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POPULATION DENSITY GROWTH: ECONOMIC EFFECTS AND MITIGATION IN LDCs

A DISSERTATION SUBMITTED TO THE GRADUATE DIVISION OF THE UNIVERSITY OF HAWAII IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN ECONOMICS AUGUST 1985

By

Michael McCarthy

Dissertation Committee:

John Power, Chairman
Alice Dewey
Fred Hung
Shelley Mark
Marcellus Snow
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ABSTRACT

Purpose

The purpose of this study is to provide a theoretical and empirical analysis of the economic effects of population density growth in LDCs*. Cross-country variations in the population density and per capita income relationship are changed by the intermediary effects of institutional and structural changes over time. The discussion brings together disparate viewpoints from the economic sub-fields of population, development, and microeconomic theory, to substantially modify the prevailing views of the causal relations involved. The conclusion is a new explanation for the presence or absence of economic development in less developed countries*.

Background

For some time there has been concern that rapid population growth since the early 20th Century would inhibit economic development* in less developed countries. Theoretical debates ensued over both the economic effects of rapid population growth and the explanation for lack of economic development in LDCs.

Hypothesis

Rapid population growth has an inhibiting effect upon attempts to raise the levels of per capita incomes (or output in the production function context) in LDCs. This occurs through the effects of rising population densities* upon institutional effectiveness*. Appropriate institutional* and structural* change can "mitigate"* or lessen the negative economic effects of rapid population growth.

* see Glossary—List of Definitions
Empirical Testing. (Data: World Bank, FAO, IMF)

Testing of the "mitigation hypothesis" is done in three steps. First, the sign and significance of the cross-country income/population relationship is determined from a production function derivation. Second, an aggregate cross-country production function is fitted and analyzed for efficiency and input substitution characteristics. It is then used to generate a Residual*, for which the explanatory values of structural and institutional change variables are tested. Third, an interaction test for the mitigation of population growth effects over time across countries is done, testing the Residual first, and then variables disaggregated from it.

Contributions and Conclusion

This study advances the theoretical and empirical discussion of population growth effects upon national incomes (per capita) for LDCs. Additionally, it empirically tests the importance of the contributions of institutional and structural change to economic growth.

The empirical results of the study show that variation in per capita income levels and growth rates, both across countries and over time, is explained by the effects of economic structural/institutional characteristics on the national per capita income/population relationship. Across LDCs, population density growth in the 20th Century has retarded economic development. Over time, in those countries where economic structures and institutions have been changed, the growth limitations of population density growth influences have been lessened, or "mitigated", and economic growth has occurred.
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LIST OF ABBREVIATIONS, SYMBOLS, AND GREEK LETTERS

\[ \alpha = \text{alpha} \quad \beta = \text{beta} \]
\[ \gamma = \text{gamma} \quad \delta = \text{delta} \]
\[ \epsilon = \text{epsilon} \quad \rho = \text{rho} \]
\[ \lambda = \text{lambda} \quad \sigma = \text{sigma} \]

A = agricultural output per capita in the agricultural sector.

C.D. = Cobb-Douglas

CES = Constant Elasticity of Substitution

d.f. = degrees of freedom

F = financial deepening, (the ratio of M2 to GDP)

GDP = Gross Domestic Product

I/P = gross real investment per capita

I/N = gross real investment per capita

I/Y = gross real investment as a share of GDP

K = an estimation of capital stock

KG = the growth rate of capital

L = the literacy rate as a percentage of the total population

M = the interaction model stands for the mitigating Residual factor in the "growth accounting" sense.

MT = total manufactured exports, as a percentage of GDP

N = the potential labor force participation rate

NG = potential labor force growth rate

P/H = population density

PG = the population growth rate.

R = the percentage of the labor force outside of agriculture.

R^2 = correlation coefficient

\[ \frac{Y}{P}, Y = \text{per capita income, income, denominated in 1979 U.S. dollars.} \]

\( \frac{Y}{P}G, YG = \text{average real per capita income and income growth rate figures for the 1960-80 period.} \)
CHAPTER I
INTRODUCTION

1.1 Historical Background

Concern about rapid population growth's effects upon economic development in LDCs intensified in the middle 20th Century. International public health programs had greatly reduced mortality in these areas, bringing unprecedented population growth\(^1\) not associated with increases in per capita income. With such an exogenous shock, economic conditions deteriorated with the effects of the increased population density growth rates and rising levels of population density. Seeing imminent political, economic, and social instability, former colonial powers and other interested parties searched for explanations and solutions to the state of affairs.

Development efforts have had mixed results. It was evident that because of the population growth, per capita incomes were not growing. LDCs were not generating the technological change that would improve productivity, to prevent or decrease problems due to population density, as the Europeans had done. This was true for a variety of reasons. The fact is that there were many differences between the context of European economic growth in the 19th Century and the LDC status in the mid-20th Century.

---

1. Preston, Coale, Ohlin, Spengler, Kuznets, Meier, and others confirm this. Preston (1976) pp.81-82, on health technology: "... some 75-90 per cent of the growth in life expectancy is attributable to factors exogeneous to a nation's contemporary level of income. The importance of exogeneous, largely imported, health technology ... may have been underestimated."
As Kuznets notes\(^2\), these include:

1) declines in death rates in the LDCs proceeded at a rate far exceeding that of the past declines in death rates in the currently developed countries.

2) levels of per capita product in the underdeveloped countries much lower than were those in the developed countries in their preindustrialization phase.

3) a much lower supply of agricultural land per capita in most underdeveloped countries today, than in most presently developed countries today, let alone their preindustrial phase.

4) the social and political concomitants of the low-income structure of the underdeveloped countries today appear to constitute more formidable obstacles to economic growth than they did in the preindustrialization phase of presently developed countries.

5) most underdeveloped countries have attained political independence only recently, after decades of colonial status.

6) a greater cultural and historical diversity among LDCs than among the European countries.

7) time framework: European populations had not grown as rapidly, and economic development took place over a long period of time.

In spite of the differences, it was thought that the path of European and American development could be followed, and that the economic development of LDCs could be accomplished quickly. This gave rise to the parlance of "five-year" plans.

LDC industrialization\(^3\) (the technical change to capital intensive production)\(^4\) was seen as the key to development, without regard to the negative economic effects of increasing populations.

---


3. Hagen and Hawrylshyn (1969) p.9: "By and large differences in per capita GDP are associated with the degree of industrialization."

4. Binswanger and Ruttan (1978) p.1: "In the simple Harrod-Domar-Mahalanobis models that dominated growth theory in the 1950's, increases in the capital-labor ratio were seen as the only source of increase in per capita income."
However, despite the fact that capital intensive development programs were often unsuccessful in LDCs, the success stories maintained hope in capital intensive development programs.

This study proposes to explain the economic development history of LDCs by analyzing the relationship between population density growth and economic growth potential, with the intermediary elements of institutional and structural change. To do so it is necessary to resolve the conflict that evolved during the 1950s, 1960s, and 1970s over the economic effects of population growth in LDCs. A causal relationship was hypothesized by each school of thought. It was said that rapid population growth either causes economic growth or prevents it. A number of differences in the analytical orientation and empirical specification of the problem has prevented resolution to this date. Articles supporting one side or the other are still being published, based on the same argumentative structures (e.g. Browning 1982).

Empirical results that were erroneous and inconclusive due to specification error have been used to substantiate theoretical positions. This is true particularly of that side of the issue claiming that population growth causes economic growth. The theoretical arguments supporting that position have been dismissed by noted economists such as Spengler and Schultz.

On the other side of the income/population growth debate (in all of its various specifications), the negative effects of population growth on per capita income growth potential have been substantially supported.
However, since rapid population density growth has been ubiquitous in LDCs, the explanation for the economic growth that has occurred in some LDCs remains unexplained.

Some rather unscientific and emotional offshoots of the debate have occurred on either side of the argument. Pro-natalist groups in developed countries protest birth control policy on moral grounds. On the other side, groups such as the Club of Rome, make doomsday predictions about the future of the human race, regarding the consequences if immediate world-wide birth control is not implemented.

Despite a brief Neo-Malthusian\(^5\) flurry of concern about rapid population growth in the 1960's and early 1970's, academic discussion about population density with respect to economic development has diminished. Counterproposals to those concerns suggested that a "demographic transition" responding strongly to small increases in economic growth would slow birth rates, counteracting the mortality decline, and thus Malthusian worries. Responses to that argument called the effect spurious, noting that the demographic transition was determined more directly by non-income causes\(^6\). But casual observation showed a few LDCs beginning to have rising living standards, and growing economies,\(^7\) despite their relatively high population densities.

---

\(^5\) decline in population interest: Neo-Malthusianism literature from mid-'50's-to-mid '60's: Coale and Hoover, Leff, Leibenstein, Enke  
\(^6\) Coale (1973), Caldwell (1976), Kuznets (1965)  
\(^7\) e.g. Korea, Taiwan, success with institutional, structural change.
But the fact that the capital intensive development programs were not more generally successful, meant that other determinants of development success had been neglected.

Seeking an accounting of the sources of economic growth, Abramowitz, Solow, and Denison (in separate studies) extended the traditional sources of growth to include the contributions of the institutional and structural change components of technology. Their studies were for developed countries, however. To date, no similar analysis for LDCs has been done. The empirical character of the growth accounting studies lacked the rigorous formal theoretical modelling of the earlier growth models. Yet they were empirically instructive, and consistent with the statements of other applied economists like Kuznets and Lewis. The implications of the growth accounting studies showed practical applicability to LDCs, considering the substantial differences between LDCs and the developed countries.

The theoretical analysis of economic institutions and structures has been recently begun. There is yet no comprehensive theoretical explanation or description of what becomes of the "population problem", or how the "sources of growth" change as economic structures and institutions reduce the influence of increasing population densities. Some authors have suggested that the "sources" identifiable as institutional and structural changes contribute to growth because they act to minimize economic transactions costs and improve resource allocation as population growth changes factor proportions.

8. Solow (1957), Denison (1967)
9. Binwanger and Ruttan (1978), Schultz (1968), North and Thomas (1973)
I would add that in so doing, they "mitigate" or reduce the negative influences of population density. This is true particularly in the case of LDCs. The mitigation hypothesis rests on the idea that institutional and structural changes, comprising the neglected part of technological change, can "mitigate" over time the otherwise detrimental economic influences of population density growth in LDCs.

1.2 Hypothesis

The approach taken in this paper increases the information brought to bear on the topic, both theoretically and empirically. Theoretically, literature on institutional and structural economic change considers how these variables interact with population density growth to increase the potential for economic growth. This view modifies the old bivariate causality model to arrive at the "mitigation hypothesis":

The hypothesis of this study is that the income retarding influence of population density growth can be mitigated by interactions between structural and institutional changes, leading to economic growth. The mitigation process, in theory, occurs through greater efficiency of markets determining factor utilization. This leads to per capita income growth.

The contributions in this study are:

1. The empirical specification of the topic is improved to eliminate the erroneous and inconclusive results in the literature. This study explores the structural and institutional connection between population densities and realized economic growth.
It is suggested that population density effects prevent efficient allocation of resources and reduce the ability of markets to function efficiently.

2. An analysis shows that appropriate institutional and structural change can substantially reduce, or mitigate these influences. Thus, in addition to the technical improvement and availability of capital goods, appropriate institutional and structural changes are important to economic growth in LDCs. Appropriate institutional and structural change is a major explanatory factor in the escape of LDCs from LDC status, according to the findings presented in this study. Those countries which have made their economic structures and institutions compatible with their rising population density levels, have reduced or "mitigated" the population density constraints, and have achieved economic growth.

1.3 Organization

The remainder of this study is organized into several chapters:

1. Chapter 2 reviews the relevant literature of the different fields of study brought together in this study.

2. Chapter 3 contains a description of the mitigation hypothesis.

3. Chapter 4 describes the analytical framework, the aggregate production function, and how an alternative to the usual Cobb-Douglas type may represent an empirical improvement.

4. Chapter 5 discusses the data set, the variables, and relevant econometric issues. Then follows a description of the empirical tests employed and the results obtained.

5. A brief conclusion chapter, followed by various appendices and the bibliography completes the study.
CHAPTER II
THE LITERATURE

2.1 The Topic

The topic of this study involves the theoretical and empirical discussion of the economic effects of population growth and the intermediation of institutional and structural changes. The quality of the intermediation determines the existence of the "mitigation effect", defined briefly in the introduction, and discussed at length in the next chapter.

The theoretical literature review is therefore comprised of a brief historical review of population issues, economic development history, and the relatively recent literature on institutional and structural change. The historical format explains the previous neglect of population concerns and institutional and structural analysis in economics until recently. Recent work on institutional change provides a basis for extension to the hypothesis of this study.

The empirical literature is focussed on the effects of population density growth on national per capita incomes, as shown in a number of studies. The review of the theoretical and empirical literature sets the stage for the hypothesis and empirical testing of this study.

2.2 Historical Overview

2.2.1 Early Views on Population

The theoretical literature on this topic is diverse, evolving as shifts in interest and emphasis have occurred. Early discourse on population density growth saw it as problematic. Malthus saw a tendency for populations to grow at a faster rate than the means of subsistence.
Ricardo perceived a relative fixity of land resources. With Mill, however, there came some faith that technology could overcome these problems. By the time of Marshall and the Neoclassicists, population growth was seen as a neutral element, assumed to be relatively constant over time. Consequently, the growth models developed (Neoclassical, for example), were equilibrium models by construction, with factor prices automatically adjusting appropriately to factor proportion changes. Radical change in the population growth rate, provoking prolonged factor disequilibrium through the disfunction of the Neoclassical adjustment mechanism, however, was not within the paradigm of these models.

