 1.8 per cent increase in coffee production; and a 0.63 per cent increase in cocoa production. As we assumed in Chapter III, improvements in transport accessibility may induce differential supply responses across crops. This again is a function of many factors, such as the crops weight content, distance to the nearest market, relative producer prices and production functions, etc.

PART III. THE FACTOR-INPUT MODEL: ESTIMATED RESULTS FOR RUBBER INPUTS

In Chapter III, the functional form of the factor-input model was discussed. To briefly review, the factor-input model hypothesized that producers optimize their use of factors of production such that improved accessibility, as represented by additional miles of roads, positively influences such eco-

conomic activities as employment and land cultivation. The extent of the economic effects, as represented by the utilization of these factors in the production of rubber, is a direct function of increased accessibility. The available data on the number of miles of nonurban roads, cultivated land and agricultural employment were not sufficient to specify a reliable distributed-lag model of factor inputs and accessibility.

Agricultural Employment

The equation estimated for the factor-input model is presented in Table V-4. From Table V-4, it can be seen that the coefficient of the variable, agricultural employment ($\ln AE$), has a positive sign and is statistically significant. The equation was estimated on annual data of agricultural employment in rubber production for Liberian workers on commercial estates from 1950 to 1967, and nonurban road mileage. Complete regression results are found in Appendix D.3.

The F-test was calculated to test the null hypothesis that there is no relationship between agricultural employment and nonurban road mileage. The F-statistic is 75.481 for the equation presented in Table V-4, whereas the critical value for F at 1 and 15 degrees of freedom at the 0.01 level is 8.68. These results indicate that we must reject the null hypothesis because the F-statistic exceeds the critical value at the 0.01 level of significance. The \bar{R}^2 , measured at 0.823, indicates that in the estimated equation (adjusted for the explanatory variables and the degrees of freedom) nonurban road mileage

TABLE V-4

FINAL REGRESSION RESULTS:
FACTOR-INPUTS ON ACCESSIBILITY

INDEPENDENT VARIABLE	DEPENDENT VARIABLES	
	lnAE	lnCL
lnNR	0.186 (8.688)	0.446 (6.332)
Constant	2.208 (15.591)	1.756 (3.934)
R ²	0.834	0.741
\bar{R}^2	0.823	0.723
F-statistic	75.481	40.089
SEE	0.089	0.230
DW-statistic	1.90	0.895
Observations	17	16

Note: t-statistics are in parenthesis.

is highly correlated with employment in rubber production and explains 82.3 per cent of the variation.

The t-test was conducted to determine if the estimated coefficients were statistically significant at 0.01 and 0.05 levels of significance. The critical values for the t-statistics are 2.947 for the 0.01 level and 2.131 for the 0.05 level. From Table V-4, it is clear that the t-statistics are statistically significant at both levels. The coefficients also have a positive sign. The results of the t-test indicate that we must reject the null hypothesis that the coefficients of lnAE are statistically insignificant.

As is frequently the case with time-series data, there is often the problem of serial correlation where the error term is not randomly distributed. The Durbin-Watson statistic of 1.90 indicates that serial correlation is not a problem in the residuals for positive serial correlation.

The above findings support the hypothesis of a positive relationship between accessibility and employment on commercial rubber estates. The magnitude of the estimated coefficient of 0.186 for nonurban roads is fairly consistent with the finding of 0.256 in Liang's (1981) study of employment in rice production.

The final results of the factor-input model for agricultural employment in the production of rubber on accessibility can be interpreted as follows. A change in the miles of roads of 1% is associated with a change in agricultural estate employment in rubber by 0.18% over the period from 1950 to 1967.

Cultivated Land

The factor-input model was also estimated for cultivated land to determine if a positive relationship existed with non-urban road mileage. The model was implemented using time-series data measured in acreage of land cultivated on commercial rubber plantations for the years 1950 through 1964. Complete regression results are found in Appendix D.3.

The estimated equation is presented in Table V-4. The results indicate that signs of the coefficients are positive and have a significant magnitude. The estimated coefficients are 1.756 and 0.446. The t-statistics indicate that they are statistically significant at the 0.01 level.

The F-test also revealed that the estimated coefficients are statistically significant. The F-statistic is 40.089 which is obviously significant at the 0.01 level of significance. Accounting for the degrees of freedom and the explanatory variable, the explained variation in cultivated land, as measured by the coefficient of determination, \bar{R}^2 , revealed a measurement of 0.723. This means that 72.3 per cent of the variation in land cultivated for rubber production can be explained by the improved transport infrastructure.

The Durbin-Watson statistic at 0.895 suggests that serial correlation is likely to be present in the residuals. The critical values of the DW-statistic at the 5 per cent significance level is 1.08 for 15 observations and one independent variable. To determine how strong the presence of positive serial correla-

tion was, the fitted values and the residuals were plotted on a graph. As the results in Appendix D.3 indicate, there is no linear relationship between the fitted values and the residuals. Serial correlation in this model indicates that the estimated coefficients are not efficient, but remain consistent.

While the results are not as strong as those found in the estate rubber employment model, there is substantial evidence to support the hypothesis of a positive relationship between accessibility and land cultivation for rubber production. These results again are consistent with the findings of Liang (1981), although the magnitude of the coefficients differ. In Liberia, accessibility is likely to have had more of an influence on Liberian-owned rubber estates than those owned by foreigners. There is considerable evidence which indicates that Liberian-owned estates consistently increased their acreage of cultivated land along new roads (Stanley, 1966).

The results of the estimated equation of the impact of road accessibility on land cultivated for rubber production indicates that over the analysis period a 1 per cent increase in the miles of roads accompanied a 0.4 per cent increase in the acres of cultivated land.

SUMMARY

The findings presented in this chapter offer empirical evidence of a transportation impact on agricultural production and factor inputs. Agricultural production is not only influ-

enced by producer prices but was found to exhibit increases that were correlated with investments in transport infrastructure. Increased transport accessibility was also found to exert a positive change not only on primary crop production but also, in the case of rubber, on the factors of production.

The significance of the transport-investment model is the discovery of a lagged effect on agricultural production, an effect which, it is believed, allows producers to increase output in the current period and adjust their factor-mix, synthesize new technical information, and become acquainted with the changing marketing realities and better transport conditions in the long-run.

Each of the distributed-lag models in Part I fitted the data quite well except in the case of palm kernels. The model did not work as well for palm kernels production as for the other crops under study.

With respect to the current year, the effect of transport investments were estimated at 0.0235, 0.631, 0.0176 and -0.0744 for rubber, coffee, cocoa, and palm kernels production, respectively, for the 1950 to 1980 period. These elasticities, except in the case of palm kernels, confirm the theoretical proposition that past and current transport investments induce a current response by producers. No evidence was found to indicate a positive response of palm kernels production in the current period.

The long-run supply responses were 0.387, 1.147, 0.902, and -0.016 for rubber, coffee, cocoa and palm kernels production, respectively. These results provide evidence to support the hypothesis of the research that the effect of transport investments on agricultural production is distributed over time.

The transport-accessibility model in Part II also worked reasonably well with the exception of palm kernels production. The estimated equations for rubber, coffee, and cocoa supported the hypothesis that accessibility exerts a positive influence on agricultural output. These models are statistically correlated with the variation in the crops' output. By way of contrast, palm kernels production contradicted the research hypothesis. Here again, the only plausible explanation that we can offer is the fact that non-estate agriculture, even smallholder estates, are insensitive to increases in road mileage. Additionally, palm kernels are harvested from the palm tree which grows wild and no economies of scale in production are evident.

The empirical findings in Part III of the effects of accessibility on such factors as employment on commercial rubber estates and land cultivation indicated that, over the analysis period, accessibility is associated with in excess of 70 per cent of the variation in these factors of production. These results confirm the research hypothesis that, as additional roads open up, land cultivation increases and additional labor is employed.

Finally, it must be pointed out that the empirical findings of this study should be viewed in the context of a country with a high-income commercial agricultural sector and a low-income subsistence agricultural sector. This is a country which began with an extremely low economic base and basically no transport infrastructure except that which was initially developed to facilitate the exploitation of the country's resources--in this case, rubber, coffee, cocoa, and palm kernels.

In Chapter VI, the purpose and further conclusions of this inquiry are discussed. Chapter VI will conclude with a brief discussion of the policy implications of the research findings and with some suggestions as to possible directions for further research.

CHAPTER VI

SUMMARY, CONCLUSIONS AND POLICY IMPLICATIONS

This study examined the effects of improved transport infrastructure and real producer prices on agricultural production and factors of production in Liberia from 1950 to 1980. The fact that improved transport conditions provide better access to product and factor markets and induce additional output is well understood by analysts of transport policies. However, very little is known from previous empirical research about how the impacts of investments in transport infrastructure are distributed over time for different crops based on current and past investments. This inquiry contributes to our understanding of the economic consequences of transport investment policies in three significant ways. First, it offers a production-oriented analytical framework for quantifying the economic impacts of transport investments. Second, the study demonstrates that consistent estimates of transport investment policy impacts can be determined for both short-run or current and long-run producer-supply responses by specific crops. Third, it shows that the magnitudes of the supply responses and the time required for the investment effects to be transmitted into additional output can also be measured.

In Chapter II, the underlying theory, analytical policy framework, research methods, and the empirical studies of transport and development were reviewed. It was revealed that no one theory explained all of the economic issues of transport impacts on development and that the theoretical relationship between transportation and other economic sectors is derived from many areas of economic theory. Additionally, it was revealed that the producer-surplus approach is superior to the transport-demand approach in areas where economic activity is low. The producer-surplus approach is superior under this condition because it does not rely on quantification of savings in vehicle-operating costs as the principal measure of transport investment impacts. Instead, the producer-surplus approach is a more comprehensive analytical framework for policy analysis than the transport-demand approach because it focuses on wider economic effects such as additions to production, changes in employment, changes in cultivated land, and other economic consequences of increased transport accessibility. It was also discovered in Chapter II that there are no "standardized" methods for transport and development research even though cost-benefit analysis is more commonly used than other methods. The econometric model was found to be more practical for the present study because it provides more flexibility in terms of research design than other research methods and the data requirements are more easily manageable.

Chapter III proposed three econometric models of the relationship between transport improvements and agricultural development. The first model introduced a polynomial distributed-lag function of transport investments and real producer prices to explain changes in primary crop production. The second model related transport accessibility and real producer prices to changes in agricultural output. The third model related the disaggregated effects of transport accessibility to changes in the factors of production. These models improve on the empirical models introduced by Liang (1981) and other researchers in the field by specifying explanatory variables that model dynamic output relationships. These extensions include: 1) an Almon distributed-lag function of the transport variable; 2) real producer prices; 3) transport investments, and 4) accessibility measured as additional transport capacity.

In Chapter IV, the historical development of macroeconomic trends, sectoral components and sectoral growth patterns of Liberia from 1950 to 1980 were surveyed. Liberia experienced a phenomenal increase in its Gross Domestic Product (GDP) from 1950 to 1980. GDP in 1975 dollars was \$149.1 million in 1950 and, by 1980, it had increased to \$802.3 million. The chapter revealed that aggregate agriculture exports accounted for 78 per cent of the GDP in 1950 and, by 1980, had declined to 16 per cent. It was also discovered that Liberia's export earnings from agriculture were principally made up of rubber exports; although other crops, such as coffee, cocoa, and palm products

were also exported. Chapter IV also revealed the historical importance of commercial estate agriculture to the Liberian economy both in terms of its export earnings capacity and its employment absorptive capacity.

The transport sector, in terms of the road system and port facilities, had a significant impact on the country's economy by facilitating the export of its primary commodities and the importation of essential equipment, machinery, and capital goods. In terms of transport expansion, Liberia went from 230 miles of roads; 42 miles of railways; and one port facility in 1950 to about 6,200 miles of roads; 305 miles of railways; and four major deep-water ports in 1980.

The empirical results in Chapter V confirmed the hypothesis that transport investments of a polynomial distributed-lag form are correlated with statistically significant changes in output over time for the four tree crops analyzed. These findings also indicate that producer prices had a positive influence in all cases except one. However, they were not a significant factor in explaining increases in perennial tree crop production when measured along with an Almon-lagged transport investment function and regressed on rubber, coffee, cocoa, and palm kernels production.

The transport investment models estimated the short-run and long-run responses of producers to transport improvements and economic incentives. The empirical findings indicate that the short-run or current supply elasticities were 0.024 for

rubber; 0.631 for coffee; 0.018 for cocoa; and -0.074 for palm kernels. The mean lag measured the average length of time required for a unit change in transport investments and producer prices to be transmitted into additional output. The empirical results offer evidence of a significant mean lag response with 5.2 years for rubber; 0.83 years for coffee, and 5.5 years for cocoa. Palm kernels, on the other hand, did not achieve reliable results which suggests that the supply of palm kernels is essentially a short-run or harvesting response. The sum of the lag coefficients was positive in all cases except for palm kernels. These lag coefficients indicate evidence of a sustained long-run response for rubber, coffee, and cocoa, as measured by their t-statistics. No evidence was found to suggest a statistically significant long-run response for palm kernels.

The empirical findings of the transport accessibility model indicated that transport accessibility and producer prices exert a positive influence on primary crop production. Improved transport accessibility and real producer prices explained 46.3% of the variation in rubber production; 84.8% in coffee; 72.0% in cocoa, and 25.1% in palm kernels.

The factor markets for rubber production tended to be highly correlated with transport accessibility when primary factors such as land and labor were considered. Increases in road mileage were found to be statistically correlated with the amount of land coming under cultivation in the production of rubber. The addition of new roads was also found to be statistically correlated with

increases in employment on commercial rubber estates. The empirical findings indicate that increased accessibility explains 82.3 and 72.3 per cent of the variation in employment and cultivated land, respectively. While the scope of this research is limited to the agricultural and transport sectors, each of the proposed empirical models have confirmed that increased transport accessibility is associated with statistically significant changes in both the product and factor markets.

The empirical models presented in this study are intended as a first step for policy analysis using econometric formulations of how the impacts of transport investment policies are distributed over time. The specification of the models necessarily imposes some limitations on their predictive capabilities. Because of the lack of available data, these models did not include some variables either implicitly or explicitly which are known to influence agricultural output (e.g., weather conditions, technological change, given production function and infrastructure stock). However, these reduced form models are able to describe some significant behavior responses of producers to price incentives and better access to markets. This study makes no claim beyond this fact. The models did achieve reasonably good results and may have important potential for policy analysis in other environments.

POLICY IMPLICATIONS

The implications for policy, as this study found, are in two areas. The most important area of this study that has

implications for public policy is investments in the transport sector. The second is in the area of agricultural policy with respect to land tenure and cash crop production.

Transport Investment Policy Implications

This study found no evidence to suggest that the Government of Liberia had a clearly-defined public transportation policy between 1950 and 1970 regarding the level of transport investments, spatial distribution, intended impacts, and specific functions. In fact, prior to the mid-1960's, the Liberian Government relied almost exclusively on foreign-controlled concessions to develop the country's transportation infrastructure under concession agreements. These agreements allowed private corporations to build roads, railway lines, and port facilities for the primary purpose of exporting foreign-dominated rubber and iron ore. The resulting transport network had almost nothing to do with the internal transportation needs of domestic markets, of the population, and of the defense and security of the country. The lack of a transport policy by the government can be characterized as passive because, from a public policy standpoint, the Liberian Government did not appreciate the extent to which transport policies could be used in a way which satisfied both the domestic and international demand for transportation facilities. The Liberian Government instead placed their policy prerogatives in the hands of foreign-dominated private interests without sufficiently considering the impact on domestic demand.

It was only after about 1967 that the Liberian Government began to explicitly formulate public policies for the transport sector. The Government began specifying the objectives of the transport sector; the type of improvements to be made; where the improvements would be made; the interrelationship between the transport and other economic sectors; and the level of investment that would be required to implement the transport improvements. This is the period when the government became more actively involved in directing the activities of the transport sector from a public policy viewpoint. The period between 1967 and 1980 can be characterized as dynamic because it revealed a more direct and balanced approach than the previous period to reducing transport friction of distance and opening up the country to expand markets.

The empirical results of this study revealed that a clear opportunity existed for the Liberian Government to direct transport investment policies in a manner in which distinguishable economic impacts in agricultural production, in agricultural employment, and land cultivation could have been determined. Had such been done, the specific transport requirements of the population, of the various economic sectors, and of both the domestic and international markets could have been reliably predicted and appropriate infrastructure planned and developed.

Based on the methodological approach used in this study, there is a sufficient basis to believe that a schedule of a specific number of miles of road and other transport media could

have been planned by the government as a specific set of transportation policies and that the economic benefits to the country predicted.

Agricultural Policy Implications

While the focus of this study was not on agricultural policy per se, a few implications for agricultural policy are worth noting. First, the evidence indicates that in 1980 fully two-thirds of the cultivated land area was in the hands of commercial (mostly large foreign-owned) estates producing primary commodities for export. These estates represented only 7 per cent of the farm population while more than 80 per cent of the farm population cultivated only about a third of the land. Such a propensity on the part of the Liberian Government to allow this situation to develop raises serious questions about its agricultural policy. Between 1924 and 1964, the national government leased in excess of three million acres of land to six foreign-owned rubber companies; land which the government claimed was in the public domain. During this same period, very little was done, with the exception of some unsuccessful attempts to increase rice production, to increase the land holdings of traditional farmers and to introduce new technologies for domestic food production. Domestically-owned (mostly Americo-Liberians) rubber farms, on the other hand, grew dramatically and technical assistance in production, higher yielding plant varieties, credits, and guaranteed purchase of output were made available

by the foreign-owned rubber concessions to improve these estates and to increase domestic output.

The policy implication of this public action is that 80 per cent of the agricultural population contributed only about 22 per cent to the GDP in 1960, 24 per cent in 1970, and 19 per cent in 1980.

Second, the land tenure policy appears to have had an adverse impact on domestic food output as measured by the reduction in land used for food production. This is compared against the export to international markets of primary commodities such as rubber, coffee, cocoa, and palm products. While the primary commodities produced substantial economic gains for smallholder estate owners, the net results were that production of cash crops shifted large tracts of land to non-food production. These export crops accounted for 78 per cent of the GDP in 1950, 35.5 per cent in 1960, 9.8 per cent in 1970, and 14.2 per cent in 1980. The Liberian Government appeared to have hinged its development policy on the expectation that the prices for primary export crops, particularly rubber, would continue to be favorable in the future, while paying little or almost no attention on how to improve domestic food production and diversify agriculture.

DIRECTIONS FOR FURTHER RESEARCH

Several possible directions for further research are indicated by this study, although only two are presented here.

The first area that requires exploration is the extent to which lagged producer prices exert a positive influence on agricultural production when measured along with lagged transport investments. Some empirical studies (Bateman, 1970) have introduced lagged producer prices (some with good results) in an attempt to estimate the long-run supply response of producers to past and current prices. Such an inquiry might produce a more significant supply response than those reported for the long-run supply elasticities in this study. Long-run responses allow for adjustment lags (i.e., planting decisions based on past and current information about infrastructural improvements, in this case roads and expected price changes). Such research would assume that expectations about future prices are based on past price trends.

A second direction for further research is to investigate why palm kernels production is insensitive to changing transport conditions in Liberia. For example, additional road capacity and other improvements that result from investments in transport infrastructure are believed to induce changes in primary crop production. No empirical evidence was found in this study to support this theoretical proposition for palm kernels production. It seems plausible that palm kernels production as joint products in Liberia is a special case in that supply responses are more a matter of how to dispose of the products as opposed to the economics of production. The supply response has been found to be positively related to producer

prices in a number of countries, Havinden and Levi (1982). The supply elasticities in other country studies were found to be between 0.22 and 0.81. It is possible that the accessibility variable in the palm kernels model is specified too broadly in that it measures accessibility indirectly in terms of the increase in road mileage rather than directly as miles of road per square mile of area. In the Liberian context, a cross-sectional study might be an approach that better captures the effect of accessibility on output. For example, miles of roads per region (county), current or lagged producer prices, and collection points as the explanatory variables may be one way to isolate the supply response.