2.2.2 Early Development Economics and Population

Early growth economists, then, were not duly concerned about population growth. Even as Lewis (1954), Rostow (1960), Fei-Ranis (1961), and Jorgensen (1967), among others, began to consider the case of LDCs, where population (in the form of surplus labor) was an issue, the growth paradigm remained the same. Whether populations grew faster or not, capital formation remained the focal growth source and primary concern, according to the growth model prescriptions.

2.2.3 Population Economics

Whereas growth and development economists dealt with the issue of population as an exogenous factor, the new field of population economics began to consider population issues as endogenous also.

---

1. Meier (1984) p.211: "But development economists have generally treated population as outside their analytical domain as an exogenous variable and as of only indirect significance to the central issues of development."
However, the union of demography and economics was an uneasy one. Schultz (1968)\(^2\) notes: "The neglect of population analysis by economists is an odd bit of intellectual history". Liu (1973)\(^3\) quotes from:

Lorimer (1957)

"... the marriage of demography and economics while both were immature ... resulted in a stormy and unfruitful marriage. Both dynamics of interactions among economic factors and the dynamics of vital trends in relation to population structure were long neglected in a hasty synthesis."

D. Kirk (1968)

"... dissatisfaction with the Malthusian approach led to the divorce of demography from economics and to a continuing suspicion among some economists that demography over-estimates the force of population growth and that population control in underdeveloped areas is in some way a diversion from and even a threat to the central purpose of economic development."

On the issue of population effects on income, two opposing schools of thought developed, each critical of the other’s work\(^4\). This evolved into a "pro and con" controversy regarding the economic effects of population growth. While making an interesting contribution to the saga of economic history, the situation did little to settle the issues. But it does leave researchers room to say that no definitive conclusions have been reached concerning population growth effects on economic development.

---

2. Schultz (1968) p.60
3. Liu (1973) p.33
4. disagreement between several generations of economists:
   1) Coale and Hoover vs. Boserup and Clark—in the 1950's
   2) Leff and Enke vs. Simon and Bilsborrow—in the 1960's and 1970's
2.2.4 Population and Economic Institutions and Structures

Making the connection between population density growth and structural and institutional change, Clark (1967), Boserup (1965, 1981), North and Thomas (1973), and Binswanger and Ruttan (1978) suggested that population density growth may necessitate, induce, or correlate with changes in institutions. This led to the assertions of Boserup, Clark, and Simon, who suggested that population growth may be beneficial. This occurs, they said, because population density growth leads to technical innovations, and hence to economic growth. North and Thomas, and Binswanger and Ruttan, instead of emphasizing the supposed benefits of population growth, analyzed the supply and demand forces through which institutions change, to accommodate the changing income streams resulting from population growth and technical change.

In brief commentary: the foregoing literature implies that population density growth is beneficial because of the technical and institutional changes which raise per capita income levels. The fallacies inherent in the argument are threefold.

1. The notion that an adjustment to structural disequilibrium represents an advance over a case without the structural disequilibrium is not necessarily true.

2. Increases in income associated with the increased population density, technical/institutional change sequence are nominal increases. Portions of that increase are certainly associated with an increasing monetization⁵ of value.

---

⁵. economic exchange using money rather than goods as a measure of value
3. Potentially adverse changes in income distribution are likely. The divergence between nominal and real per capita income gains, if any, and the welfare implications of economic growth, with respect to the broad definition of economic development, is an empirical question not addressed in this study.

In their more recent work, Spengler (1956)\(^6\), Kuznets (1965)\(^7\), and Schultz (1968)\(^8\), disagree with the viewpoint espoused by Clark and Boserup. They suggest that high levels and growth rates of population density lengthen the transition to economic development, because high levels and growth rates of population density require more extreme institutional and structural changes.

---

6. Spengler (1956) *World Population*, chapter—"Agricultural Development" p.390, in reference to Boserup's statement that one beneficial innovation caused by population growth is agricultural intensification: "In semi-arid areas the process of intensification would overstep inherent environmental limits, lead to deterioration, and a lowered carrying capacity."
p.115: "It has been said "faster growth of the labor force leads to faster technical progress, and faster growth of output per worker" This argument overlooks the fact that technical progress depends not merely upon research and replacement investment but on the whole set of forces that result in technical progress, some of which are inversely related to the rate of population growth."

7. Kuznets (1965) *Economic Growth and Structure* p.389: "Colin Clark, for example, postulates that rapid population growth may, by stimulating transformations in farming systems, have a favorable impact on economic development, and Boserup suggests that advanced agricultural techniques have only been adopted under compulsion of a slowly rising population density. Both Clark and Boserup hold that population pressure is likely to expand world food production."
Kuznets (1965) chapter—"Reflections on Economic Growth" p.137: The discussion "on the positive contributions that population growth may make to the increase in per capita product has been pursued largely against the background of the developed countries ... the whole structure of their (LDC) society is unfavorable to the adoption of many potentials of modern technology, since it necessitates major changes that no living society can absorb within a short period."

8. Schultz (1968) p.57, on Boserup's hypothesis: "... gaps in the underlying economic logic ... the thesis is in general wrong".
2.2.5 Economic Development Theory: Economic Institutions and Structures

Institutional change as an economic growth concern was initially considered outside the realm of economist's involvement, though recalcitrant institutions were sometimes seen as hindrances to economic growth (Johnston, 1967). They were discussed by the prerogative of senior economists in more philosophical moments, in terms of human values, social mores, and political and social organization as non-economic factors affecting production. In later work, however, Kuznets (1965) and Lewis (1954) in particular, increased their discussion of institutions, stressing their importance in detail. But there has been some lag from their work to the comprehensive study of institutions in development.

Attempts by development agencies in the early 1950's to implement institutional change (e.g. land reform) were less than successful. Blase (1971) attributes this to the "layering of institutional constraints", where the institutional constraints are interrelated, such that the removal of only one barrier was not effective. Hence, emphasis on land reform, once thought to be a panacea for transforming traditional agriculture, was lessened.

9. Binswanger and Ruttan (1978) p.3: "With few exceptions, technical change was treated as exogenous to the economic system, and institutional change was not dealt with at all in formal growth theory. "North and Thomas (in Binswanger and Ruttan (1978) p.333: "There is a tendency to abstract from institutional change or to treat institutional change as exogenous to the economic system."
The superficial attempt at institutional change through imposed land policies was succeeded by an emphasis on capital intensification and industrialization that continued through the 1950's into the 1960's. These had mixed success, and left unanswered questions.10

Dissatisfaction with the less than successful capital-intensive economic growth policies produced some criticism. Kuznets noted:

"... the concentration of economic analysis on short-run problems narrowed its focus, leading to an oversimplification of relations of economic variables. Variables were considered in isolation from others which were treated as noneconomic or exogeneous. Institutional variables were taken for granted."

Work such as that of Nelson and Leibenstein, implying a threshold effort of saving and capital accumulation required to escape a low level economic equilibrium, was interesting as a theoretical model, but did not prove practically instructive. It was criticized as being improbable because of the assumptions about relations between population growth rates and saving rates necessary to operationalize it. Analysis of the capital intensive economic growth policies led to the analysis of economic structures, and the discussion of the importance of a time element in the process of economic change. While the Rostow "take-off theory" was later seen as limited and to some extent erroneous11, the inherent notion of a time dimension required for the growth process was important, though it was insufficiently acknowledged.

10. McKinnon (1973): "Can one explain why economic wealth is high or rising in a fairly pervasive way in some countries, while other countries languish?... Various views have been found wanting both in empirical explanation and as guides to policy."
11. Kuznets (1965), on Rostow's Take-off Theory, chapter—"Problems in Comparisons of Economic Trends"
For example, Hla Myint suggested:

"Rostow's take-off theory at least suggests by means of historical examples that this effort has to be sustained for two or three decades during which fundamental reorganization in the institutional and productive structure should be taking place."12

The theoretical discussion of institutions disappeared for a time in economic development discussions, only to reappear recently in another area of economics. The context has, however, been changed. Institutions are now defined as the rules of governing specific activities, rather than a framework of cultural values. Binswanger and Ruttan (1978) have synthesized and reformulated the literature of induced innovation and collective action theory. They note that in economics, the formal analysis of institutional performance has evolved primarily out of an attempt to understand the implications of market structure for the behavior of the firm. Schultz (1968) and Powelson (1972) approach the concept of the supply and demand for institutional services.

Other, differently oriented economists, e.g. North and Thomas (1973), see institutional changes evolving out of political theories of the State. Institutional changes (including laws, contracts, accepted behavior patterns of economic agents) occur as fiscal pressures force governments to revise policy. For example, institutional change in property rights is instigated by fiscal pressure upon government.

The effect is to reduce public-private differentials in gains from innovation. Despite the fact that the mechanics of these changes is not well specified in their models, the change in concern from the sectoral structure of an economy, to the rules or laws organizing those sectors, represents a closer inspection of economic behavior. Also in terms of political state action, Olson (1982) points to the institutional connection to the historical erosion of the strength of nations. Collective action at the national level becomes more difficult as traditions become older and more entrenched. As society becomes more differentiated with special interest groups, institutional change at the national level becomes more difficult. This explains the variation in institutional effectiveness that is a significant determinant of per capita income differences across countries.

Even though structural change became an important applied and empirical topic, its exact function and interconnections with economic development, economic institutions, and population growth, took some time to be fully explored. Kuznets' notes some general features linking structural and institutional change:

1. "... a rise in capital formation proportions; redistributions of population and the labor force, with shifts from agriculture and the countryside to nonagricultural sectors and the cities".

2. "... changes in the organizational units; and a transformation of values. These changes do not occur in a vacuum; they are made in societies that usually have a long tradition of the premodern economic organization and social structure, and they must be directed by agents with the power to overcome resistance and incur necessary costs."

Perhaps one of the problems in integrating the various relevant areas of the literature has been that the discussants of structural change have come from a macroeconomic background of interest (generally international trade and development), while discussants of institutions have, until recently, come from a theoretical microeconomic background. The time it has taken to bring together the theoretical constructs from different areas of interest has prevented a comprehensive formulation of the LDC development context until recently.

On the empirical side, attempts at empirically testing the contributions of institutional and structural change have been few, and broadly socio-political in nature (e.g. Adelman)\textsuperscript{14}.

2.2.6 Recent Growth Economics: Theory and Practice

The emphasis on particular economic growth sources varied in cycles, with the prevalent focus of the theorists of the day. At one point, institutional, structural, and entrepreneurial forces were seen as exogenous non-economic inputs to production. Later as technical change became the topic of the day, the institutional, structural, and entrepreneurial elements were incorporated into the concept of technological change. These elements, by and large, were overshadowed by the predominant interest in the technical advances in capital equipment.

\textsuperscript{14} Adelman (1968) uses variables such as indices of political stability, social tension, etc.
The vernacular definition of technological change has eroded to equate with technical change, defined as improvements in the efficiency of capital goods. The "non-economic" factors composing the bulk of the production function "Residual" measuring technological change have often been disregarded.

When capital intensive growth theory failed to produce success in generating economic growth in all cases, development programs in the field turned to more pragmatic and case-by-case analyses of economic conditions. The notion that institutional, structural, and entrepreneurial change might be endogenous has recently been advanced, but the determinants of the process have only been speculated upon. As an extension of the work of Kuznets, Lewis, and others of their generation, it was found that the management of structural change and institutional infrastructure was important. From this work there has been research on the nature of structural disequilibrium and the role played by relative factor abundances. Another research thrust was a disaggregation of the sources of growth analyzed through production function efficiency changes (growth accounting Residual analysis). These two research orientations are now discussed.

15. The Residual, in the "growth accounting" sense and the sense used here, is not the residual or error term discussed in econometrics, but includes also the contributions of the intercept which represents the contributions of technology in the "growth accounting" terminology. The growth accounting Residual represents that part of the dependent variable which remains unexplained after the production function variables are accounted for. In theory this unexplained element represents the efficiency parameter (of a Cobb-Douglas production function) incorporating technical and institutional/structural change, as well as the contribution of unmeasured factor inputs, such as those of institutions.
2.3 **Definition and Measurement**

2.3.1 **Factor Abundance and Proportions Problems in Growth Literature**

There has been a general consensus that some kind of structural disequilibrium has been responsible for the failure of LDCs to experience economic growth. But there has been difficulty and dissention among economists in finding an acceptable definition and approach to the problem. Issues concern concepts of factor equilibrium, balance, sufficiency, and proportionality. Further, they concern the optimality of factor quantities or growth rates in production, relative to per capita income level and rate of economic growth. Earlier discussions concerning the sufficiency or excess of any one factor have given way to the study of factor proportions and Neoclassical quantity-price adjustments as being the important issues.

One source of dissention between demographers and economists came with the introduction of the "Optimum Population" concept\(^{16}\) which dissatisfied some economists. The notion involved a concept similar to the Golden Rule in growth theory\(^{17}\), but was defined for a point in time. The "optimum population" was defined as maximizing the standard of living, (the average product of labor) for a given state of technology (other production factors held constant), and a given social-welfare function. The concept was introduced as economic theory was beginning to dynamize its models, and so was considered obsolete.

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16. Votey (1969) p.273: "... this is a subject that has been criticized frequently for various reasons as an impractical or inappropriate topic for consideration by economists."

17. Phelps (1961): In the Golden Rule approach, the objective is to maximize per capita consumption.
Furthermore, the population optimum theory was said not to be compatible with the Neoclassical Model. "Optimum" was perhaps an error in word choice, implying a necessary welfare judgment distasteful to neoclassicists.

Sources of contention aside, if "optimality" was defined as equilibrium in factor markets with respect to population level, then the optimum population concept would address concerns entirely analogous to those pursued by development economists. These concerns include balanced growth (in the sense of maintaining factor market equilibrium, not balanced sectoral growth), and equilibrium factor proportions, given technology. All of these have in common an "optimal" or best development strategy, with respect to factor availability and level of technology. What was ignored by critics was that the essential core of the optimum population discussion was a structural equilibrium concern. It asked the question: "given technology and the existence of a capital stock, what would an optimum population be to insure factor market equilibrium?"