In spite of the fact that there are areas where further research is indicated, this study, using available empirical information, offers an analytical framework for public decision makers to consider broader economic development consequences of transport investment policies. Although the models were formulated for a country study of Liberia, the models provide an improved methodology to inform public policy and can be adapted for use in other countries.

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APPENDIX A

THE ALMON DISTRIBUTED-LAG MODEL:
MATHEMATICAL PROCEDURES

APPENDIX A

THE ALMON DISTRIBUTED-LAG MODEL:

MATHEMATICAL PROCEDURES

The Almon model as a polynomial distributed-lag model can be estimated, as in this simple case of a second-degree polynomial, with a finite period lag with no endpoint restrictions. Following Gujarati (1978), the model can be written as:

$$Y_t = \alpha + \beta_0 T_t + \beta_1 T_{t-1} + \dots + \beta_s T_{t-s} + \epsilon_t \quad (1)$$

Or more additively as:

$$Y_t = \alpha + \sum_{i=0}^s \beta_i T_{t-i} + \epsilon_t \quad (2)$$

The Almon distributed-lag model assumes that β_i can be approximated by a suitable-degree polynomial in i , the length of the lag. The shape of the lag can be written as a quadratic function or a second-degree polynomial in i :

$$\beta_i = a_0 + a_1 i + a_2 i^2 \quad (3)$$

The polynomial function can be expressed more generally as:

$$\beta_i = a_0 + a_1 i + a_2 i^2 + \dots + a_n i^n \quad (4)$$

where n is an n th-degree polynomial in i . The n th-degree polynomial is assumed to be less than s , which is the maximum length of the lag. More generally, the model in equation (2) can be written as, for example, some n th-degree polynomial approximation as:

$$\begin{aligned}
 Y_t &= \alpha + \sum_{i=0}^s (a_0 + a_1 i + a_2 i^2 + \dots + a_n i^n) T_{t-i} + \epsilon_t \quad (5) \\
 &= \alpha + a_0 \sum_{i=0}^s T_{t-i} + a_1 \sum_{i=0}^s i T_{t-i} + a_2 \sum_{i=0}^s i^2 T_{t-i} \\
 &\quad + \dots + a_n \sum_{i=0}^s i^n T_{t-i} + \epsilon_t
 \end{aligned}$$

Where: n = the number of degrees polynomial.
 i = the number of periods over which the lag is distributed
 s = the endperiod of the lag

The above equation can be estimated using the ordinary least-squares regression technique. The disturbance term ϵ_t is assumed to be normally distributed and serially uncorrelated with the β 's. The estimated a 's will be the best linear unbiased estimates.

The dependent variable Y_t must be regressed on the newly constructed Z variables, as defined below, and not the original independent variable represented by T_t .

Defining:

$$Z_{0t} = \sum_{i=0}^s T_{t-i} \tag{6}$$

$$Z_{1t} = \sum_{i=0}^s iT_{t-i}$$

$$Z_{2t} = \sum_{i=0}^s i^2T_{t-i}$$

.....

$$Z_{nt} = \sum_{i=0}^s i^nT_{t-i}$$

Rewriting, we get:

$$Y_t = \alpha + a_0Z_{0t} + a_1Z_{1t} + a_2Z_{2t} + \dots + a_nZ_{nt} + \epsilon_t$$

Once the a's are estimated using the ordinary least-squares regression technique, the β 's can be estimated from the following:

$$\hat{\beta}_0 = \hat{a}_0 \tag{7}$$

$$\hat{\beta}_1 = \hat{a}_0 + \hat{a}_1 + \hat{a}_2$$

$$\hat{\beta}_2 = \hat{a}_0 + 2\hat{a}_1 + 4\hat{a}_2$$

$$\hat{\beta}_3 = \hat{a}_0 + 3\hat{a}_1 + 9\hat{a}_2$$

.....

$$\hat{\beta}_s = \hat{a}_0 + s\hat{a}_1 + s^2\hat{a}_2$$

The application of the Almon polynomial-distributed lag form requires, first and foremost, that the maximum length of the lags, "s", be specified in advance. Second, after having specified "s", the degree of the polynomial, "n", will also have to be specified. On the basis of the Weierstrass theorem, the degree of the polynomial should generally be at least one more than the number of turning points in the curve relating β_i to i ; otherwise, there will be no reduction in the number of lag parameters to be estimated. In practice, however, a priori knowledge of the number of turning points in the curve may not be apparent. Selecting the degree of polynomial is an iterative process. The expectations are that a fairly low-degree polynomial (e.g., 2 or 3) will yield good results. The procedure is to start with a high degree of polynomial (e.g., 4 or 5) and then test the last a_i coefficient for significance. If it is significant, then the order of the polynomial is determined. If it is not, then the practice is to keep reducing the degree of polynomial until the a_i coefficient is significant, Johnston (1984).

APPENDIX B

NATIONAL ACCOUNTS AND SOCIAL DATA

APPENDIX B
LIST OF VARIABLES

VARIABLE NAME	VARIABLE DESCRIPTION
ME	MONETARY ECONOMY, in current U.S. \$ millions
AG	AGRICULTURE'S SHARE OF GDP, in per cent
N	POPULATION, in thousands
RG	RUBBER EXPORT EARNING'S SHARE OF GDP, in per cent
TE	TRADITIONAL ECONOMY, in current U.S. \$ millions
TG	TRANSPORT SECTOR'S SHARE OF GDP, in per cent
Y	GROSS DOMESTIC PRODUCT, in current U.S. \$ millions
YC	PER CAPITA GDP, in current U.S. dollars

Sources: Clower et al. (1966). Growth Without Development: An Economic Survey of Liberia, Northwestern University Press, Evanston.
I.B.R.D. (1963). The Economy of Liberia, Report No. AF-10a, September.
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I.B.R.D. (1982). Liberia: Recent Economic Developments and Medium-Term Prospects, Report No. 4178-LBR, December.

APPENDIX B.1

NATIONAL ACCOUNTS AND SOCIAL DATA

YEAR	ME <u>1</u> /	AG <u>2</u> /	N <u>3</u> /	RG <u>2</u> /	TE <u>1</u> /	TG <u>2</u> /	Y <u>1</u> /	YC <u>4</u> /
1950	35.8	77.59	741.0	32.76	22.2	*	58.0	78.27
1951	45.7	*	761.6	73.09	21.7	*	66.4	87.18
1952	52.6	*	783.1	41.06	20.9	*	73.5	93.85
1953	58.4	*	805.0	27.14	20.0	*	78.4	97.39
1954	80.5	*	827.5	19.35	18.8	*	99.3	120.00
1955	79.1	*	846.0	32.49	18.4	*	97.5	115.24
1956	89.7	*	869.7	29.17	18.0	*	107.7	123.83
1957	90.9	*	894.0	25.43	17.0	*	107.9	120.69
1958	97.1	*	919.1	22.75	17.5	*	114.6	124.68
1959	130.1	*	944.8	20.81	17.8	*	147.9	156.54
1960	133.0	43.48	978.0	23.93	18.1	14.95	157.1	160.63
1961	137.0	33.33	1009.3	15.51	18.4	22.78	155.4	153.96
1962	153.6	30.49	1041.6	14.40	18.6	25.96	172.2	165.32
1963	151.2	29.29	1074.9	12.53	18.9	20.69	170.1	158.24
1964	157.2	28.91	1109.3	11.79	19.2	11.39	176.4	159.01
1965	228.7	15.98	1139.0	9.47	31.0	5.85	259.7	228.00
1966	247.0	16.10	1170.0	9.60	31.0	5.72	278.0	237.60
1967	266.2	26.03	1214.0	9.27	30.0	6.88	286.2	235.75
1968	276.8	24.17	1253.0	8.38	31.0	6.92	307.8	245.65
1969	300.3	22.13	1293.0	7.26	31.0	7.06	356.6	275.79
1970	323.1	10.67	1335.0	6.10	55.3	8.40	378.4	283.44
1971	342.5	10.05	1380.0	6.02	57.5	8.68	400.0	289.85
1972	372.2	8.86	1426.0	8.61	58.9	8.42	431.1	302.31
1973	375.2	12.67	1474.0	10.57	58.2	7.17	453.2	307.46
1974	459.7	12.89	1523.0	5.19	110.6	5.69	570.3	374.45
1975	559.1	9.25	1574.0	4.38	117.3	6.02	676.4	429.73
1976	568.6	11.19	1628.0	5.65	130.2	6.45	698.8	429.23
1977	621.5	12.20	1684.0	5.10	155.0	6.81	788.5	468.23
1978	640.0	14.08	1743.0	5.55	170.0	7.04	840.0	481.92
1979	766.3	14.65	1834.1	5.87	187.1	6.92	953.1	519.65
1980	800.8	15.88	1905.6	6.14	200.2	6.09	1001.0	525.29

1/ In current U.S. \$ millions.

2/ In per cent.

3/ In thousands.

4/ In current U.S. dollars.

APPENDIX C

AGRICULTURE AND TRANSPORT SECTOR DATA

APPENDIX C.1

COMMODITY PRODUCTION, 1950-1980

YEAR	RU ^{1/}	CF ^{1/}	CC ^{1/}	PA ^{2/}
1950	66.700	0.224	1.010	41.000
1951	79.300	0.166	0.636	47.000
1952	78.000	0.410	1.060	24.000
1953	78.800	0.909	0.596	35.000
1954	82.800	0.601	1.450	25.000
1955	87.500	0.736	1.060	21.000
1956	88.500	1.050	1.000	22.000
1957	83.900	0.871	0.970	23.000
1958	94.800	1.060	1.330	25.000
1959	96.200	2.200	1.780	43.000
1960	106.700	2.000	2.200	33.600
1961	90.800	2.200	1.500	28.400
1962	100.100	4.200	1.800	18.900
1963	88.500	8.100	2.300	13.200
1964	95.500	17.800	2.100	15.100
1965	116.100	7.000	1.000	26.600
1966	121.900	19.600	3.400	25.800
1967	136.700	9.200	2.800	29.400
1968	140.000	9.300	4.200	29.000
1969	152.000	9.500	3.700	23.200
1970	172.100	8.700	4.100	21.300
1971	181.000	8.200	5.200	23.100
1972	180.300	9.300	4.800	23.500
1973	188.700	7.300	6.300	30.900
1974	194.700	7.900	5.400	27.500
1975	181.500	8.600	5.500	24.700
1976	188.000	21.200	5.500	18.300
1977	171.600	22.200	6.700	16.500
1978	172.000	19.100	8.900	12.000
1979	173.900	18.100	7.500	24.533
1980	180.200	28.000	8.200	24.533

^{1/} In thousand lbs.