18. Bizien (1979) p.28-29: notes that the Neoclassical model has the ambiguous characteristic that living standards improve indefinitely with population declines.

19. Bizien (1979) p.387: "There are numerous difficulties in defining the concepts of overpopulation, underpopulation, optimum population, population pressure, and population problems. Over-and under-population imply that there is some more desirable population size for the given area, possibly the optimum population. But optimum population may be calculated by a variety of sometimes conflicting criteria including standard of living, productivity, and national strength. Furthermore, optimum population is an extremely elusive proposition in a dynamic world where economic, social, and technological changes require a constant recalculation of the ideal."
Eckaus' (1955) work rephrased the same structural equilibrium concern and inverted the question. "Given population levels and growth, what is the optimal assignment of available capital amongst economic sectors?" He speaks about "the factor proportions problem". The LDC situation is characterized by Eckaus and others as having "factor proportions problems". This means that for a current state of technology and choice of techniques\(^{20}\), factor prices are in disequilibrium with factor quantities. Productive factors are not supplied in optimal or equilibrium proportions to the production sectors where they would be most productive.

Complicating the factor proportions problem is what has been called in the literature, "population pressures". Population pressures\(^{21}\) aggravate the factor proportion problem by making capital inputs relatively scarce, with respect to equipping a growing labor force. The concern for optimality of population is thus related to the concerns of resolving a factor proportions problem that prevents the rise in living standards sought for economic development. If population growth were determined solely by the demand for labor, given the prevailing growth of capital, then no particular attention to the population factor would need be given. It is only because in LDCs especially, population growth is determined by other factors\(^{22}\), that there needs be special attention given to it.

\(^{20}\) Sen (1972) addresses the issue of choice of technique in LDCs.
\(^{21}\) Bizien (1979) p.387: "The concept used in this chapter is that of population pressure; the concern is with places where, under existent land use and technology and at the present stage of development, there is pressure on the land . . . with the population inhabiting these places."
\(^{22}\) e.g. children as social security insurance
If population growth creates a disequilibrium in production relations, a factor proportions problem, an appropriate question is: what means might be taken to mitigate this problem? Adjustments to these disequilibria play a role in mitigating the interrelated population and factor proportion problems. The concept of mitigation in this study might be thought of as pertaining to "efficiency factor adjustments to solve market disequilibria". Through a variety of institutional and structural changes, some "optimal", "balanced", or "equilibrium" production relations conducive to economic growth are attained.

The indeterminacy of a solution for LDC development problems results from the essential "second best" nature of LDC economic processes. In a first-best world, Neoclassical adjustment mechanisms assure an optimal growth path with instantaneous adjustments to factor quantity/price relationships. It is because LDC economies are characterized by disequilibria in factor markets that development practice is so ad hoc, although guidelines to approach second best solutions are being sought. The resolution of both the multi-aspected "factor proportions" problem (term used here to characterize the general discussion of market disequilibrium for factors), and the influence of "population pressures" is approached in the hypothesis of this study.

23. Lipsey, R.G. and Lancaster, K.J. (1956)
2.3.2 Finding and Measuring Sources of Economic Growth

Through the empirical "sources of growth" analysis by Denison (1967) of the American and European economies, and from field experimentation, the sources of growth literature grew to include technological advance and industrial scale economy concerns. The empirical work on "growth accounting" has suggested that factors other than capital accumulation have contributed to economic growth. The further use of the production function to isolate institutional, structural, and entrepreneurial forces was undertaken by Abramowitz (1956). The concept of the production function Residual capturing these forces was the take-off point for some path-breaking work by Solow (1957) and Denison (1967).

Solow used the Residual of an aggregate production function for a time-series of American manufacturing to show that a large share of economic growth was attributable to sources other than capital and labor inputs. This source, en masse was identified as technology.

Denison (1967) extended the use of the Residual to disaggregate the economic growth in selected developed countries into various factors. The results show the proportion to which several heretofore "non-economic" factors are responsible for economic growth in these countries. The most important of these include scale economies, education, structural change in the locational emphasis and distribution of production from rural to urban (from agricultural to manufactured), and increased trade in manufactured goods.
2.4 Literature Focus: Theory

The theoretical and empirical relationship between national population densities and per capita incomes can be categorized by their effects upon the availability of other factor resources, within an implied production function framework.

With rapid population growth, there are a number of concerns that might be thought of as partial effects upon income and per capita income:

1. Land Resources—There has been a long-standing concern regarding insufficient land resources for agriculture or living space, that is, the Malthusian-Ricardian notion of population growth outstripping food supplies produced on fixed land resources. This has been discounted by neoclassicists, in whose world factor substitution and technological progress supposedly eliminate problems of resource fixity. However, in the real world, factor supplies are not always assured in the short run. The "pressure" of population density is such that short-run, long-run differences become more crucial. Both Spengler and Kuznets note that land resources can become scarce with respect to rising populations, even without the other underdevelopment problems of LDCs.

24. "pressure" of population density—the accepted literature term
25. Spengler (1956) Population Theory and Policy p.303: "... when a nation's population density rises, it is likely that its land and other resources are in nearly full use, with the result that economic progress tends to be restricted by the increasing scarcity of these agents of production."
26. Kuznets—Economic Growth and Structure (1965), chapter—"Reflections on Economic Growth" p.137: "... even in the advanced and developed economies, population increase means further pressure upon limited natural resources."
2. **Capital**

1) The diversion of income from saving to consumption, reducing the additions to capital goods or investment in human capital, occurs in one case through the dependency effect. This is defined as the increase in the proportion of the non-working population. It is brought about by the age-structure changes associated with rapid population growth. When household size is increased, income expenditure is diverted from saving to consumption. Reduction of the saving rate implies investment reduction. This was discussed by Leff (1969)\(^{27}\) and later by Gupta, who found Leff's results understated. Mason (1981)\(^{28}\) added the "rate of economic growth effect" to the model. It showed that the net effect of dependency and rate of economic growth determine the saving rate, in addition to the level of income. Enke (1966, 1971) and Mason and Suits (1978) extend the previous savings and investment versus consumption trade-offs. They equate the value of averted birth to the social costs of population growth.

2) Another population growth effect concerning capital accumulation is that as the saving rate declines due to the dependency effect, the remaining savings is diverted from capital deepening to capital widening as a result of the increasing labor force\(^{29}\). Furthermore, with rapid population growth, the composition of investment shifts, with increased expenditure on social capital, due to increased youth dependency.

\(^{27}\) Leff (1969) and Mason (1981)
\(^{28}\) Gupta (1975) pp.358, 371
\(^{29}\) Power (1955), Kuznets (1965)
3) Aside from the effects on capital accumulation, the growth of population directly affects the capital/labor ratio by eventually increasing the size of the labor force.

3. Efficiency Factor

1) "Structural problems" is a concept sometimes used rather vaguely. It essentially recognizes the necessity to change the distribution of factors and production processes between different sectors of the economy. Such structural change affects the production function efficiency parameter. Rapid population density growth affects the locational distribution and the abundance of labor with respect to other production factors. It also affects the allocation of production between consumer goods, and export or capital goods.

2) "Institutional effectiveness" is a determinant of development affected by population density growth. The use of this concept has also been sometimes vague, and its connection with economic processes rather obscure. A decline in the effectiveness of existing economic institutions (as a factor of production determining the management of production and exchange) can be noted with increasing population densities. For example, a barter economy may no longer be an effective mode of organization as an exchange system.

Eckaus (1955): "factor proportions problem"
3) Suggestions of positive returns to population growth typically cite potential "increasing returns to scale in market size". This can be dismissed for most LDCs, where existing large populations do not imply scale economies in market size for additional population growth, according to some authors.

The population growth rate affects the relative proportions and qualities of capital and labor inputs, while population density determines the population effects upon the other factors noted. The scale effect depends upon total population as a measure of market size.

The reason for the discussion of these population growth effects upon production parameters is that empirical results biased by deficient econometric modelling have been used to justify erroneous theoretical arguments. It is therefore important to identify the expected theoretical effects of population growth before discussing various empirical treatments.

2.5 Empirical Literature

Population effects upon all of the factors of production taken together, might be thought of as representing the sum or total effect of population variables upon per capita incomes. In this context, production function analysis is the implied theoretical foundation.

32. Simon (1981)
33. Kuznets (1965), Spengler (1956)
The limitations of the production function in representing all aspects of production have long been recognized. Its appeal has been its ability to mathematically model the contributions of the major inputs of production, capital and labor, and to analyze the substitutability between them. Though accepting the theoretical foundation of the production function in determining the effects of various factors upon income generation, interest here lies in the partial regression relationship between income and population variables. Theoretical speculations differ on whether this relationship is positive or negative across countries.

The temptation to restrict the already limited production function model to bivariate testing of the two variables of interest, as is done by some of the authors cited, incurs specification error, biasing the results.

All of the references noted here study cross-section samples of countries to analyze income/population characteristics. The first group is explicitly empirical, making no attempt to relate to a theoretical framework such as the production function. Simon and Browning test the relationship of national income\textsuperscript{34} to population characteristics, using a bivariate regression specification.

\textsuperscript{34} Aside from the interpretation of income per capita, with its functional form implications, and its usefulness in standardizing incomes for country population size differences in a cross-country sample, the coefficients yielded by the use of income and income per capita can be compared in the regression estimation. For regression interpretation, a partial regression coefficient of one when income is the dependent variable is equivalent to a coefficient of zero when per capita income is the dependent variable.
The members of the second group use a production function theoretical framework, from which they estimate a production function form. They then modify it to include additional variables for testing, with varying degrees of departure from the theoretical framework.

It is interesting to note the rationalizations of the authors for the methodological postures they take: either self-justified license, strict rigor, or a middle ground, referring to the theoretical framework, then proceeding with modifications.

**Group 1: No Theoretical Framework**

1. Simon (1980) regresses income growth on population density and gets a positive regression coefficient.

There are, however, some reasons to question the validity of this result:

1) the regression is underspecified. Income growth is dependent upon additional factors whose omission affect the result.

2) by not controlling for income level, in a cross-country sample of growth rates, bias from heteroskedasticity results.

35. Correction for heteroskedastic bias: While growth rates are calculated with respect to initial levels per country, across countries, percentage units vary in absolute magnitude because of different initial levels. Growth rates can be standardized with respect to a sample mean level. This notion is tested in the empirical section of this study. For now, it is noted that this idea explains some seemingly perverse results noted by a number of authors using growth rates in their regression specifications, apart from the production function framework for which growth rates are defined and derived as a mathematically appropriate form.
The resultant population coefficient tends to the positive, since some of the LDCs with high population levels may have begun to experience income growth at higher rates than developed countries, which have high income levels, but have reached a growth plateau.

2. **Browning (1982)** initially does a bivariate regression of income growth on population growth. In following regressions he adds investment and then exports as independent variables. He obtains a weakly positive population growth coefficient. This is to be expected, however, since he also does not control for income level in the cross-section growth rate sample. In addition, in per capita income terms, his result implies a negative relationship.

3. **Chenery and Taylor (1968)** do an empirical analysis sans theoretical framework, showing regressions determining the sectoral shares of product in a cross-section sample. They compare the cross-section to the time series results to determine the similarities between historical and cross-country patterns. For labor data they use population figures. The share of gross fixed investment as a share of GDP is the proxy for capital stock. Income is stated in per capita terms. Their results confirm the importance of structural change in the growth process.

**Group 2: Production Function Framework**

All of the authors in this group use a similar cross-country regression specification derived from a production function.
Variation in their results stems from differences in the sample used, the modifications in which other variables are added for testing, and in one case, the choice of production function specified.

1. Thirlwall (1972) derives his regression work from a production function theoretical framework, and estimates a Cobb-Douglas growth rate specification. He purports to add the capital growth rate to the population growth rate (differing from Simon's use of population density). But careful inspection of his study, and a check of his sources, shows this variable to be investment growth rather than capital stock growth. As an independent variable determining the rate of income growth, the addition of the investment growth variable improves the specification. Regressing GNP on the population growth rate, the population coefficient is positive, but less than 1, implying that the per capita income growth effect is negative. Regressing GNP/P on the population growth rate, the population coefficient is negative, but insignificant, according to his results.

2. Hagen and Hawryshyn (1969) derive their cross-country regression work from a production function theoretical framework. They estimate a Cobb-Douglas growth rate specification, to show growth variations across countries. They use investment data as a capital proxy, acknowledging the limitations of this proxy. Their labor force input was estimated as the growth rate of the product of the population level and the labor force participation rate.
Their results are generally unsatisfactory, from the point of view of information expected to be gained from production function estimation (precluded by the capital stock proxy). In addition, the regression form does not measure population effects on income in per capita terms, the preferred development indicator.

3. Humphries (1976) works from a production function theoretical framework to show growth variations across countries. She uses the Hagen and Hawrylshyn (1969) data set to re-estimate their work using a CES production function, noting the limitations of their methodology in using a Cobb-Douglas form. She also uses the investment share of GDP data as a capital proxy, without apologizing for the limitations of this proxy. She further deviates from the usual production function specification by including imports as a factor of production. Assumably following Hagen and Hawrylshyn, the labor force input she uses seems to be estimated as the growth rate of population times the labor force participation rate. Her results show an improvement over Hagen and Hawrylshyn's estimations.

4. Robinson (1975) derives a cross-country regression from a the production function theoretical framework. He estimates a Cobb-Douglas growth rate specification, to show growth variations across countries. He also uses investment data as a capital proxy, acknowledging the limitations of this proxy. The population growth rate is used as a proxy for the labor force growth rate.
He estimates three models, the basic Cobb-Douglas model, a two sector model, and a model with a foreign exchange constraint. He notes rather unsatisfactory results with respect to the labor input, while the investment coefficient was significant at the 5 per cent level.

5. Hazledyne and Moreland (1977) use a cross-country production function structure in a log-linear Cobb-Douglas production function estimation form to model cross-country income growth variation. The labor input is the working age population. As a capital stock proxy they use total energy consumption. This is curious. Ignoring the question of whether the variable is a good proxy for capital stock, one would expect that in a cross-country model, a per capita figure would be used to control for country size. Their results for the production function were not completely satisfactory. Of interest, however, is their test of the low-level equilibrium trap, showing some indication of its existence, over a cross-section of LDCs.

Commentary: Empirical Literature on Income/Population Relationships

This study questions the specification of the above results. It proceeds to test the relationship between population densities and per capita incomes across countries, using a better specification to derive some important implications from the results.

If, as suggested here, assertions of a positive relationship between per capita income and population variables in LDCs are the result of mis-specification, and the relationship is indeed negative, what ramifications does this have for economic growth possibilities?
If investment is the *sine qua non* of economic growth, as former development theory suggested, what then are the chances for economic development in LDCs, where high population densities and growth rates inhibit capital formation?

In this study, the "sources of growth" concept will be extended, with some necessary modifications to LDCs. In contrast to Denison's work in developed countries, for application to LDCs, scale economies become a less important factor. Other factors include the lack of effective institutional infrastructure, preventing the realization of any potential scale economies. Education must be measured differently. Institutional and structural change become more important. The hypothesis is advanced, that in the course of constituting conditions for economic growth, they mitigate or lessen the negative influence of the high levels of population density and population density growth rates in LDCs.
CHAPTER III
HYPOTHESIS

"Without a more refined analysis of the causes and consequences of population growth and more empirical studies of modern developing countries, it is difficult to devise policies that might mitigate the adverse effects of future population growth."—Meier (1984)

3.1 Background

Historical observation shows that typical LDCs experienced disruption of their social, economic, and political institutions through their exposure to colonialism and early development efforts. Of major importance was the introduction of modern public health techniques. In particular, improved sanitation and water supply systems, along with the control of smallpox, yellow fever, and malaria, drastically reduced mortality. This led to rapid population density growth in LDCs.

Early development efforts typically sponsored by former colonial powers and later by international agencies, focussed on importing capital-intensive technology. The failure of these efforts to generate economic growth and development led to the search for alternative development strategies. One such formulation involved the search for factor optimality. Others spoke in terms of correcting factor proportion problems or structural disequilibria. Regardless of the way the problem was approached, what was looked for was a way to "mitigate" or reduce the influence of the adverse economic consequences of rapid population density growth.
It is the purpose of this study to show that the contributions of institutional and structural change to the growth process are a source of mitigation in reducing the constraining influence of population density on per capita incomes, as seen across countries. The mitigation scenario is constructed by deductively uniting a number of definitions and results from economic development experience:

**FACTS**

1. Per capita incomes levels in many LDCs have failed to increase substantially, even with the monetization that should increase the reported percentage of real incomes, and even with the availability of foreign aid.

2. Population density increases pose problems in terms of absolute shortages of food and basic needs in many LDCs.

3. Some few LDCs have overcome economic problems that include high levels of population density (e.g. Korea, Taiwan).

**IF**

**STYLISTED FACTS**

1. High population density levels and growth retard economic development through a number of mechanisms.

2. Structural and institutional change contribute to economic development.

**AND**

**ACCEPTED DEFINITIONS**

1. Effective institutional change maintains market efficiency otherwise negatively affected by increased population densities.

2. Effective structural change improves the optimal allocation of factor resources, given their changing proportions.
THEN the influence of population density is lessened through effective institutional and structural changes, to bring about economic development. This process is called population density "mitigation". The validity of the mitigation concept is tested in the empirical section of this study.

The mitigation process in this study is conceptualized as the institutional and structural changes that accommodate changes in population density increases. The mitigation process, through effective institutional and structural changes, can bring about economic development given the growth rate of population density.

The presentation of the mitigation concept and how it is actualized is followed by a discussion of the relationship between institutional and structural change, and the functions they perform in the development process. Then the history of successful development programs becomes the basis for the selection of "mitigating variables". These are to be tested empirically, individually and as a group, where their effects are measured through the production function efficiency parameter.

3.2 The Mitigation Concept

This study suggests that the key to "mitigation" lies in the ability to change economic institutions and structures. Rapid population density growth has reduced the effectiveness of existing institutions and structural characteristics, and prevented the success of the early development programs to some extent.
By reducing the economic influence of increased population density, the effects are "mitigated" by increasing the effectiveness of economic institutions and structural characteristics. The change of institutions and economic structures is included within the broad definition of technology, but current usage has narrowed the concept to refer mainly to the technical improvement of capital goods. Careful consideration of the context of economic production suggests that technology comprises more than technical change. It is the purpose of this study to revive the full definition of technology to include changes in economic institutions and structures. It proposes to show the importance of these changes to economic growth.

Where countries can effectively change the institutions and the economic structures whereby their resources are allocated, the income growth inhibitions coming from increased population densities can be "mitigated". Policies aimed at stimulating economic growth make modifications in institutional arrangements to direct flows of resources and entrepreneurship into channels that maximize economic growth. With appropriate institutional and structural change, negative population density effects have less influence. Change in production function efficiency occurs through increases in institutional effectiveness and structural efficiency. The institutional changes are not endogenous in the sense of being "induced" in an automatic way, such as via the "invisible hand", but rather depend upon the actions of economic agents.

1. Binswanger and Ruttan (1978) p.336: "The same sequence that North and Thomas observed in European development, where institutional change occurred in response to changes in labor-land price ratios, has been reported in contemporary developing countries."
The characteristics of these changes are dependent upon country and culture specific initial conditions.

Empirically, the contributions of technology in developed countries is measured in the growth accounting work of Abramowitz (1956), Solow (1957), and Denison (1967). In an aggregate production function theoretical framework, production function efficiency characteristics indicate institutional/structural variation across countries. The analysis of production function efficiency differences provides a supplement to the traditional Neoclassical view that differences in economic development between LDCs and "developed countries" are "a function of capital/labor ratio differences caused by technological diffusion lags". In this view, technological change is associated solely with technical improvements in capital inputs.

2. Park (1977) citing Nelson (1956)
   "... modern economic growth implies major structural changes and correspondingly large modification in social and institutional conditions under which the greatly increased product per capita is attained."
Postwar Economic Growth (1964) chapter—"Findings and Questions" p.127: "... trends in the recent study of economic growth have pointed up the importance of social and political institutions as distinct from traditional economic variables. ... technological progress also implies that large weights should be attached to the institutional and social arrangements that govern the methods by which knowledge and the purely economic factor are used. ... the main question in the economic growth of underdeveloped countries is how to make the institutional changes that would permit effective functioning of the purely economic variables, and do it without great human costs."
Summarizing, the hypothesis motivating this study is:

While increasing levels of population density inhibit the ability of countries to raise their per capita income levels, it is hypothesized that the constraints can be mitigated through appropriate structural and institutional change.

The description of how mitigation works via institutional and structural change follows.

3.3.1 Mitigation by Institutional and Structural Change

It is well known that literature from the biological sciences discusses the effects of population density growth in terms of the biological and behavioral effects of crowding. Economists extend this to consider the effects of congestion on the effectiveness of economic institutions governing economic transactions, and the distribution of the costs and benefits of innovation and entrepreneurship. The accepted view is that there are two cases in which institutional change is forthcoming:

1. where the effectiveness of existing institutions reaches limits comparable to production techniques reaching the limits of output.
2. where technical and structural change create the demand for new institutional forms to distribute the costs and benefits of those changes.
These statements respectively imply that adjustments to institutional effectiveness must be made in response to increasing levels of population density. The essential function of economic institutions is as a social contract for distributing the costs and benefits of technical and structural change, thus minimizing the private and social (external) costs of exchange. Theoretically, institutional changes can be made to mitigate or reduce the influence of changes in population density upon economic activity. Further, if the spatial distribution of population density growth is uneven, and its effects vary over economic production sectors, economic structural change may be important to the reassignment of productive factors amongst economic sectors and locales.

3.3.2 "Mitigation" in Terms of Institutional and Structural Change

In this study "mitigation" refers to the function of institutional and structural change in reducing the negative influence of increased population densities. Population growth causes factor proportion changes in production. Neoclassical growth theory predicts that when factor proportions change, factor price changes will occur to efficiently allocate resources via structural changes. Recent writers on economic institutions depict institutional change as a means of decreasing economic transactions costs, when factor proportions change creates economic disequilibria. Such disequilibrium was called "the factor proportion problem" by Eckaus (1955).
According to the mitigation hypothesis of this study:

1. structural changes in response to factor price changes act to maximize total factor productivity through efficient resource allocation: given an effective institutional environment.

2. institutional changes in response to factor price changes function to minimize the costs of economic exchange and distribute the benefits of innovation.

Effectively, the results of institutional and structural changes through the mitigation process work to decrease the emphasis upon land resources, and create an economic environment conducive to the pursuit of comparative advantage in production, given changed factor quantities and proportions.

Through "mitigation", both the issues of "the factor proportions problem" and "population pressures" discussed in the literature are addressed. Essentially, the solution to both of these problems through mitigation involves optimizing allocative efficiency through structural change, and maintaining the effectiveness of economic institutions, given the circumstances of population density. According to North and Thomas⁴:

"... the effectiveness of institutional change is measured as the reduction of the differential between the private and social costs of institutional and technological innovation."

In practice, this amounts to a reduction in economic externalities.

⁴ North and Thomas (1973)
Continuing in the North and Thomas line of thought: in an effective institutional environment, the private/social cost differential is reduced to an optimal level. The returns to investment are greater because of greater stability in the social and political atmosphere, and because of lower social costs and private risks. Effective institutions speed adjustment to new technology and population growth, by accommodating new kinds of economic activity and effecting appropriate structural changes.

3.3.3 The Relationship Between Institutional and Structural Changes

There is a simultaneous relationship between institutional and structural changes. They may follow or precede one another, depending upon whether institutional changes are used as policy instruments to induce technical change (e.g. tax incentives for research), or whether the institutional changes are de facto means to redistribute the costs and benefits of technical and structural changes. It is for this reason that institutional changes often accompany structural changes.

5. Powelson (1972), on effective vs. efficient institutions
6. Higgs (1980), "Urbanization and Invention" p.18: "... the following sketch of the developmental process is suggested. Fundamental exogenous forces—perhaps a restructuring of property rights or a broadening of markets set capital accumulation in motion; as a result the income level increased. Growth induced structural change, which in turn spurred technological progress, kept diminishing returns from retarding the growth process."
It is suggested in this study that what is called "structural change" in economic development literature is really composed of two parts:

1. the changing sectoral emphases, per se, here identified as structural change.

2. institutional changes, that is, changes in laws, regulations, contracts, etc. by governing, consulting, or entrepreneurial agents, who reformulate economic institutions to achieve a desirable (in terms of social interest or private lobbying power) distribution of changed cost and benefit streams.

**Structural changes** may occur autonomously as the result of factor proportion changes. For example, rapid population growth may cause migration and shifts in production emphasis between economic sectors. When structural change precedes institutional change, as in the case of rural-urban migration, there are two aspects of the migration flow:

1. the productive relocation of labor—a structural change

2. a potential of excess rate of flow (more migrants than jobs)—may cause institutional failure, requiring institutional changes.

This is discussed in Blase (1971)\(^7\) as "premature migration".

\(^7\) Blase (1971), on "premature" rural to urban migration
Institutional changes are made:

1. as a means of governing structural changes induced by population growth. For example, government sponsored land reform may be instituted to prevent excessive migration rates following rapid population growth. The purpose of this institutional change is to reallocate the costs and benefits to land ownership and agricultural labor, to insure efficient use of agricultural land.

2. as a result of policy to initiate appropriate structural changes, for example, government subsidy policies for certain economic sectors, such as export manufacturing. Export growth may require institutional changes in trade policy regulations and banking.8 Another example of institutional change used as a policy instrument is to assist in generating an agricultural surplus, where financial system and banking reforms may be made 9 to extend previously non-existent agricultural credit.

It is not suggested that the institutional changes made through government policy are always correct and effective. Changes in institutions by policy edict have sometimes shown perverse results, historically. For example, minimum wage requirements in urban manufacturing set by government policy to ease urban poverty, can induce rural to urban migration in excess of job availability. It can also stimulate industry to be more capital intensive than otherwise.

8. Paul Kuznets (1977): Export growth may require institutional changes in trade policy regulations, as noted in his Korean case study.

9. McKinnon (1973), on increasing financial effectiveness
These changes shift the distribution of labor and product from rural to urban sectors, in the course of changes in emphasis between production sectors. In time, further institutional change of labor relations policy may be made to correct unwanted structural change side effects that create disequilibrium in labor markets between rural and urban sectors. While sometimes institutional adjustments are erroneous in the short run, economic development depends upon institutions to approach effectiveness in the long-run.

3.4 "Mitigation": Analytical Measurement

Having discussed the theoretical explanation for the "mitigation" concept as a function of institutional and structural change, the next step is to consider how it might be measured and discussed within the context of an economic model. Institutional and structural changes are necessary in a "second best" world where production factor quantities do not respond automatically to factor price changes. In particular, human fertility in LDCs has not responded in many cases to economic disincentives in a "first best" Neoclassical sense. This is a source of factor market disequilibrium.

Other factors constant, the more rapid growth of labor implies an increased demand for capital (capital widening). In theory, capital accumulation is limited in LDCs by the effects of population growth, through the dependency effect trade-off between saving and consumption.

10. Binswanger and Ruttan (1978), on bounded rationality and satisficing behavior in government decision-making
If capital cannot grow, the effect upon per capita product growth will be negative. Even if, over a longer term, factor proportions could be changed (substituting labor for capital) to employ the currently excess labor, the implications would still be negative as far as increasing economic growth. In the absence of sufficient capital widening through additional units of capital, another way to maintain economic growth in the presence of population growth is to increase the production function efficiency factor, through appropriate institutional and structural changes. This "mitigation" policy is a partial short-run alternative to capital-widening, to make more efficient use of existing resources.