^{2/} In million lbs.

Sources: Clower et al. (1966). Growth Without Development: An Economic Survey of Liberia, Northwestern University Press.
 I.B.R.D. (1966). Report No. AF-45a, June.
 I.B.R.D. (1982). Report No. 4178-LBR, December.

APPENDIX C.2

COMMODITY PRICES, 1950-1980
(in 1975 constant prices)

YEAR	RUP <u>1/</u>	CFP <u>2/</u>	CCP <u>2/</u>	PAP <u>2/</u>
1950	254.300	115.600	89.100	34.590
1951	310.400	110.400	82.600	30.950
1952	195.200	105.500	80.800	30.080
1953	127.100	117.100	88.600	24.170
1954	126.500	153.300	140.600	24.480
1955	207.200	108.400	89.700	25.820
1956	175.300	89.300	63.300	25.630
1957	155.000	90.500	69.100	26.170
1958	142.200	92.200	101.600	23.800
1959	187.200	71.000	84.700	25.790
1960	190.000	57.200	64.500	23.150
1961	145.700	44.600	50.700	23.330
1962	141.800	48.500	47.400	21.800
1963	129.000	64.100	56.700	22.270
1964	123.700	80.700	51.900	23.820
1965	123.800	69.000	37.600	26.690
1966	111.100	72.700	52.100	22.540
1967	93.000	71.600	61.400	21.220
1968	93.600	73.100	73.300	16.130
1969	118.700	69.000	93.800	16.670
1970	88.900	80.600	65.600	22.390
1971	72.200	77.400	48.500	21.150
1972	68.800	74.600	53.700	16.190
1973	109.900	70.000	90.600	23.750
1974	99.400	67.700	112.500	34.360
1975	65.900	58.000	74.600	19.740
1976	85.930	94.800	109.600	18.200
1977	84.280	206.130	158.340	16.980
1978	88.210	131.180	123.290	21.740
1979	99.720	124.360	105.410	20.930
1980	103.750	96.430	75.630	16.940

1/ In U.S. cents per kilogram.

2/ In U.S. cents per pound.

Sources: World Bank. (1980). Commodity Trade and Price Trends, 1971-1980 Editions, Washington, D.C.

APPENDIX C.3

TRANSPORT INVESTMENTS, 1950-1980
(in U.S. \$ millions, 1975 constant prices)

YEAR	TI	YEAR	TI
1950	3.19 ^{1/}	1966	19.42
1951	27.85	1967	19.17
1952	10.83	1968	16.70
1953	0.63	1969	5.88
1954	9.73	1970	13.46
1955	0.59	1971	14.46
1956	1.76	1972	12.33
1957	1.54	1973	4.14
1958	4.77	1974	6.13
1959	5.59	1975	9.50
1960	1.87	1976	40.53
1961	2.01	1977	27.43
1962	6.85	1978	44.76
1963	7.69	1979	32.80
1964	9.32	1980	29.62
1965	12.68		

^{1/} Transport investments have been deflated using the Liberian GDP price deflators in the following: United Nations. (1979). Yearbook of National Accounts Statistics, Vol. II, International Tables, p. 24 and p. 449; and United Nations. (1981). Yearbook of National Accounts Statistics, Vol. II, International Tables, p. 450.

Sources: Stanley, W.R. (1966). Changing Patterns of Transportation Development in Liberia, University of Pittsburgh.
Clower et al. (1966). Growth Without Development, Northwestern University Press, Evanston.
I.B.R.D. (1966). Report No. AF-45a, June.
I.B.R.D. (1969). Report No. AW-5a, May.
I.B.R.D. (1979). Report No. 2662-LBR, December.
I.B.R.D. (1982). Report No. 4178-LBR, December.

APPENDIX C.4

NONURBAN ROAD MILEAGE, 1950-1964

YEAR	NR
1950	230.0
1951	237.5
1952	250.0
1953	275.0
1954	300.0
1955	306.0
1956	328.0
1957	470.0
1958	522.0
1959	540.0
1960	1,150.0
1961	1,200.0
1962	1,300.0
1963	1,402.0
1964	2,280.0

Sources: Stanley, W.R. (1966). Changing Patterns of Transportation Development in Liberia, Ph.D. Thesis, University of Pittsburgh.

Clower et al. (1966). Growth Without Development: An Economic Survey of Liberia, Northwestern University Press, Evanston.

I.B.R.D. (1978). Liberia: Proposed Fourth Highway Project, Staff Appraisal Report, Report No. 1827-LBR.

APPENDIX C.5

CULTIVATED LAND AND AGRICULTURAL
EMPLOYMENT: RUBBER, 1950-1964

YEAR	CL ^{1/}	AE ^{2/}
1950	70.96	23.10
1951	72.56	23.90
1952	73.04	24.70
1953	72.95	26.90
1954	73.79	29.00
1955	73.54	27.20
1956	72.49	26.70
1957	71.62	27.00
1958	71.79	30.00
1959	76.63	34.00
1960	82.89	35.00
1961	90.29	26.76
1962	191.10	35.50
1963	193.20	35.50
1964	193.40	35.25

1/ In thousand acres.

2/ In thousands.

Sources: Clower et al. (1966). Growth Without Development: An Economic Survey of Liberia, Northwestern University Press, Evanston.

I.B.R.D. (1966). The Current Economic Position and Prospects of Liberia, Report No. AF-45a, June.

I.B.R.D. (1982). Liberia: Recent Economic Developments and Medium-Term Prospects, Report No. 4178-LBR, December.

APPENDIX D

EMPIRICAL RESULTS OF MODELS

APPENDIX D.1.1

TRANSPORT-INVESTMENT MODEL: RUBBER

PDL REGRESSION RESULTS

Dependent Variable: lRU

Alpha 0 = 2.352563E-02
Alpha 1 = -2.250746E-02
Alpha 2 = 1.219445E-02
Alpha 3 = -1.54623E-03
Alpha 4 = 5.465359E-05

R Squared = .9806952

R Squared (Adjusted) = .9710428

Stand Error of Estimate = 4.312372E-02

Var-Cov Matrix for Unlagged Coefficients

const	lRUP	lTI
.2340209	-4.564455E-02	-5.607018E-03
-4.564455E-02	8.987409E-03	1.054696E-03
-5.607018E-03	1.054696E-03	3.239157E-04

Estimated Coefficients

	Coefficient	Stand Error	T-value
const	3.963871	.4837571	8.19393
lRUP	6.013941E-02	9.480195E-02	.6343689
lTI(0)	2.352563E-02	1.799766E-02	1.30715

APPENDIX D.1.1 (CONTINUED)

lTI(-1)	1.172105E-02	5.747213E-03	2.039432
lTI(-2)	1.579314E-02	8.285803E-03	1.906048
lTI(-3)	2.843205E-02	7.116062E-03	3.995476
lTI(-4)	4.363963E-02	5.405862E-03	8.072649
lTI(-5)	5.672936E-02	7.088628E-03	8.002869
lTI(-6)	.0643265	9.031635E-03	7.122354
lTI(-7)	6.436787E-02	8.877791E-03	7.250438
lTI(-8)	5.610216E-02	6.829936E-03	8.214155
lTI(-9)	.0400895	5.454115E-03	7.350322
lTI(-10)	1.820189E-02	6.763746E-03	2.691096
lTI(-11)	-6.376995E-03	7.127259E-03	-.8947331
lTI(-12)	-.0291519	1.028665E-02	-2.833956
sum of lag coeff's	.3873998	2.995112E-02	12.9344

Average lag = 5.149756

Durbin-Watson Statistics = 1.720433

APPENDIX D.1.1 (CONTINUED)

OLS REGRESSION RESULTS

Dependent Var: lRU

Means and Stand Deviations

	Mean	Stand Deviation
lRUP	4.584527	.2149853
Alpha 0	25.92874	7.114242
Alpha 1	139.9528	49.07373
Alpha 2	1123.111	442.4913
Alpha 3	10318.48	4381.866
Alpha 4	101935.2	45684.84
lRU	5.011685	.2534183

Correlation Matrix

	Alpha 0	Alpha 1	Alpha 2	Alpha 3	Alpha 4	lRU
lRUP	-.6143	-.5211	-.4174	-.3301	-.2615	-.7219
Alpha 0		.944	.8753	.8127	.7582	.8912
Alpha 1			.9811	.9459	.9077	.7844
Alpha 2				.9904	.9704	.6543
Alpha 3					.9943	.5468
Alpha 4						.4603

R Squared = .9806954

Adjusted R Squared = .9710431

Number of observations = 19

Stand error of estimate = 4.312349E-02

Log of likelihood function = 36.27023

APPENDIX D.1.1 (CONTINUED)

Analysis of Variance

	DF	Sum of Squares	Mean Square	F Ratio
Regression	6	1.13366	.1889433	101.6023
Residual	12	2.231562E-02	1.859635E-03	

Estimated Coefficients

	Coefficient	Standard Error	t-Statistic
Const	3.96383	.4837566	8.193853
1RUP	6.014725E-02	.0948018	.6344526
Alpha 0	.0235275	.0179977	1.307251
Alpha 1	-2.251031E-02	2.614741E-02	-.8609003
Alpha 2	1.219546E-02	9.212955E-03	1.323729
Alpha 3	-1.546351E-03	1.121791E-03	-1.378466
Alpha 4	5.465821E-05	4.400205E-05	1.242174