In contrast to the additive character of capital-widening (adding units of capital) "mitigation" operates through increasing the production function efficiency parameter over time, by multiplying the efficiency of each unit of capital or labor affected. Over time, with international economic development programs, one would expect cross-country production function efficiency differences to decline. Over time, within one country, production function efficiency parameters would be expected to increase.

In a given country, economic growth occurring through institutional and structural change must be conceptually separated from the growth occurring in the conventional sense, from the rise in the capital/labor ratio through technical change. Through increases in the production function efficiency parameter, composed of technical change and institutional/structural factor components, inputs are used more efficiently. The diminishing returns to increased labor are offset.
Thus the increased efficiency factor can be said to "mitigate" against the "negative" partial effects on output of the rapidly growing factor, labor. This can occur through labor-using structural change or improved labor market institutions.

The mitigation process describes the function of the composite institutional/structural change factor, of which the growth accounting Residual of the production function is partially composed. If an increase of this growth factor is found to mitigate against or lessen the negative influence of rapidly growing levels of population density, economies can grow even if the capital/labor ratio is not increasing. While this cannot be depended upon indefinitely, since the institutional technology cannot keep pace over time with an increasing population growth rate, it can give a mitigating effect, until population density growth can be controlled.

3.5 Mitigation Variables: History and Description

Having defined "mitigation" in the production function context, the next step is to decompose the mitigating production function efficiency parameter to disaggregate the variables that contribute to it. First, the variables must be identified. From the history of development programs it is possible to isolate a number of institutional and structural change variables. A number of these variables are selected for later empirical testing, representing the mitigation process.

Recent development work has brought ad hoc realization that certain policies might be beneficial for LDC development. Thus a "stylized formula" for structural change based on case studies of successful implementation of sequential "structural changes" has been developed.
However, a general theory of how and why these changes are effective has not been presented. These "structural changes" are in fact a combination of institutional and structural changes. The descriptions of the development process and prescriptions for generating economic growth have not discussed the relationship between structural and institutional changes and their joint effects upon production.

It is important to identify institutional and structural variables, as well as the effects of technical advance that are important to the growth process. The history of development programs based on these strategies follows the following sequential policy goals:

1. to create an agricultural surplus
2. to support import substitution manufacturing
3. to increase trade and exports based upon comparative advantage

Accompanying these phases typically are institutional changes:

1. land reform
2. trade policy reform
3. monetary, credit, and banking reform

These programs have been identified as growth sources in the development history of those LDCs which have begun to experience economic growth. They closely parallel those defined by Denison (1967) for the United States and Europe, although the time periods in which the changes occurred were vastly different. Denison's growth sources include:

1. increases in education
2. increased agricultural efficiency
3. increased proportion of non-rural labor
4. increased trade

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Oshima (1982), in his study of Japanese economic development, has confirmed the importance of these factors as contributors to Japanese economic growth. Paul Kuznets (1977), in his study of Korean growth history, adds the liberalization of financial institutions to this list. Based on the empirical analysis of growth by Denison, Oshima, and Kuznets, and their agreement on the basic sources of growth, those factors are chosen as the institutional and structural variables for the empirical section of this study.

The stylized "structural change" growth strategies show some success in generating economic growth for those countries implementing them. Institutional and structural changes are hypothesized to have mitigated the effects of rapid population density growth that occurred from around 1910 to the 1960s, increasing population densities markedly. They present themselves as prospective variables for empirical testing of the mitigation hypothesis.

1. **Rural to urban structural changes** are adjustments to the economic disequilibrium created by rapid population growth in LDCs, and the development of urban based industry. Induced migration is a structural change, the result of disequilibrium in the spatial distribution of economic factors and their associated production processes, given current institutions. The change in the dominant focus of economic institutions from rural to urban follows a change in comparative advantage and leads to economic growth.
Many of the offices, businesses, and industries responsible for economic growth are dependent upon the "central place" characteristics of urban areas. The creation of centers for institutional administration and the efficient geographical distribution of production is an important mitigation element. Rural to urban change shifts emphasis away from traditional agriculture to manufacturing, extending production beyond agriculture and other primary forms such as mineral extraction. The changing structural character of an economy implies a change in the institutions that govern its activities.

2. Agricultural efficiency increases, through the change from traditional to intensified agriculture mitigates population growth in two ways:
   1) by supplying more food for the larger population.
   2) to release labor to a growing industrial sector.

In addition to the structural change of sector productivity, increasing agricultural efficiency involves land tenure and labor contracts. Land reform in the early 1950's stabilized agricultural production by preventing excess premature rural to urban migration in the early stages of manufacturing and industrial development, and insuring the efficient use of arable land. As agricultural and industrial investment goods became available, agricultural labor was gradually freed for manufacturing and industrial employment.

11. Hoover (1948)
12. Blase (1971), on "premature" rural to urban migration
These are institutions mitigating against population effects by minimizing the transactions costs between labor, management, and ownership in agriculture. As an example, work in Korea and Taiwan has investigated the sectoral contribution of agriculture (structural), and the effect of land reform policies (institutional). It has been found that land reform can help to stabilize income distribution in the rural sector. During a period of structural change, appropriately implemented land reform can prevent excessive migration flows based upon overexpectation and lack of information, thus minimizing external costs. By stabilizing rural sector production, land reform contributed indirectly to the rapid increase in agricultural efficiency occurring later.\textsuperscript{13}

Agricultural efficiency is also increased through institutional changes complementary to technical changes. An irrigation project to increase agricultural output in an area may require the redefinition of property rights, labor contracts, and local law regarding water use and system maintenance, for the technical change of the water control infrastructure to be implemented. Land-augmenting technical changes both increase agricultural efficiency and reduce the dependence upon the land resources themselves.

3. Foreign capital has influences in changing the structure of production. Large inflows of foreign capital partially substituted for domestic capital in funding investment through the 1960's.

\textsuperscript{13} e.g. this coincides with the growth experience of Korea and Taiwan
Often this resulted in shifts of production emphasis from local to export orientation. This is a structural change in the composition of finance and production. At the same time, it requires institutional change in international contractual relations. There has, however, been some discussion to the effect that the pursuit of foreign capital has not had positive results in all cases.14

4. **Financial sector efficiency increase** through "financial deepening or liberalization"15, contributes to the development of financial markets. It increases the effectiveness of the financial intermediation system. This includes institutions that finance private and public investment. Increasing the ability to finance investment mitigates against population growth effects. It does so by preventing the decline in the capital/labor ratio occurring with the growth of the labor force that would inhibit per capita income growth. Monetization of the economy, is an institutional change that increases the proportion of economic exchange where money rather than goods is used as a measure of value. Increased monetization must be accompanied by financial liberalization for the full benefit of the institutional change to be effective.

14. e.g. Gupta (1975), on contributions of foreign capital to economic growth.
Hagen and Hawrylshyn (1969) p.89, test the conventional view that investment of foreign capital contributes more to growth than exports.
15. McKinnon (1973): "... the inadequate economic performance of many LDCs is attributed to repressive, though understandable economic policies that they themselves have pursued ... the centerpiece of the theory is the domestic capital market within each developing country and the way in which that market's operations are influenced by monetary and fiscal policies ... the brute fact of underdevelopment is overwhelming fragmentation in real rates of interest."
Increasing the level of monetization and financial intermediation increases the efficiency of financial markets, as population density, and the velocity of transactions increases. This is another case, as noted by Blase, where all related institutions must be changed at once to maintain institutional effectiveness. Piecemeal approaches to change produces the "layered constraint" problem that frustrated early institutional change efforts in the 1950's. The improvement of financial systems through financial liberalization occurred in a number of countries. Most of these have since experienced per capita income growth.

5. Improvement of literacy through education, and job-training systems (the sponsorship of education is an institutional function of government), mitigate against the adverse economic effects of population growth, by raising the level of human capital, and the ability to manage the new institutions and productive processes.

6. Trade liberalization and export promotion in the increase of manufactured exports in the early 1960's was a source of funds for investment and the development of urban institutional infrastructure (management and financial centers). This is a structural change in terms of product flows, but an institutional change in terms of the contractual arrangements involved. Institutional changes in government policy to promote export strategies and comparative advantage through sectoral development of manufacturing, industry, and services for economic growth, are most successful when focussed on manufactured goods, as opposed to primary exports.

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16: Blase (1971): "the layering of institutional constraints"
When population density growth makes it impossible for traditional economic sectors to provide full employment, institutional change in marketing arrangements, can mitigate against the population growth effect of unemployment in traditional sectors. This can be achieved, for example, by exploiting a comparative advantage in the manufacture of labor intensive manufactured goods. The fact that the development of exports includes many institutional changes necessary to begin and implement an export led development plan are frequently ignored when exports are discussed. These include refinements in international trade laws relating to tariff and quota considerations, and financing abilities.

The Measurement of Institutional/Structural Variables

The variables chosen to represent institutional and structural change in the economies of LDCs are hypothesized to mitigate, or lessen the influence of population density constraints to per capita incomes. As these variables mitigate against population growth and density influences, then across countries it is expected that higher levels of the above variables are associated with higher per capita income levels. Within a country over time, increasing levels of the mitigating variables contribute to increased per capita income by virtue of the mitigation of population growth and density effects.

The incorporation of these institutional and structural change variables of economic growth into a production function framework follows.
CHAPTER IV
ANALYTICAL FRAMEWORK

4.1 Production Function Framework

4.1.1 Production Function Analysis

The formal theoretical foundation implied by the literature on population growth and per capita income relationships is the production function. Empirical studies of this topic, however, often do not formalize the production function framework, noting that the purpose of their inquiry does not justify repeating the familiar caveats concerning aggregate production functions. The explanation given for not beginning with the formal production function is that since their purposes are largely empirical, the exercise in theory would be nothing more than a formality. Dealing with the theoretical existence, identification, and aggregation problems of an aggregate cross-country production function would not contribute to the purposes of their analyses. Thus noting, they proceed directly to their estimating regression model.

1. Browning (1982) p.30: "The model of income growth determination in less-developed countries is a complex process that is not well understood. The field of economic development has yet to develop a tightly woven theoretical model of economic development, and the empirical work that has been done has not clarified the issue to any great extent. The model of growth to be presented will thus be incomplete. For this reason, the model's form will be fairly informal, rather than a tightly derived theoretical structure."
The topic here might conceivably be discussed without a production function framework, proceeding directly to regression analysis, as done elsewhere. In this study, however, its inclusion may be appropriate, since the hypothesis here discusses a topic addressed by others in a production function format. In addition, empirical estimates of production functions give supplemental information relevant to the mitigation hypothesis.

4.1.2 The Production Function

For initial expository purposes, the Cobb-Douglas form is chosen for heuristic convenience, in describing the institutional/structural factors in the production function context. Another reason for choosing the Cobb-Douglas form is that it is the production function form most often seen in the literature. Rather than restructure conventional production function analysis by adding an additional factor of production, as has been done for theoretical purposes, (e.g. as in the addition of an entrepreneurial factor input specified in some studies), the conventional Cobb-Douglas form is maintained.

The "mitigation hypothesis" can be stated and empirically tested through the analysis of the Residual, in terms of the efficiency factors composing it. Discussion of the Residual was initiated by Abramowitz (1956) and Solow (1957), and carried forward by Denison (1967).

2. Powelson (1972), for example makes institutional contributions a factor input, derives demand and supply relations, etc.
The Denison approach is usually identified as the production function "Residual" or the "growth accounting" approach. The Residual is usually attributed to technological change. The residuals from the regression analysis are conceptually different from the Residual in the standard "sources of growth" analysis. The Residual includes the constant term, which in the production function format is a technological change parameter. The average contribution of variables left out of the regression will be included in the constant term—if the omitted variables are not correlated with any of the included variables. With this assumption, the constant term in the regression equations is comparable to the Residual, as noted by Robinson (1979). Changes in the Residual over a period of time can be construed as the result of technological change. The Residual can be decomposed and tested for the presence of technological change variables (comparable to Denison's) in the usual regression manner. The proxies for technological change are the mitigating variables referred to in this study. They can be tested to determine if efficiency gains can be measured by these variables. This study however, does not intend to pursue the discussion of disembodied/embodied characteristics of technological change as done elsewhere. The purpose is to ascertain the relationship between the the production function efficiency factor and the mitigating variables as a preliminary to additional empirical testing.

3. Jorgenson (1966) p.296, on technological embodiment: "one can never distinguish a model of embodied technical change from a model of disembodied technical change on the basis of factual evidence."
Furthermore, one would like to distinguish that portion of technological change which is technical change, from that contributed by institutional/structural changes. Technological change is too often identified solely as the technical change embodied in new capital; institutional and structural contributions remain ignored.

4.1.3 Aggregation Characteristics

The degree of aggregation necessary for a cross-country production function strains the theoretical framework. Since the theoretical foundation of the production function is the microeconomics of the firm, increasing levels of aggregation involve some concessions to theoretical exactitude. The sequential levels of aggregation from micro-level production function of the firm, to a cross-country production function, assuming equal efficiency and homogeneous inputs between units are:

1. from the production function of the firm, to the industry
2. from the production function of the industry to the country,
3. from the country level, to aggregation across countries

To some extent, questions of existence and identifiability at the extreme aggregate levels must be waved aside. This is permissible in so far as the use of the production function at this level is different. The aggregate production function serves as a conceptual foundation from which to proceed to empirical estimation in a regression framework.
Despite the protests of the theoretical framework, this cavalier approach has been justified by Solow (1957) and others⁴, who find that its usefulness outweighs its defects of rigor. Indeed, the aggregate production function has found some measure of rigorous justification, by writers who have found it acceptable within the limits of its purpose, under the stipulation of certain conditions on the behavior of capital.⁵

4.1.4 Production Function Factor and Efficiency Characteristics

The traditional Cobb-Douglas production function makes income a function of labor \((L)\) and capital \((K)\), with technology an augmenting multiplicative constant \((A)\) efficiency parameter:

\[ Y = Ae^{mt}K^\alpha L^{1-\alpha} \]

In the cross-section where \(t = 0\), the technological growth factor \(e^{mt}\) reduces to 1.

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⁴. Hagen and Hawrylshyn (1969) p.64 "starting from an aggregate production function of course begs the question of aggregation. However, we will be in limited company in eschewing the issue and proceeding on the basis of an aggregate production function, even though this may require—in the words of a pioneer in production function application, R.Solow—'a willing suspension of disbelief'."

⁵. For a statement of the very restricted conditions under which aggregation is theoretically possible, see F.M. Fisher, (1969). The difficulty revolves around the issue of whether the value of capital remains constant under shifting of factors among firms and industries. The author indicates, however, that the argument is of varying importance according to the purpose to which production functions are to be put, the implication being that it is a stronger argument the more rigidly the concept of aggregate production function is interpreted.
In the Cobb-Douglas form the following characteristics are present:

1. factor shares are marginal products and factor elasticities
2. factor share coefficients are constant across countries
3. constant capital output ratio
4. constant returns to scale

The efficiency parameter, \( A e^{mt} \), representing disembodied technological change in a time dimension has two elements:

1. technical change efficiency factor
2. institutional/structural change efficiency factor
3. \( m \) is the growth rate of the sum of 1 and 2 over time \( t \). This reduces to 0 in the cross-section production function, making \( A \) a scalar constant, representing the average level of technology for the sample.

Initially, it is assumed for simplicity that the production function factor inputs incur equal average efficiency augmentation, that is, Hicks-Neutral technical change.

4.1.5 Production Function Characteristics

To determine the best production function type for the current use, important production function characteristics are considered. For empirical purposes, the simplest production function form satisfying the requirements of the model at hand is preferred, given the extreme aggregation characteristics of a cross-country production function.
In some estimations of aggregated production functions described in the literature, the results do, in fact, approach the Cobb-Douglas form. The Cobb-Douglas production function has been recommended by Domar (1962) for Residual generation. However, since the topic of this study speculates upon the possibility of variations in the elasticity of substitution between factor inputs across countries, in addition to neutral and non-neutral efficiency differences, the CES or the Trans-Log Production Function may be preferred.

There are a number of characteristics of production functions that are of interest:

1) efficiency parameter, portraying the level of neutral technology.
2) an efficiency indicator showing non-neutral technological bias.
3) increasing or decreasing returns to scale.
4) substitution elasticity characteristics between factor inputs.

These characteristics have different representations in the various production function forms.

The Cobb-Douglas form $Y = Ae^{mt} K^\alpha L^{1-\alpha}$ shows the following characteristics of interest:

1) accommodates neutral efficiency increase in A parameter for changes over time.
2) non-neutral in the ($\alpha$) coefficient for changes over time.
3) scale economies and substitution elasticity restricted to 1.
The Cobb-Douglas production function probably overstates the elasticity of substitution for LDCs. The degree of overstatement is an empirical question. But because an elasticity of substitution different from one is likely, the CES or Trans-Log production function form is preferred.

The CES form: \[ Y = \gamma (\delta K^{-\rho} + (1-\delta)^{-\rho} L)^{-\left(\nu/\rho\right)} \], shows the following characteristics of interest:

1. Accommodates neutral efficiency increase in \( \gamma \)
2. accommodates non-neutral efficiency increase seen as input coefficient changes over time
3. economies of scale in \( \nu \)
4. elasticities of substitution in \( \rho \)

The CES production function does not constrain linear homogeneity or scale characteristics, and does not constrain the elasticity of substitution to equal one. The CES production function does satisfy the Neoclassical requirements of:

1. positive marginal products
2. marginal products fall over relevant ranges of inputs
3. the ability to characterize returns to scale
To explain productivity differences among a number of countries, Arrow, Chenery, Solow, and Minhas\(^6\) devised the cross-sectional CES function:

\[ Y = \gamma (\delta K^{-\rho} + (1-\delta)L^{-\rho})^{-(\psi/\rho)} \]

assuming that \(\gamma\) varies from country to country while \(\delta\) and \(\rho\) remain constant. This implies that all countries have the same production function, but the efficiencies of capital and labor are different between countries.

The **Trans-Log** production function is written as:

\[
\ln Y = \ln a_1 + (aA)(\ln A) + \sum_{i=1}^{n} a_i \ln X_i + \frac{1}{2} (AA)(\ln A)^2 \\
+ \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \ln X_i \ln X_j + \sum_{i=1}^{n} \gamma_i A \ln X_i \ln A
\]

Despite its less constrained characteristics, making it more general in nature than the Cobb-Douglas or the CES, and the ability to calculate varying elasticities of substitution between inputs, the **Trans-Log** production function is less easily interpreted heuristically. In addition, the requirement for factor price data to compute the elasticity of substitution presents problems.

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Given the degree of aggregation of the data, the possibility of further introduction of aggregation error leads to the rejection of this specification on the grounds of spurious precision. It is not practical for the purposes here.

In conclusion, the CES form is chosen over the Cobb-Douglas form for its allowance of substitution elasticities different from one. The CES form is chosen over the Trans-Log form because the characteristics of interest are heuristically more visible, and because the CES form lacks the more stringent data requirements of the Trans-Log form.

4.2 Production Function Interpretation and Use

4.2.1 Discussion of Production Function Characteristics

Much ado is made in the literature about whether factor input coefficients represent marginal products, whether factor shares are constant, and regarding the magnitude of the elasticity of factor substitution. Some assumptions in the work of Denison (1967) have received some criticism in the literature by those working on models for LDCs (e.g. Hagen (1969), Humphries (1976). Considering the fact that Denison's work was for developed countries, a unit elasticity of substitution was probably more justified than Hagen's use of a cross-country Cobb-Douglas production function for LDCs. The quality of Denison's capital data means that his factor coefficients probably approach marginal products more closely than Hagen's LDC model. Hagen was constrained to use investment data as a proxy for capital stock data.
Another criticism of the growth accounting approach is the assumption that marginal products are proportional to factor prices, since relative factor shares are used as weights on the rates of growth of the factor inputs. If one assumes a production function that is homogeneous of degree one, with constant returns to scale, and perfect competition, the coefficients are constant factor shares. However, since factor market disequilibrium is an important part of the development process, it is wise to take care in interpreting these coefficients as exact marginal products. But perhaps the general proportions are maintained. Denison was assuming constant factor shares in one country over a period of time. Since factor proportions change during the course of development, for time series analysis, the only way relative shares would remain constant would be if the elasticity of substitution were unity, i.e. Cobb-Douglas. But here also, Denison's use of the Cobb-Douglas form is probably more justified than Hagen's, because the unit elasticity of substitution hypothesis is more likely valid with Denison's developed country sample than with Hagen's LDC group.

Aside from the interest in relative factor contributions across countries, the use of the cross-country production function to derive insight into the development processes of LDCs is a concession to the scarcity of time-series data. It accedes to the idea that a sample ranked by per capita income level represents an analog to the time-path of a single country's economic development.
The use of the cross-country production function is based on the notion that it is possible to interpret a succession of LDCs increasing in per capita incomes as one country growing through time. For the cross-section, if countries are assumed identical in production modes, the assumption of constancy across countries may not be unreasonable. In the case of cross-section analysis of individual industries as suggested by Arrow, et al.  

"There are of course differences in efficiency levels, but it is fairly plausible to assume that these are approximately neutral in their incidence on capital and labor" ... "Support for use of an aggregate function comes from the fact that for the most part individual country studies have indicated relative factor shares are very roughly of the same order of magnitude (60-70 per cent labor). This assumes complete similarity across countries, but since the factors of a production function are based on biologically based demographic factors and the constraints upon capital accumulation are fairly consistent across countries, the assumption of homogeneity across countries is not as ridiculous as it might seem."

But for a valid analysis of inter-country comparison, it is important to keep the difference in mind to correctly interpret results. As has been discussed by Solow (1957) and others, the information obtained by use of the cross-country production function justifies the fiction of the assumptions made—as long as one remembers what is really being measured.

The question arises of how much information an estimated production function gives about the importance of technical progress.

If one assumes a C.D. production function (with Hick's neutral rate of technical progress), reliable estimates of K and L, and the same rate of technical progress for all countries, estimation of the coefficients would obtain a value, which (in the case of least-squares) would be the constant in the regression. Change in this constant over a substantial time period indicates a change in contribution of technology. The justification of a departure from the Cobb-Douglas production function to the CES form for LDCs is that it allows one to distinguish between scale characteristics and the bias of technological change. The CES form also allows the calculation of an elasticity of substitution not assumed to be unity, a quality appropriate for LDCs.

4.2.2 The Transition Between Theoretical Model and Estimation Form

The range between those authors who make no pretense at a theoretical framework such as Simon (1981) and Browning (1982), and those who insist on derivation of each variable added to the basic production function, seems to require some discussion. Humphries' (1976) insistence on the rigor of deriving additional variables from the theoretical framework is unusual. Some variables of interest have no place in a formal production function model, but are important to a complete specification in regression estimation. Hagen (1969) best sums up the most reasonable position when he speaks of the theoretical framework as a guide for selecting additional regression variables for testing. Allowing for the importance and usefulness of the production function specification, structural departures from it for the purpose of testing peripheral relationships are valid.
CHAPTER V
EMPIRICAL FORMULATION AND RESULTS

Introduction

Since population in the form of labor is a factor of production, one might expect either positive or negative marginal contributions to total income with population growth, depending upon whether diminishing returns are operative or not. In addition, since population density growth has effects external to the provision of labor, the net result is not obvious, and causal relations are not clearly determinable.

The purposes of the empirical work here are:

1. to resolve the empirical discussion concerning the sign of the per capita income and population density relationship.
2. to show empirically that mitigation can reduce the negative influence of population density increases upon per capita incomes.

5.1 Empirical Testing Outline

The empirical testing of the hypothesis seeks to show mitigation of the negative influence of population densities on per capita incomes, through interaction with institutional and structural change variables over time. Where LDCs make sufficient gains in the effectiveness of their economic institutions and structures over time, the negative influence of population density levels upon per capita incomes lessens, and becomes a less significant determinant of per capita income variation.
The key empirical questions and the plans to answer them are:

1. what is the sign and significance of the per capita income/population density relationship across countries in a fully specified regression equation? To show this, the relationship between per capita incomes and population density across countries is tested with a more complete specification than the usual bivariate regression. This is done to establish the foundation of the discussion, noting that the origin of the literature divergencies come from their specification differences.

2. what is the importance of the contributions of institutional and structural change variables to per capita income levels across countries, measured either directly or through production function Residuals? Through production function estimation and the analysis of the efficiency parameter changes between time periods, deductions can be made concerning the importance of efficiency differences across countries. The production function Residuals are tested for the presence of structural and institutional factors that could account for the efficiency differences across countries and the change over time. This study seeks to test the hypothesis that institutional and structural changes (identified by Denison as responsible for economic growth in Europe and the United States) over time, can explain the variation in economic growth over a group of LDCs.
3. through the interaction of population density and mitigating variables over time across a sample of countries, do increases in levels of the mitigating variables decrease the size and significance of the population density coefficients, compared to the cross-section results? The plan is to test whether institutional and structural change has an interactive relationship with population conditions, whereby the influence of population density as a constraint upon per capita income growth is mitigated or lessened. The structure of interaction testing, by interpretation, defines the mitigation concept discussed in this study. The interaction test determines whether the increase of mitigating variable values actually lessens the negative influence of increasing population densities. The interaction test for the mitigation of population growth effects over time across countries is a pooled time series cross-section regression model. The interaction model tests the production function Residual first, and then variables disaggregated from it. The results from the interaction test are compared to the cross-section results to show confirmation of the mitigation hypothesis.

The intention is to let the three points in question and the three estimation procedures provide a framework for the empirical work.
This determines the specification chosen, the regression format, and the result discussions. For example, it is important to note that the interaction test addresses the issue of the effects over time of increasing levels of mitigating variables. Therefore, the interaction test is not meaningful over the cross-section because the cross-country partial correlations between population density and mitigating variables are not of interest with respect to the hypothesis. Functional forms are chosen for theoretical reasonability, ease of interpretation, and fit of the data.

Apart from the hypothesis to be tested, this study has two basic empirical differences from previous production function based studies.

1. a method is devised to estimate capital stock data.
2. a CES production function specification is fitted to the data, in addition to two different forms of the usual Cobb-Douglas production function.

The results gained by these means provide an interesting and informative comparison to previous studies found in the literature.
5.2 Variables, Defined and Measured

1. Income Variables
   1) \( Y/P, Y \), real per capita and real total income level variables, denominated in constant 1979 U.S. dollars. Per capita income level is a proxy for the level of economic development, accepting the fact that the degree of monetization, the degree of equality of income distribution, the mis-valuation of exchange, and the existence of "underground" or "black market" economies may affect its validity.

   2) \( YPG, YG \) are average yearly real per capita and total real income growth rate variables for the 1960-80 period.

2. Capital Stock and Investment, and Saving Variables
   1) \( I/N \), the total gross real investment per worker is used in the pseudo production function type regression equations.

   2) \( I/Y \), the share of total gross real investment in GDP. This variable shows structural change in the composition of expenditures out of GDP. For this reason it is used in the interaction model.

   3) \( K \), an estimation of capital stock calculated by a modified version of the summed investment series. An initial stock is defined on the basis of historically extrapolated data to generate an initial capital stock. The summation of investment then, defines the end of period capital stock data used for the cross-section regression.

   4) \( K/N \), capital stock per worker. \( K \) is estimated as described.

   5) \( KG \), the growth rate of capital, \((actually \ K^*/K \ or \ I/K)\).