Var-Cov Matrix for Estimated Coefficients

	Const	1RUP	Alpha 0	Alpha 1	Alpha 2	Alpha 3	Alpha 4
	.2340204	-4.564443E-02	-5.607054E-03	8.604164E-03	-3.103321E-03		
	3.733446E-04	-1.422898E-05					
	-4.564443E-02	8.987381E-03	1.054703E-03	-1.664485E-03	6.00995E-04		
	-7.212556E-05	2.739842E-06					
	-5.607054E-03	1.054703E-03	3.239172E-04	-4.385397E-04	1.442523E-04		
	-1.656839E-05	6.150686E-07					
	8.604164E-03	-1.664485E-03	-4.385397E-04	6.836868E-04	-2.372222E-04		
	2.808406E-05	-1.065819E-06					
	-3.103321E-03	6.00995E-04	1.442523E-04	-2.372222E-04	8.487854E-05		
	-1.025845E-05	3.956562E-07					
	3.733446E-04	-7.212556E-05	-1.656839E-05	2.808406E-05	-1.025845E-05		
	1.258414E-06	-4.912023E-08					
	-1.422898E-05	2.739842E-06	6.150686E-07	-1.065819E-06	3.956562E-07		
	-4.912023E-08	1.936181E-09					

Durbin-Watson Statistic = 1.720408

APPENDIX D.1.1 (CONTINUED)

In-Sample Prediction

	Y-HAT	E-HAT
1	4.566529	.0394712
2	4.52438	-4.138021E-02
3	4.618956	-5.995609E-02
4	4.73998	1.401978E-02
5	4.766815	3.618482E-02
6	4.906484	1.151587E-02
7	4.951883	-9.882839E-03
8	5.022365	1.634907E-03
9	5.083353	6.464744E-02
10	5.17685	2.115016E-02
11	5.264146	-6.914538E-02
12	5.279895	-3.989483E-02
13	5.240275	3.072509E-02
14	5.200147	8.533249E-04
15	5.205735	3.026479E-02
16	5.155679	-1.067923E-02
17	5.140096	6.903813E-03
18	5.161333	-3.333084E-03
19	5.217099	-2.309871E-02

APPENDIX D.1.2

TRANSPORT-INVESTMENT MODEL: COFFEE

PDL REGRESSION RESULTS

Dependent Variable: lCF

Alpha 0 = .6305853
Alpha 1 = -.3580008
Alpha 2 = 4.971679E-02

R Squared = .8835396

R Squared (Adjusted) = .8613567

Stand Error of Estimate = .4054218

Var-Cov Matrix for Unlagged Coefficients

const	lCFP	lTI
1.392737	-.3324486	2.812881E-02
-.3324486	8.229747E-02	-8.239511E-03
2.812881E-02	-8.239511E-03	6.930255E-03

Estimated Coefficients

	Coefficient	Stand Error	T-value
const	2.041529	1.180143	1.7299
lCFP	-.5876537	.2868753	-2.048464
lTI(0)	.6305853	8.324816E-02	7.574766
lTI(-1)	.3223013	3.089463E-02	10.43228
lTI(-2)	.1134509	4.463762E-02	2.541598
lTI(-3)	4.033998E-03	4.804337E-02	8.396576E-02
lTI(-4)	-5.949317E-03	3.782718E-02	-.1572762
lTI(-5)	8.350094E-02	7.845923E-02	1.064259
sum of lag coeff's	1.147923	.1186293	9.676561

Average lag = .8319481

Durbin-Watson Statistics = 1.590883

APPENDIX D.1.2 (CONTINUED)

OLS REGRESSION RESULTS

Dependent Var: LCF

Means and Stand Deviations

	Mean	Stand Deviation
LCFP	4.372962	.3207171
Alpha 0	11.67431	4.676285
Alpha 1	27.98304	11.52428
Alpha 2	101.2245	43.26274
LCF	1.845962	1.088824

Correlation Matrix

	Alpha 0	Alpha 1	Alpha 2	LCF
LCFP	.3759	.3153	.3036	.2465
Alpha 0		.9249	.8486	.8145
Alpha 1			.9814	.599
Alpha 2				.5013

R Squared = .8851616

Adjusted R Squared = .8632876

Number of observations = 26

Stand error of estimate = .4025887

Log of likelihood function = -10.73657

APPENDIX D.1.2 (CONTINUED)

Analysis of Variance

	DF	Sum of Squares	Mean Square	F Ratio
Regression	4	26.23481	6.558703	40.46642
Residual	21	3.403631	.1620777	

Estimated Coefficients

	Coefficient	Standard Error	t-Statistic
Const	2.106725	1.164474	1.809165
ICFP	-.6041539	.2831686	-2.133548
Alpha 0	.6346662	8.300538E-02	7.646085
Alpha 1	-.3621342	9.083791E-02	-3.986597
Alpha 2	5.043743E-02	1.732804E-02	2.910741

Var-Cov Matrix for Estimated Coefficients

Const	ICFP	Alpha 0	Alpha 1	Alpha 2
1.355999	-.3237193	2.862822E-02	-2.688619E-02	4.781342E-03
-.3237193	8.018445E-02	-8.350356E-03	7.440173E-03	-1.359733E-03
2.862822E-02	-8.350356E-03	6.889894E-03	-6.89919E-03	1.190553E-03
-2.688619E-02	7.440173E-03	-6.89919E-03	8.251526E-03	-1.541217E-03
4.781342E-03	-1.359733E-03	1.190553E-03	-1.541217E-03	3.002609E-04

Durbin-Watson Statistic = 1.608482

APPENDIX D.1.2 (CONTINUED)

In-Sample Prediction

	Y-HAT	E-HAT
1	-.2956002	-1.139977E-02
2	.1012412	-5.224124E-02
3	-7.061392E-03	-.1309386
4	.5117349	-.4537349
5	1.374494	-.5864938
6	.7422453	-4.924526E-02
7	.6987856	8.921446E-02
8	1.307879	.1271215
9	1.71005	.3819497
10	1.888491	.9905089
11	2.163043	-.2170433
12	2.520948	.4550526
13	2.797637	-.5786365
14	2.750152	-.5201519
15	2.092337	.1586634
16	2.195065	-3.206526E-02
17	2.450708	-.3467077
18	2.485488	-.255488
19	1.785612	.2023885
20	1.644405	.4225954
21	2.035394	.1166063
22	2.849196	.2048045
23	2.644853	.4551474
24	3.170661	-.2206607
25	3.153575	-.257575
26	3.223666	.1083338

APPENDIX D.1.3

TRANSPORT-INVESTMENT MODEL: COCOA

PDL REGRESSION RESULTS

Dependent Variable: lCC

Alpha 0 = 1.759327E-02
Alpha 1 = 6.670234E-02
Alpha 2 = -1.421368E-02
Alpha 3 = 7.741165E-04

R Squared = .8993421

R Squared (Adjusted) = .8606275

Stand Error of Estimate = .2126864

Var-Cov Matrix for Unlagged Coefficients

const	lCCP	lTI
.5572104	-.1542823	6.861985E-03
-.1542823	4.706433E-02	-3.330767E-03
6.861985E-03	-3.330767E-03	3.200397E-03

Estimated Coefficients

	Coefficient	Stand Error	T-value
const	-1.350458	.7464653	-1.809137
lCCP	.221967	.2169432	1.023158
lTI(0)	1.759327E-02	5.657205E-02	.3109887

APPENDIX D.1.3 (CONTINUED)

lTI(-1)	7.085605E-02	.0268125	2.642649
lTI(-2)	.1003362	.0241688	4.151475
lTI(-3)	.1106783	2.786931E-02	3.971334
lTI(-4)	.1065272	2.622681E-02	4.061769
lTI(-5)	.0925276	2.028853E-02	4.560588
lTI(-6)	7.332406E-02	1.524885E-02	4.808497
lTI(-7)	.0535614	1.756239E-02	3.049779
lTI(-8)	3.788429E-02	2.343305E-02	1.616704
lTI(-9)	3.093737E-02	2.626388E-02	1.177944
lTI(-10)	.0373654	.0236782	1.578051
lTI(-11)	6.181306E-02	2.347254E-02	2.63342
lTI(-12)	.1089251	4.763718E-02	2.286557
sum of lag coeff's	.9023293	.1517242	5.947167

Average lag = 5.817603

Durbin-Watson Statistics = 2.57718

APPENDIX D.1.3 (CONTINUED)

OLS REGRESSION RESULTS

Dependent Var: ICC

Means and Stand Deviations

	Mean	Stand Deviation
ICCP	4.291	.3870669
Alpha 0	25.92874	7.114242
Alpha 1	139.9528	49.07373
Alpha 2	1123.111	442.4913
Alpha 3	10318.48	4381.866
ICC	1.417526	.5697063

Correlation Matrix

	Alpha 0	Alpha 1	Alpha 2	Alpha 3	ICC
ICCP	.7649	.7821	.7702	.7463	.7541
Alpha 0		.944	.8753	.8127	.9356
Alpha 1			.9811	.9459	.871
Alpha 2				.9904	.8032
Alpha 3					.7462

R Squared = .8993423

Adjusted R Squared = .8606278

Number of observations = 19

Stand error of estimate = .2126861

Log of likelihood function = 5.45099

APPENDIX D.1.3 (CONTINUED)

Analysis of Variance

	DF	Sum of Squares	Mean Square	F Ratio
Regression	5	5.254115	1.050823	23.23012
Residual	13	.5880599	4.523538E-02	

Estimated Coefficients

	Coefficient	Standard Error	t-Statistic
Const	-1.350458	.7464643	-1.809139
lCCP	.2219672	.2169429	1.02316
Alpha 0	1.759278E-02	5.657209E-02	.31098
Alpha 1	6.670271E-02	4.814359E-02	1.385495
Alpha 2	-1.421374E-02	9.620747E-03	-1.477405
Alpha 3	7.741199E-04	5.209334E-04	1.486025