   6) \( S/P, S/Y \), per capita saving and saving rate, respectively
3. **Population Variables**

1) **P/H**, population density, defined as total population divided by the number of hectares of arable land. The use of arable land figures corrects somewhat for cross-country land fertility and climatic differences.  
2) **PG**, the population growth rate.  
3) **N**, the potential labor force participation  
4) **NG**, potential labor force growth rate  
5) **D**, dependency ratio = 1−N

4. **Test Variables**

1) **Y**², non-linear income variable to control sample variances  
2) **Dum**, dummy variables used to separate samples according to per capita income range, continents, and colonial influence.

**Mitigating Variables**

The mitigating variables are chosen because their policy origins capture the structural and institutional change components of technological change. The idea is to refute the notion that these components of technological change cannot be measured.

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1. Hance (1980) p.384: "There are a number of explanations for the rather widespread tendency to underestimate population pressure in Africa:  
   1) the tendency to use continental or national density figures, rather than population density on arable land.  
   2) statements regarding the lack of population pressure are frequently made with no reference to capacity of the land. It is meaningless to compare densities on Africa's leached latosols with those on the rich alluvials of monsoon Asia and conclude that Africa does not suffer from population pressure."

2. Hagen and Hawrylshyn (1969) p.81: on testing the difference in labor force and population growth as an independent variable.
1. \( R \), the percentage of the labor force outside of agriculture. Over time it measures rural to urban sectoral shifts in population and production structure, in response to changing economic opportunities. It can include evidence of institutional and structural changes:

1) rural to urban migration is a structural change response to industrialization.

2) land reform in the agricultural sector, is an institutional change, redistributing labor, to increase the use of available arable land, and moderate the rate of rural to urban movement. Under previous institutional regimes some land may have been withheld from production.

2. \( A \), agricultural output per capita in the agricultural sector. This is a measure of agricultural efficiency and an indication of investment in rural agriculture. Increasing agricultural efficiency prevents sectoral imbalance and institutional disequilibria, (such as caused in rural land tenure and rural labor markets by rapid rural population growth). It has been noted that generating an agricultural surplus is an important development stage, of which increasing agricultural efficiency is an important element.

3. \( M_T \), total manufactured exports, as a percentage of GDP. Change in the manufactured export share of national product indicates structural change as a sectoral production shift, and implies an increase in institutional complements. These include trade agreements and regulations, the increase in financial intermediation, etc.
4. The literacy rate, as a percentage of the total population, is a variable representing human capital investment. Increases in knowledge and research potential are found to be important in the Denison (1967) study. Despite measurement problems, literacy is the best educational input variable for LDCs. Years of education data are sparse and unreliable (the definition of a school year varies across countries). For a cross-section, government expenditure on education is affected by overall economic conditions of that year. Contrary to the developed countries studied by Denison, where years of education was the preferred variable, for LDCs literacy figures seem to be more reliable.

5. Financial deepening (the ratio of $M_2$ to GDP) is a measure of financial market efficiency, developed by Shaw (1973) and McKinnon (1973). "Financial deepening" policies increase the institutional services provided by financial intermediaries through greater monetization of the economy, increased savings resulting from equilibrium interest rates, and increased credit availability. These counterparts of institutional effectiveness lead to economic growth, as has been shown to be the case in a number of countries.

6. In the interaction model, $M$ is the Residual, used as a mitigating variable. This is the Residual generated by the estimated production functions.
The foregoing variables have been selected to test for population density effect mitigation properties. Other possible variables, such as the share of foreign capital in GDP and increases in government efficiency, have been considered, but have been discarded for the following reasons:

1. **foreign capital** is too heterogeneous a variable for use in this study, which already has made concessions to high levels of aggregation. There are too many different types of foreign capital available. Furthermore, data are too incomplete and inconsistent to be considered reliable. Results from other studies have been inconclusive. Also, regression interpretations are difficult because of collinearity with investment.

2. **government efficiency** is plagued by definitional, measurement, and data problems. Comparable data on the share of government operating expenditures are not available. Furthermore, the relationship between government operating expenditures as a share of GDP is not likely to be a linear relationship. This indicator is likely to rise with the initial cost of establishing new institutional infrastructure, fall when emphasis is given to free market forces in generating economic growth, and rise again when a more affluent society begins to demand more government social services at later stages of development. As a development variable, it is best handled as an index in the manner done by Adelman (1968). Her study was designed for the use of such indices.

The unavailability of capital stock data has presented a problem for empirical studies of LDCs. A number of different approaches have been used:

1. use of a proxy, e.g. energy consumption
2. use of investment growth $I^*/I$ as opposed to $K^*/K$ capital growth
3. use of $I/Y$, gross fixed investment as a share of GDP
4. calculate a sum of investment series as a capital stock approximation.

A two-step variation of the last approach is chosen here:

1. hypothesize an average capital/output ratio appropriate to the initial level of economic development, to calculate an initial capital stock.
2. use the initial capital stock as a base for a time series summation of investment to the desired date. This gives a more accurate measure of the capital stock than the proxies noted above.

5. Hagen and Hawrylshyn (1969)
   p.69: "as Denison points out, $I/Y$ is not an estimator of the growth of capital stock $K^*/K$, although the two are related through the average capital/output ratio $K/Y$.
   p.74: "The futility of any attempts at adjusting $I/Y$ to obtain an estimate of $K^*/K = I/K$ lies in the fact that capital stock data are simply not available, and short of the possibilities of great intuition on the question of relative sizes of average capital coefficients one is left with no choice except to use $I/Y$ and realize exactly in what sense using this is inappropriate."
7. the rationale for the capital share i.e. $K/Y$ ratio method is:
   $Y = rK + wL$, $r$ and $w$ being respectively the prices of capital and labor and $\frac{Y}{A} = \alpha K + \beta L$ where $\alpha$ and $\beta$ are respectively the shares of capital and labor and if $\alpha = rK = .4$ and $r = 20$ per cent, $K/Y = 2$. 

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Beginning the capital stock series by an estimated initial capital output ratio, instead of an unrealistic assumption of no capital stock, is seen to be an improvement over other methods.

The procedure is as follows:

1. Average yearly income, gross investment, and investment growth data are available for a twenty year period, 1960-79. Projecting the growth rate of investment back in time to an arbitrary small rate of .1 per cent (1940), and an initial average capital output ratio of 1, calculated investment data is summed to create a 1960 base year capital stock.

2. Using a standard present value formula, the average yearly investment rate for the period is calculated. Using a standard sum of yearly annuity formula, the 1979 capital stock is calculated from the investment share of GDP and income data.

5.3 Data Sources

The data are obtained primarily from World Bank sources (World Bank Development Report). Exceptions to this are the arable land figures taken from FAO Agricultural Production Yearbook, and population, money supply, and some income information taken from the IMF International Financial Statistics.
Table 1

Data Set Countries

1. Bangladesh  13. Indonesia  25. Ivory Coast
5. Afghanistan 17. Egypt      29. Korea
8. Pakistan    20. Philippines 32. Chile
10. Zaire      22. Peru       34. Brazil

The countries are chosen from the 1981 World Bank Development Report's list of low and middle per capita income countries. The sample of countries is a list of all the countries meeting the sample criteria. These are:

1. per capita income under $2500 (1979)
2. population greater than 8 million (1979)
3. data available for all variables
4. non-Communist—in addition to the fact that data availability is poor for the Communist countries, the nature of the command economy biases the operation of market forces that include the incidence of institutional and structural change. For these reasons those countries have not been included.
The restriction of the sample by country size and per capita income level is done for the purpose of maintaining homogeneity of LDC characteristics, and is thought not to bias the sample. For the purposes of this study, this sample is large enough for statistical purposes, but could be expanded by relaxing the country population size criterion. While one might prefer a larger sample for greater econometric degrees of freedom, there are some reasons why increasing the sample size might not be desirable:

1. The per capita income criterion cannot be relaxed without creating excessive heteroskedastic bias, and destroying the sample homogeneity of LDC characteristics.

2. Relaxing the population size criterion is reasonable, but potentially undesirable for the following reasons:

   1) The purpose of the choice criterion of a minimum population of 8 million, is to minimize possible bias from inter-country migration, and to give a sufficient market size for relative economic autonomy.

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8. Browning (1982): "In this work a deliberate attempt to select a more homogeneous sample of countries and time periods within countries will be made. The risk is that one can bias the results if the criteria for choosing a more restricted sample are inappropriate."

9. Hagen and Hawrylshyn (1969) p.75, on the consequences of raising the per capita income criterion: "the more developed a country (the higher its nonagricultural labor percentage), the less any shift in labor from agriculture will be simply a movement toward efficiency, and the more it will be partly a result of response to a shift in relative wages."

10. Kuznets suggests that 10 million is the dividing point between a large country and a small country. In Economic Growth, chapter—"The Problem of Size" p.91: "we prefer to consider the small nations—for present purposes, units with less than 10 million population."
As countries become smaller from the 8 million level the degree of autonomy becomes less. The economies may depend upon trade for basic commodity exchange. Trade then, is an allocation mechanism rather than a development strategy. This fact may also bias the value of the mitigation variables used, that relate to the agricultural sector, where there are differences in the autonomy of agricultural production.

2) By relaxing the population size criterion to 5 million (1979) 14 countries are gained. However, 11 of the 14 are African. Their inclusion would make the sample (heretofore balanced between continents) heavily biased toward African characteristics. The possible effect of this bias is unknown. Without an overwhelming reason on econometric grounds, that is not obvious to the author, it would seem that the current sample size best serves the purposes of the study.

The countries meeting the per capita income and population size criteria, but eliminated because of data insufficiency or non-market economies are Mozambique, Iran, and Syria on the former grounds, and Viet Nam, China, Syria, Korea, Cuba, and Romania on the latter.

An important characteristic in the way that the data set has been constructed is that there are no missing observations for any variable. This eliminates a source of bias that has plagued other studies¹¹ and requires special procedures for correct estimation.

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¹¹. Browning (1982), was required to modify his estimation technique because of a large number of missing observations.
5.4 Empirical Tests: Introduction

The importance of the mitigation hypothesis of this study is in bringing together in one model the population factors and institutional/structural factors that determine the success or failure of economic development in LDCs. The difficulty in setting up an introduction to the mitigation analysis comes from the fact that previous work did not connect the two factors. In different types of previous literature:

1. In most studies the discussion of income/population relationships was underspecified, leaving out technological factors, and thus obtaining results underestimating the severity of population effects.

2. In other studies, formal production function estimation and Residual analysis emphasized the contributions of technological factors, but failed to discuss the importance of relative population density levels.

The attempts here to extend and complete the approaches previously taken, and to join them together for testing the mitigation hypothesis through the interaction model, will be done in three parts.

The first set of regression analyses begins with an informal empirical analysis of the income/population relationship specified in a number of ways. This is done to exhaust the possibility of random results, and to correct the impression resulting from the literature that the relationship is essentially ambiguous and insignificant.
A number of institutional/structural variables are added to the regression in an informal way to complete the specification. In this way the full significance of the partial effect of population density increases on per capita incomes can be seen.

The second format of testing moves from the informal empirical analysis to the more formal Cobb-Douglas and CES production function estimation. The population/income relationship, while less visible, can be deduced from the estimations. However, an additional contribution is the analysis made possible by the production function efficiency parameters, and their comparison between time periods to note the progression of technological change. The Residuals from these production functions are generated to test for the presence of the institutional and structural variables described in Chapter 3.

In the third set of tests the Residuals and the mitigation variables are tested separately in a pooled data model, to establish their relationship over time with the population density partial regression coefficient.

There is a natural progression of the empirical estimations that begins with the informal extension of literature results, moves into a more formal production function/growth accounting Residual format, and concludes with the mitigation test of the hypothesis of this study.

5.5 Relationships between Population and Income Variables

The purpose of this section is to proceed toward resolving the empirical dissention seen in previous literature regarding the effects of population density increases upon per capita incomes.
Determining the sign and the significance of the relationship between population density and per capita incomes for a cross-country sample with an improved specification is the subject of Part 1.

With regards to specification, per capita income rather than total income defines development level. The correct specification of the population variable is less obvious. Economic theory says that levels and growth rates of population variables are associated with different effects on potential per capita income growth, as noted in Chapter 2. These include effects on the quantities and qualities of labor, capital, land resources, and upon the viability of economic institutions and structures. Empirically, the following questions are relevant:

**Specification Issues: Empirical Questions**

1. Do population/land and population/institution factors (the result of past population growth), or saving reduction and capital dilution (the spreading of less private relative to social capital among more workers) determine the current level of per capita income? That is, is the level of per capita income a function of population density, the population density growth rate, or both?

2. Is the growth rate of per capita income a function of the population density growth rate, but not population density? This would indicate that the current economic growth rate (but not the level) is affected through saving reduction and capital dilution, and not by the effects of population/land and population/institutional factors.

The general question is: what are the relative importances of growth rates and the levels of income and population variables in assessing the economic status of a country?

Empirical testing indicates that some of the writers noted in the literature, by using income growth rates as their dependent variable, have missed a determinant of income determination, population density. Population density is a significant factor in determining the level of per capita income across countries. When per capita income growth is the dependent variable (the preferred development indicator), the rate of population growth is the appropriate independent variable. The population density element is included in the effect of population growth, however, as population growth for a given area is population density growth. But, since its inclusion is not explicit, the importance of population density is not spoken of in the growth specification, where it is replaced by the population growth rate. Whenever "population growth" is mentioned, it is wise to think "population density growth". Differing approaches in the literature tend to give the impression that population growth and population density increases are different entities. They are not.

In doing cross-sectional analysis across countries, the division of population levels by units of arable land corrects somewhat for country size and land fertility differences.