Var-Cov Matrix for Estimated Coefficients

	Const	lCCP	Alpha 0	Alpha 1	Alpha 2	Alpha 3
Const	.557209 -7.197679E-05	-.1542819	6.861988E-03	-6.368615E-03	1.39191E-03	
lCCP	-.1542819 1.674953E-05	4.706421E-02	-3.330762E-03	1.878955E-03	-3.535742E-04	
Alpha 0	6.861988E-03 -2.23461E-05	-3.330762E-03	3.200401E-03	-2.427371E-03	4.405114E-04	
Alpha 1	-6.368615E-03 2.413211E-05	1.878955E-03	-2.427371E-03	2.317805E-03	-4.560061E-04	
Alpha 2	1.39191E-03 -4.984361E-06	-3.535742E-04	4.405114E-04	-4.560061E-04	9.255877E-05	
Alpha 3	-7.197679E-05 2.713716E-07	1.674953E-05	-2.23461E-05	2.413211E-05	-4.984361E-06	

Durbin-Watson Statistic = 2.57718

APPENDIX D.1.3 (CONTINUED)

In-Sample Prediction

	Y-HAT	E-HAT
1	.5551263	3.287369E-02
2	.7899311	4.306894E-02
3	.6647798	7.722028E-02
4	.5216345	-.5216345
5	.9253091	.2986909
6	.9145044	.1154955
7	1.268929	.1660708
8	1.496152	-.1881522
9	1.577132	-.1661318
10	1.515639	.1333611
11	1.481611	8.738934E-02
12	1.669561	.1714391
13	1.793662	-.1076618
14	1.659857	4.514356E-02
15	1.765177	-6.017654E-02
16	1.964379	-6.237908E-02
17	2.056419	.1295811
18	2.146016	-.1310159
19	2.167184	-6.318388E-02

APPENDIX D.1.4

TRANSPORT-INVESTMENT MODEL: PALM KERNELS

PDL REGRESSION RESULTS

Dependent Variable: lPA

Alpha 0 = -7.437174E-02
Alpha 1 = .1469649
Alpha 2 = -5.189354E-02
Alpha 3 = 6.563298E-03
Alpha 4 = -2.752799E-04

R Squared = .6797541

R Squared (Adjusted) = .5196312

Stand Error of Estimate = .1893137

Var-Cov Matrix for Unlagged Coefficients

const	lPAP	lTI
.8404529	-.2369634	-1.676416E-02
-.2369634	7.036913E-02	3.544619E-03
-1.676416E-02	3.544619E-03	4.035774E-03

Estimated Coefficients

	Coefficient	Stand Error	T-value
const	2.256476	.9167622	2.461354
lPAP	.2651418	.2652718	.9995097
lTI(0)	-7.437174E-02	6.352774E-02	-1.170697

APPENDIX D.1.4 (CONTINUED)

lTI(-1)	2.698764E-02	2.760887E-02	.9774988
lTI(-2)	6.008581E-02	3.233272E-02	1.858359
lTI(-3)	.0543925	2.928404E-02	1.857411
lTI(-4)	3.277067E-02	2.332752E-02	1.404808
lTI(-5)	1.147656E-02	2.297487E-02	.4995268
lTI(-6)	1.598722E-04	2.445659E-02	6.536979E-03
lTI(-7)	1.863283E-03	2.228833E-02	8.359904E-02
lTI(-8)	1.302275E-02	1.924422E-02	.67671
lTI(-9)	2.346824E-02	2.291524E-02	1.024132
lTI(-10)	1.642181E-02	2.799791E-02	.586537
lTI(-11)	-3.150016E-02	2.455564E-02	-1.282808
lTI(-12)	-.1502884	4.446245E-02	-3.380119
sum of lag coeff's	-1.551113E-02	9.625878E-02	-.1611399

Average lag = 74.62666

Durbin-Watson Statistics = 2.168224

APPENDIX D.1.4 (CONTINUED)

OLS REGRESSION RESULTS

Dependent Var: LPA

Means and Stand Deviations

	Mean	Stand Deviation
LPAP	3.037895	.1903298
Alpha 0	25.92874	7.114242
Alpha 1	139.9528	49.07373
Alpha 2	1123.111	442.4913
Alpha 3	10318.48	4381.866
Alpha 4	101935.2	45684.84
LPA	3.082106	.2731459

Correlation Matrix

	Alpha 0	Alpha 1	Alpha 2	Alpha 3	Alpha 4	LPA
LPAP	-.2777	-.1619	-.122	-.0995	-.0832	.0632
Alpha 0		.944	.8753	.8127	.7582	.0252
Alpha 1			.9811	.9459	.9077	-.1399
Alpha 2				.9904	.9704	-.276
Alpha 3					.9943	-.3698
Alpha 4						-.4375

R Squared = .6797516

Adjusted R Squared = .5196274

Number of observations = 19

Stand error of estimate = .1893145

Log of likelihood function = 8.162737

APPENDIX D.1.4 (CONTINUED)

Analysis of Variance

	DF	Sum of Squares	Mean Square	F Ratio
Regression	6	.9128769	.1521462	4.245152
Residual	12	.4300797	3.583998E-02	

Estimated Coefficients

	Coefficient	Standard Error	t-Statistic
Const	2.256481	.9167655	2.46135
1PAP	.2651407	.2652728	.9995019
Alpha 0	-7.437106E-02	6.352828E-02	-1.170677
Alpha 1	.1469624	8.506088E-02	1.727732
Alpha 2	-.0518925	2.939438E-02	-1.765389
Alpha 3	6.563161E-03	3.630814E-03	1.807628
Alpha 4	-2.752743E-04	1.462932E-04	-1.881661

Var-Cov Matrix for Estimated Coefficients

Const	1PAP	Alpha 0	Alpha 1	Alpha 2	Alpha 3	Alpha 4
.8404591	-.2369652	-1.676434E-02	3.084843E-03	4.975571E-04		
-1.252737E-04	6.063368E-06					
-.2369652	7.036968E-02	3.544643E-03	-5.358364E-05	-4.398304E-04		
7.748568E-05	-3.598127E-06					
-1.676434E-02	3.544643E-03	4.035842E-03	-4.689911E-03	1.398684E-03		
-1.522855E-04	5.475992E-06					
3.084843E-03	-5.358364E-05	-4.689911E-03	7.235353E-03	-.0024264		
2.837534E-04	-1.075894E-05					
4.975571E-04	-4.398304E-04	1.398684E-03	-.0024264	8.640295E-04		
-1.052374E-04	4.116764E-06					
-1.252737E-04	7.748568E-05	-1.522855E-04	2.837534E-04	-1.052374E-04		
1.318281E-05	-5.268743E-07					
6.063368E-06	-3.598127E-06	5.475992E-06	-1.075894E-05	4.116764E-06		
-5.268743E-07	2.140171E-08					

Durbin-Watson Statistic = 2.168198

APPENDIX D.1.4 (CONTINUED)

In-Sample Prediction

	Y-HAT	E-HAT
1	2.914631	2.436863E-02
2	2.594742	-1.474182E-02
3	2.870084	-.1550843
4	3.266987	1.401292E-02
5	2.964281	.2857192
6	3.418861	-3.786067E-02
7	3.25438	.1126205
8	3.336208	-.1922084
9	3.158282	-9.928156E-02
10	3.136995	.0030054
11	3.25632	-.09932
12	3.410293	2.070738E-02
13	3.286981	2.701889E-02
14	3.046705	.160295
15	2.853211	5.378932E-02
16	2.837953	-3.495238E-02
17	2.888414	-.4034141
18	2.998066	.2019343
19	3.066613	.1333875

APPENDIX D.2.1

TRANSPORT-ACCESSIBILITY MODEL: RUBBER

```
eval rgattr (1NR, 1RUPNR, 1RUNR sv(r1:=residuals)) print coefs, rsq, anov
```

	coef	stand_err	dgfd	F_ratio	sig
constant	3.750	0.663	12.000	32.006	0.000
1NR	0.112	0.036	12.000	10.000	0.008
1RUPNR	0.002	0.100	12.000	0.001	0.981

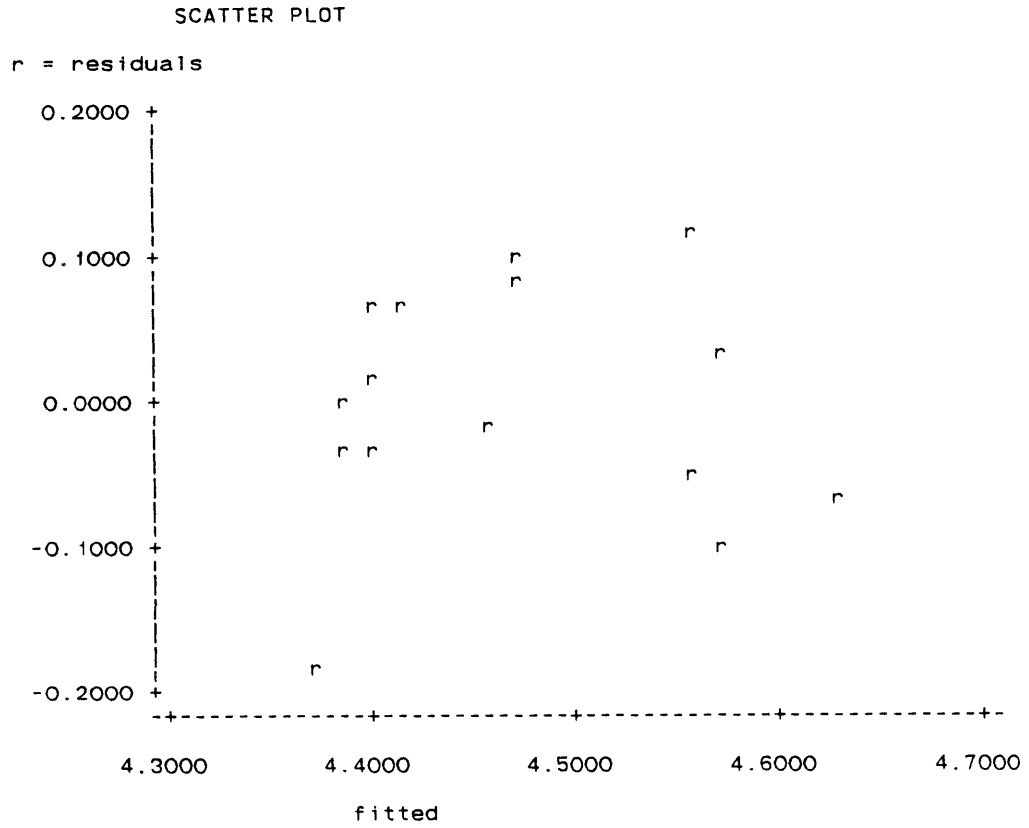
rsquare	adj_rsquare	SEE	OBS
0.539	0.463	0.0837	14.000

	sum_of_squares	dgf	mean_square	F_ratio	sig
total	0.194	14.000	0.014	*	*
regression	0.105	2.000	0.052	7.024	0.010
error	0.090	12.000	0.007	*	*

```
residuals  
fitted
```

```
4.375 -0.175  
4.379 -0.006  
4.384 -0.027  
4.394 -0.027  
4.404 0.013  
4.407 0.065  
4.414 0.069  
4.455 -0.025  
4.466 0.086  
4.471 0.096  
4.556 0.114  
4.560 -0.051  
4.569 0.037  
4.577 -0.094  
4.632 -0.073
```

APPENDIX D.2.1 (CONTINUED)



APPENDIX D.2.2

TRANSPORT-ACCESSIBILITY MODEL: COFFEE

eval rgattr (1NR, 1CFPNR, 1CFNR sv (r1:=residuals)) print coefs, rsq, anov

	coef	stand_err	dgfd	F_ratio	sig
constant	-15.081	4.289	12.000	12.364	0.004
1NR	1.820	0.281	12.000	41.845	0.000
1CFPNR	0.874	0.617	12.000	2.002	0.183

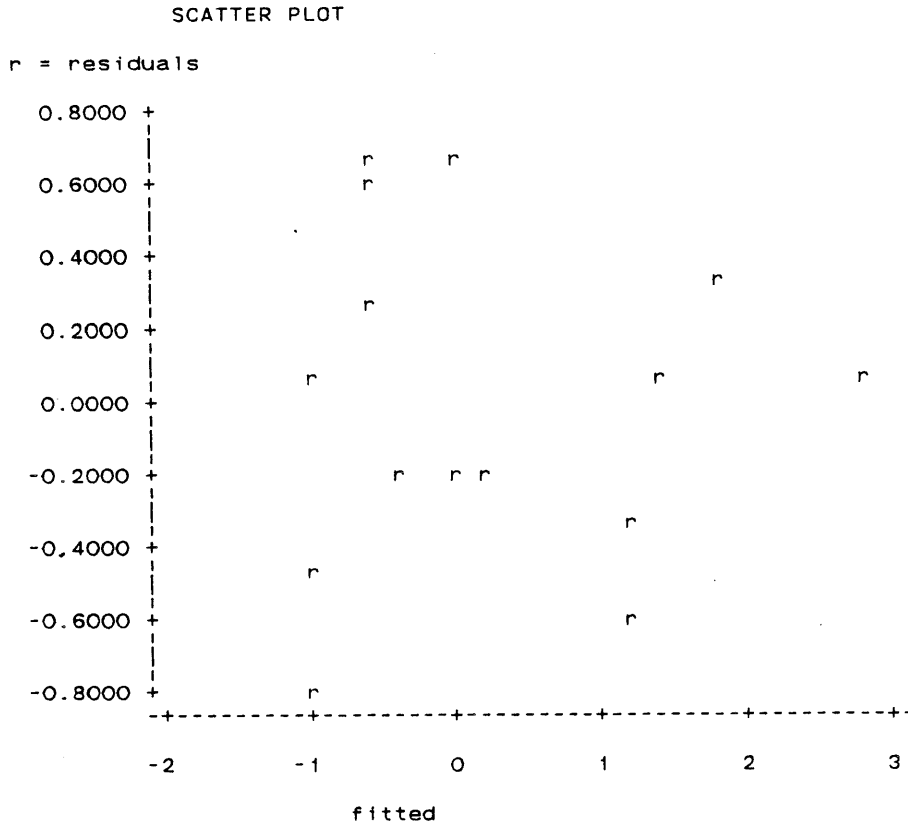
rsquare	adj_rsquare	SEE	OBS
0.870	0.848	0.4919	14.000

	sum_of_squares	dgf	mean_square	F_ratio	sig
total	22.254	14.000	1.590	*	*
regression	19.353	2.000	9.676	40.028	0.000
error	2.901	12.000	0.242	*	*

residuals
fitted

-1.034	-0.462
-1.016	-0.780
-0.963	0.071
-0.698	0.603
-0.304	-0.205
-0.571	0.264
-0.614	0.663
0.052	-0.190
0.260	-0.201
0.093	0.695
1.280	-0.587
1.140	-0.352
1.359	0.076
1.740	0.352
2.826	0.053

APPENDIX D.2.2 (CONTINUED)



APPENDIX D.2.3

TRANSPORT-ACCESSIBILITY MODEL: COCOA

eval ngattr (1NR, 1CCPNR, 1CCNR sv (r1:=residuals)) print coefs, rsq, anov

	coef	stand_err	dgfd	F_ratio	sig
constant	-6.423	1.911	12.000	11.292	0.006
1NR	0.630	0.116	12.000	29.268	0.000
1CCPNR	0.630	0.302	12.000	4.358	0.059

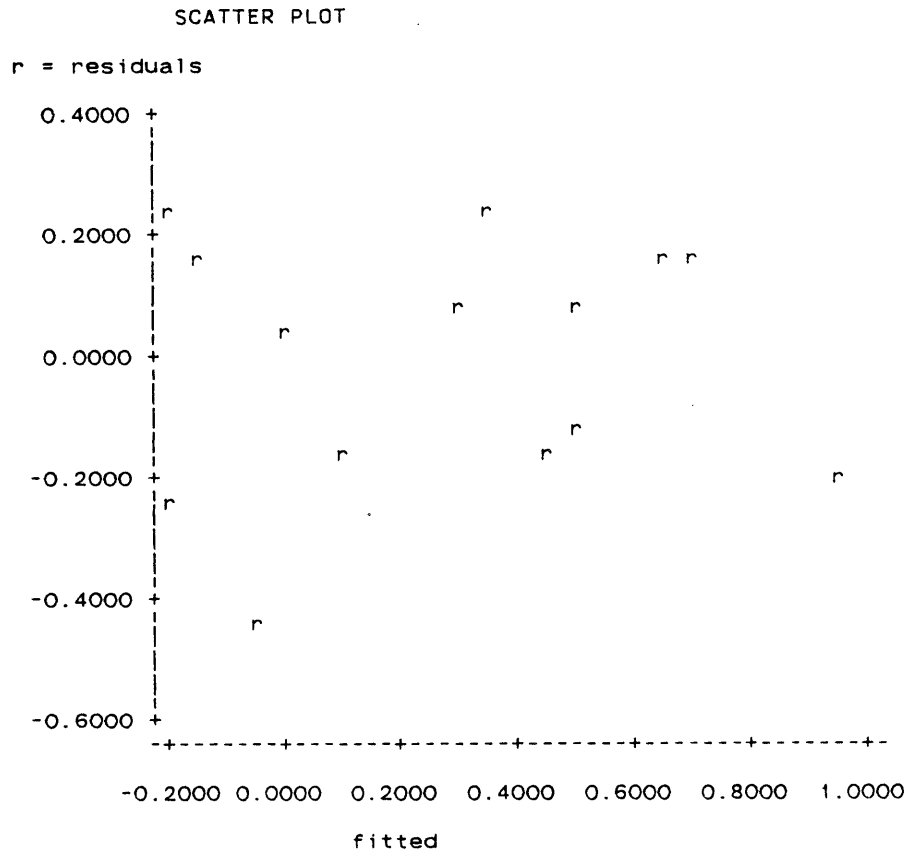
adj_rsquare	rsquare	SEE	OBS
0.760	0.720	0.2236	14.000

	sum_of_squares	dgf	mean_square	F_ratio	sig
total	2.488	14.000	0.178	*	*
regression	1.891	2.000	0.945	19.014	0.000
error	0.597	12.000	0.050	*	*

residuals
fitted

-0.169	0.179
-0.197	-0.256
-0.178	0.237
-0.060	-0.457
0.285	0.086
0.015	0.044
-0.161	0.161
0.120	-0.151
0.429	-0.144
0.336	0.241
0.640	0.148
0.515	-0.110
0.523	0.065
0.684	0.149
0.934	-0.192

APPENDIX D.2.3 (CONTINUED)



APPENDIX D.2.4

TRANSPORT-ACCESSIBILITY MODEL: PALM KERNELS

```
eval rgattr (1NR, 1PAPNR, 1PANR sv (r1:=residuals)) print coefs, rsq, anov
```

	coef	stand_err	dgfd	F_ratio	sig
constant	1.082	3.906	12.000	0.077	0.786
1NR	-0.149	0.161	12.000	0.864	0.371
1PAPNR	0.961	0.961	12.000	0.999	0.337

```
adj_rsquare  
rsquare SEE OBS
```

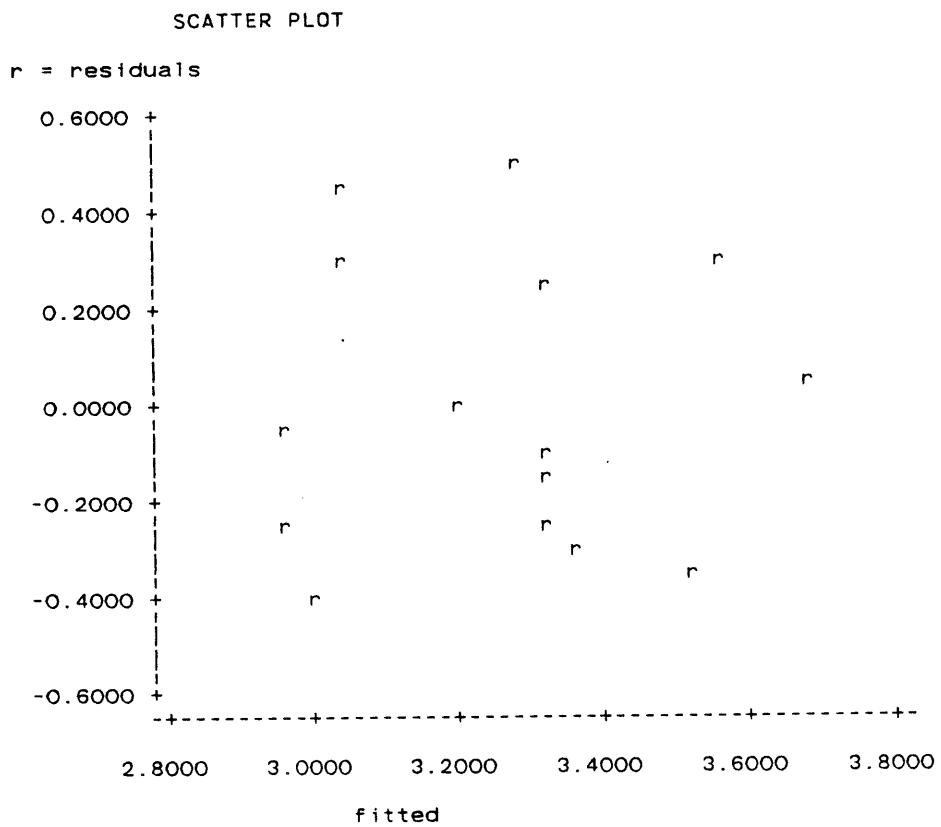
```
0.358 0.251 0.3209 14.000
```

	sum_of_squares	dgf	mean_square	F_ratio	sig
total	1.928	14.000	0.138	*	*
regression	0.690	2.000	0.345	3.342	0.070
error	1.238	12.000	0.103	*	*

```
residuals  
fitted
```

```
3.676 0.038  
3.564 0.286  
3.529 -0.351  
3.305 0.250  
3.304 -0.085  
3.352 -0.308  
3.335 -0.244  
3.301 -0.166  
3.194 0.024  
3.267 0.495  
3.050 0.465  
3.051 0.295  
2.974 -0.035  
2.983 -0.403  
2.975 -0.261
```

APPENDIX D.2.4 (CONTINUED)



APPENDIX D.3.1

FACTOR-INPUT MODEL: AGRICULTURAL EMPLOYMENT

+++++ Dependent Variable: 1AE ++++++

	coef	stand_err	dofd	T_ratio	sig
constant	2.208	0.142	15.000	15.591	0.000
1NR	0.186	0.021	15.000	8.688	0.000

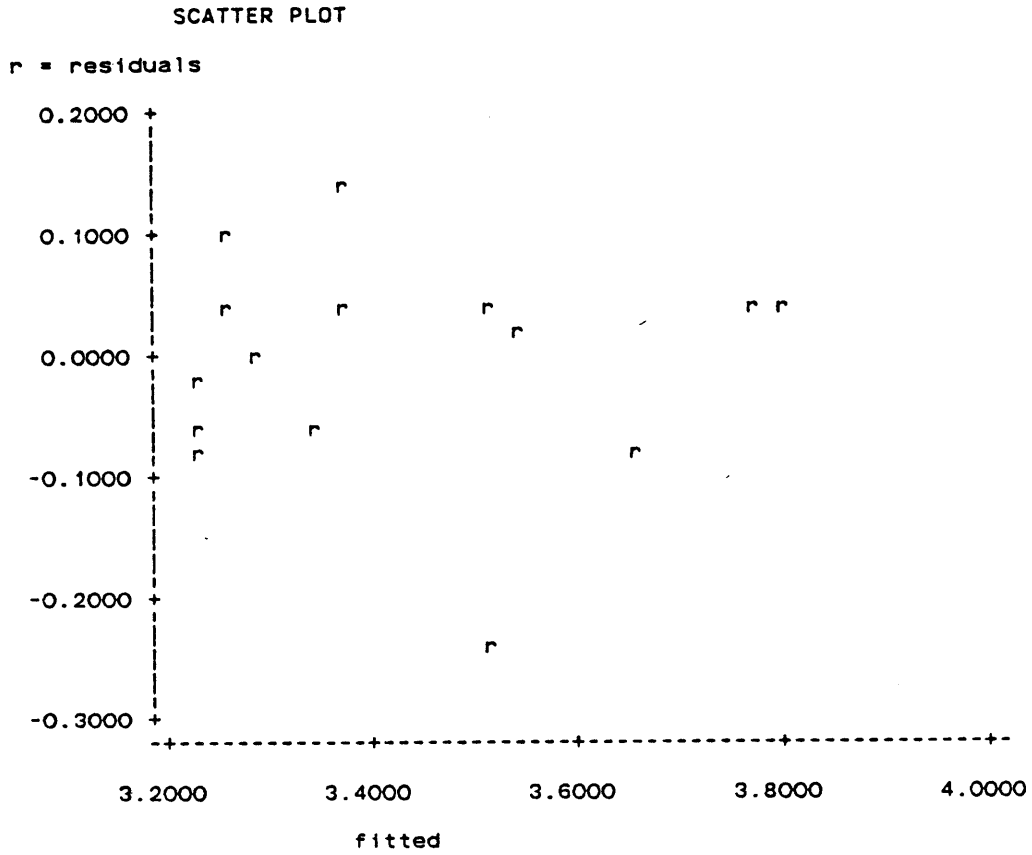
rsquare	adj_rsquare	SEE	obs
0.834	0.823	0.089	17.000

	sum_of_squares	dof	mean_square	F_ratio	sig
total	0.715	16.000	0.045	*	*
regression	0.597	1.000	0.597	75.481	0.000
error	0.119	15.000	0.008	*	*

residuals
fitted

3.218	-0.078
3.224	-0.050
3.234	-0.027
3.251	0.041
3.267	0.100
3.271	0.032
3.284	0.001
3.351	-0.055
3.370	0.031
3.377	0.150
3.517	0.038
3.525	-0.238
3.540	0.030
3.554	0.016
3.644	-0.082
3.785	0.043
3.801	0.049

APPENDIX D.3.1 (CONTINUED)



sample_durbin_watson

1.900

APPENDIX D.3.2

FACTOR-INPUT MODEL: CULTIVATED LAND

+++++ Dependent Variable: ICL ++++++

	coef	stand_err	dgfd	T_ratio	sig
constant	1.756	0.446	14.000	3.934	0.001
1NR	0.439	0.069	14.000	6.332	0.000

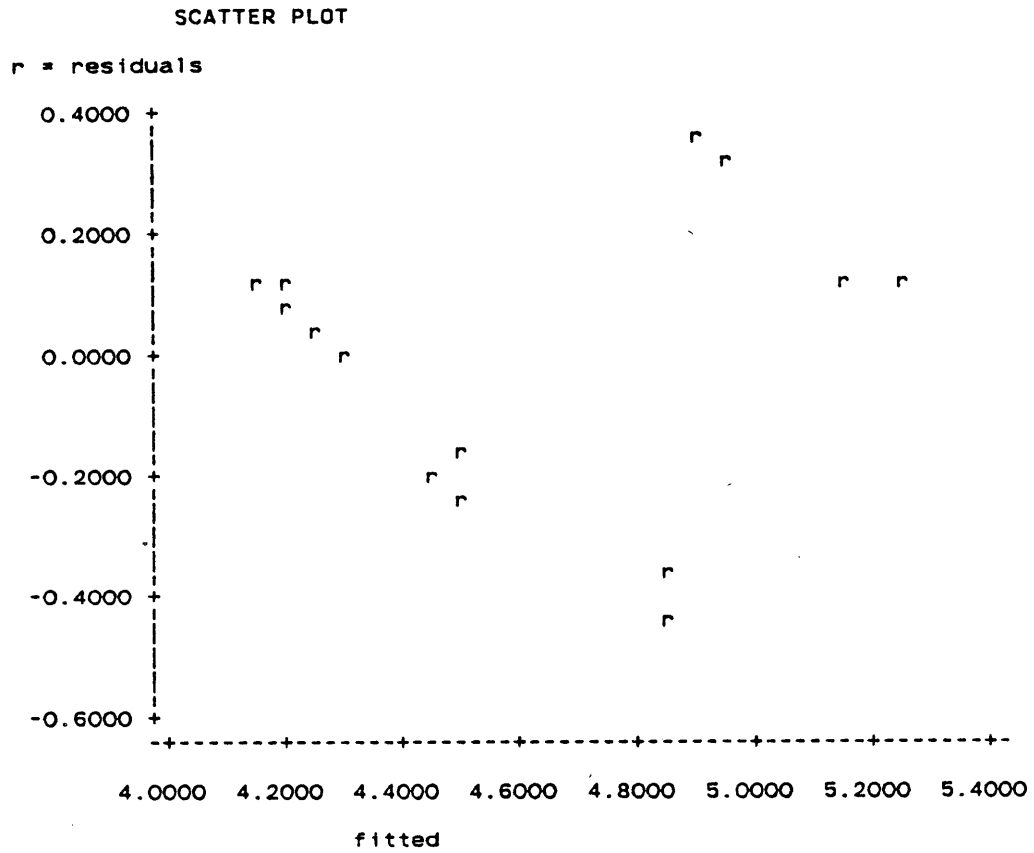
rsquare	adj_rsquare	SEE	obs
0.741	0.723	0.230	16.000

	sum_of_squares	dgf	mean_square	F_ratio	sig
total	2.864	15.000	0.191	*	*
regression	2.123	1.000	2.123	40.089	0.000
error	0.741	14.000	0.053	*	*

residuals
fitted

4.142	0.120
4.156	0.128
4.179	0.112
4.221	0.069
4.259	0.042
4.267	0.030
4.298	-0.014
4.456	-0.184
4.502	-0.228
4.517	-0.178
4.848	-0.431
4.867	-0.364
4.902	0.351
4.935	0.329
5.149	0.116
5.254	0.101

APPENDIX D.3.2 (CONTINUED)



sample_durbin_watson

0.895