Regression Specification: Econometric Considerations

In addition to the form of the income and population variables, the resolution of the divergent results in the literature depend upon an improved specification including other important variables.
The regressions noted in the empirical work cited from the literature were underspecified. The issues of best specification and functional form were of such a lesser order they were never discussed. Econometric theory says that the omission of important variables biases the coefficients of the included variables. This was the cause of the positive and/or insignificant population coefficients in previous studies.

The underspecification in previous literature studies suggests:
1. the omitted variable bias noted perhaps reflected a lack of theoretical grounding of the regression model, that should have determined the regression specification.
2. perhaps additional variables were omitted to avoid other econometric problems associated with a more complete specification.

Improving the specification of the underspecified regressions found in the literature on income/population relationships in LDCs is necessary to obtain accurate estimation of the relationships involved. In the more complete specification attempted in this study, with the inclusion of institutional/structural variables, a multicollinearity problem results. But it is apparently confined mostly amongst the institutional and structural variables, not affecting the population density variable to any great extent. Measures are taken to deal with the multicollinearity.
The Relationship Between Per Capita Income and Population Density Levels

The following regression equations are given to evaluate the relationship of primary interest in this dissertation. It is the relationship between per capita income and population density levels that determines the population density coefficient. As specification improvements to the regression models from the literature, and to substantiate the above specification discussion, other independent variables are added to improve the specification. Initially a capital or investment variable is added, and finally a group of institutional and structural variables completes the specification.

Note on Subsequent Regression Equation Tables:

In all of the 36 country cross-section OLS regressions to follow, the T statistics are shown in parentheses beneath the relevant coefficient. F statistics, degrees of freedom (d.f.) and $R^2$ are shown next to the regression, except where noted. In general, for the cross-section regressions, where the degrees of freedom vary around 30, a T statistic in excess of 2.00 shows significance at the 5 per cent level.

The first four regressions show two different specifications for the pseudo production function determination of per capita income, with population density and investment and capital per worker variables. Note the increase in absolute value of both the population density and the investment variables between the 1960 and 1979 cross-sections.
Table 2

Basic Specification Regressions

1960
\[ \ln Y/P = 3.80 - 0.10 \ln P/H + 0.58 \ln I/N \]
\[ (10.88) (-1.01) (6.89) \]
\[ R^2 = 0.68 \]
\[ d.f. = 33 \]
\[ F = 34.49 \]

1979
\[ \ln Y/P = 0.11 - 0.16 \ln P/H + 0.68 \ln I/N \]
\[ (.27) (-2.38) (15.98) \]
\[ R^2 = 0.89 \]
\[ d.f. = 33 \]
\[ F = 127.39 \]

1960
\[ \ln Y/P = 4.09 - 0.17 \ln P/H + 0.66 \ln I/N - 0.10 \ln K/N \]
\[ (10.75) (-1.50) (5.94) (-1.32) \]
\[ R^2 = 0.69 \]
\[ d.f. = 31 \]
\[ F = 24.09 \]

1979
\[ \ln Y/P = 6.01 - 0.29 \ln P/H + 0.91 \ln I/N + 0.28 \ln K/N \]
\[ (7.14) (-1.70) (3.77) (3.15) \]
\[ R^2 = 0.49 \]
\[ d.f. = 31 \]
\[ F = 10.07 \]

1960
\[ \ln Y/P = 3.69 - 0.16 \ln P/H + 0.56 \ln I/N + 8.11 \ln PG \]
\[ (7.17) (-1.35) (6.62) (.68) \]
\[ R^2 = 0.68 \]
\[ d.f. = 32 \]
\[ F = 22.77 \]

1979
\[ \ln Y/P = 0.15 - 0.17 \ln P/H + 0.68 \ln I/N - 0.18 \ln PG \]
\[ (.29) (-2.17) (14.60) (-.02) \]
\[ R^2 = 0.89 \]
\[ d.f. = 32 \]
\[ F = 82.35 \]

1960
\[ \ln Y/P = 3.87 - 0.16 \ln P/H + 0.67 \ln I/N + 0.09 \ln K/N + 7.60 \ln PG \]
\[ (7.33) (-1.38) (5.91) (1.29) (.64) \]
\[ R^2 = 0.54 \]
\[ d.f. = 31 \]
\[ F = 17.84 \]

1979
\[ \ln Y/P = 5.80 - 0.29 \ln P/H + 0.91 \ln I/N + 0.28 \ln K/N + 7.51 \ln PG \]
\[ (5.67) (-1.69) (3.72) (3.13) (.40) \]
\[ R^2 = 0.49 \]
\[ d.f. = 31 \]
\[ F = 7.21 \]

1979
\[ \ln S/Y = -13.21 + 0.68 \ln Y/P + 0.04 \ln YPG + 0.003 (D*YPG) \]
\[ (-.28) (2.17) (14.60) (.02) \]
\[ R^2 = 0.47 \]
\[ d.f. = 34 \]
\[ F = 9.90 \]

1979
\[ \ln S/P = -13.30 + 1.69 \ln Y/P + 0.04 \ln YPG + 0.01 D \]
\[ (-12.71) (9.72) (.45) (.39) \]
\[ R^2 = 0.83 \]
\[ d.f. = 34 \]
\[ F = 56.04 \]

While the pseudo production variables in the regressions above show significance, for the most part, neither the population growth or the dependency variables show contribution to per capita income or saving level.
Result Summary

Modification of the implicit production function regression base yields an inspection of the partial "effects" of population densities on per capita income levels across countries. The most reasonable extension of the bivariate model of the literature, where various income variables are regressed on various specifications of population, is the addition of investment and/or capital variables, in a pseudo-production function specification:

The regressions are similar in form to the logarithmic form of the Cobb-Douglas production function. The population density coefficients are significantly negative (at the 5 per cent level). These equations deviate from the bivariate models used in a number of articles in the literature by using a more complete specification.

The results confirm that previously underspecified work underestimates the negativity of population density effects on per capita incomes. It is found that population density level has a negative and significant correlation with per capita incomes across countries, holding investment levels constant. That is, low levels of per capita income are substantially explained by high levels of population density. An improved specification strengthens this result, by adding the investment and capital variables.
Specification: Theoretical Considerations and Empirical Results

There is a potential gap between theoretical relationships and their empirical representation. What may be a valid consideration in theory, may not be substantiated empirically, where the observation of reality is restricted in time and space. For example, the economic effects of changing population growth rates, have been noted with emphasis in the theoretical literature on dependency effects upon savings. Yet they do not show significance for the data of the 1960-1980 sample period of this study. This indicates that the effects of changes in population growth rates that were determinants of saving and per capita income levels earlier in the century\(^{12}\) have declined. This may be because population growth rates have stabilized, thus reducing the dependency effect. In any case, empirical results show that neither the dependency effect, nor the rate of growth effect discussed in the population literature is significant in determining saving or per capita income levels over the sample period. They are uncorrelated with other explanatory variables, ruling out collinearity as the explanation for the lack of significance. The results indicate that variation in population growth does not explain variations in per capita income across countries. The empirical insignificance of population growth rate change (by regression interpretation) effects on development levels is shown for completeness. But since population growth changes are not relevant to the mitigation testing, this variable is dropped from the interaction model in Part 3.

\(^{12}\) because of international public health breakthroughs and the attending mortality decline
Results show evidence for the following conclusions:

1. the current level of per capita income is a function of population density, but not of the population growth rate. This suggests that population/land and population/institution factors (the result of past population growth), rather than the dependency effect of population growth rates, are more important in determining the current level of per capita income.

2. changes in the growth rate of per capita income are a function of the population growth rate, but not population density. This indicates that current changes in economic growth rates are affected by population growth rate effects, but not by the effects of population/land and population/institutional factors.

Further, the population growth rate effect noted here differs from that noted by Mason (1981) and Leff (1969), in that it does not affect the levels of saving or per capita income, but the growth rates of per capita income. However, the growth rate of per capita income is not the preferred development indicator. The most important guide to the appropriate specification of an income variable is that economic development is defined in terms of level of per capita income, rather than the rate of economic growth.

Since low levels of per capita income remain a problem in LDCs, and since the dependency effect caused by population growth rate changes has been somewhat discounted for the data in this study, the importance of the influence of population density discussed here is given greater emphasis.
Specification: Addition of Institutional/Structural Variables

When institutional/structural variables are added to improve the regression specification, the mitigating institutional and structural change variables show themselves to be significant in explaining variation in per capita incomes across countries. The result holds both when they are included explicitly in the regression, and when tested as a production function Residual. Countries with higher levels of these variables exhibit higher levels of per capita income.

The addition of the mitigating variables markedly improves the specification of the regression model. It captures the essential institutional/structural elements of interest, and establishes the cross-country result base line for the full test of the mitigation effect. Part 3 of the empirical work tests whether increasing levels of these variables through time enables countries to improve their relative per capita income levels, by mitigating against the constraints of population density.

Significance Tests

T tests show significance at the 5 per cent level in most cases. Given the degrees of freedom, a T statistic of approximately 2.0 shows significance at the 5 per cent level. The notable exception is the coefficient of the population growth variable which is shown to be insignificant.
Table 3
Addition of Institutional/Structural Variables

1960 OLS

\[
\ln \frac{Y}{P} = 5.65 - 0.12 \ln \frac{P}{H} + 0.11 \ln \frac{I}{N} + 0.25 \ln R + 0.02 \ln F + 0.06 \ln L + 0.15 \ln MT
\]

\[
(52.56)(-3.70) (10.89) (8.77) (3.52) (4.24) (1.99) (x)
\]

\[
d.f. = 29 \quad R^2 = 0.88
\]

\[
F \text{ test of the restriction} = 7.37 \text{ for } 1, 28 \text{ d.f.}
\]

1979 OLS

\[
\ln \frac{Y}{P} = 6.26 - 0.20 \ln \frac{P}{H} + 0.20 \ln \frac{I}{N} + 0.31 \ln R + 0.50 \ln A + 0.34 \ln F + 0.13 \ln L + 0.06 \ln MT
\]

\[
(18.39)(-3.33) (2.29) (4.82) (7.30) (x) (2.01)(2.26)
\]

\[
d.f. = 29 \quad R^2 = 0.74
\]

\[
F \text{ test of the restriction} = 22.11 \text{ for } 1, 28 \text{ d.f.}
\]

Exponential form results for comparison to interaction model, Part 3.

1979 OLS

\[
\frac{Y}{P} = 4.85 - 0.03 \frac{P}{H} + 1.89 \frac{I}{N} + 1.12 R + 0.0004 A + 0.90 F + 0.32 L + 1.68 MT
\]

\[
(22.29)(-2.39) (3.05) (5.53) (3.63) (x) (1.87)
\]

\[
d.f. = 29 \quad R^2 = 0.67
\]

\[
F \text{ test of the restriction} = 5.01 \text{ for } 1, 28 \text{ d.f.}
\]

\[T \text{ statistics for restricted coefficients are noted by (x). The ridge}
\]
regression estimation of these equations is described in the Econometric
Testing Appendix. F tests show significance at the 5 per cent level for
the hypothesis, that is, the coefficients as a group. For the degrees
of freedom here, the critical test statistic is approximately 4.

The use and specification of the institutional and structural variables
is supported by their significance in these regression equations.
Functional Form

The choice of functional form is not determined by a priori considerations. The estimated regressions suggest an actual form somewhere between the linear in double log form and the curvature of the exponential form. The double log functional form gives a better fit of the data, compared to the linear or exponential form. This is confirmed by a comparison of F tests and by likelihood ratio tests. Likelihood ratio tests done to determine appropriate functional form, showed that the relation implied by the data is linear in logarithms. The exponential coefficients for population density, however, are instructive when one wants to compare it to the exponential form used in the pooled interaction model used in Part 3 of this chapter. Details of the likelihood ratio tests are given in the appendix on empirical testing.

Sample Separation Tests: Table 4

Separating the sample, and doing regressions for low and high per capita income countries, shows that population density becomes a less significant factor as per capita incomes rise across countries. Regressions show the decline in size and significance of the coefficient measuring the change in per capita income, with respect to increases in population density. This is confirmed through a dummy variable test. Details of this methodology are given in the appendix on empirical testing.

While a number of historical factors doubtlessly contribute to explain this, the fact remains that population density has a significant correlation with "underdevelopment", but not with higher levels of per capita income.
Table 4

Miscellaneous Test Regressions

1960
\[ \ln \frac{Y}{P} = 4.16 - 0.19 \ln \frac{P}{H} + 0.58 \ln \frac{I}{N} - 0.26 \text{ Dum} \]
\[ (11.28)(-1.67) \quad (6.97) \quad (-1.76) \]
\[ R^2 = 0.71 \quad \text{d.f.} = 32 \quad F = 25.48 \]

1979
\[ \ln \frac{Y}{P} = 0.25 - 0.19 \ln \frac{P}{H} + 0.66 \ln \frac{I}{N} - 0.09 \text{ Dum} \]
\[ (.51)(-2.30) \quad (14.53) \quad (-0.83) \]
\[ d.f. = 32 \quad F = 84.36 \]

1960
\[ \ln \frac{Y}{P} = 4.15 - 0.19 \ln \frac{P}{H} + 0.66 \ln \frac{I}{N} - 0.08 \ln \frac{K}{N} - 0.24 \text{ Dum} \]
\[ (11.12)(-1.67) \quad (6.04) \quad (-1.13) \quad (-1.60) \]
\[ R^2 = 0.71 \quad d.f. = 31 \quad F = 19.59 \]

1979
\[ \ln \frac{Y}{P} = 6.04 - 0.31 \ln \frac{P}{H} + 0.91 \ln \frac{I}{N} + 0.31 \ln \frac{K}{N} - 0.44 \text{ Dum} \]
\[ (7.47)(-1.89) \quad (3.94) \quad (3.59) \quad (-1.95) \]
\[ d.f. = 31 \quad F = 9.18 \]

1960-1980
\[ \left(\frac{Y}{P}\right)_G = -2.66 + 0.72 \frac{Y}{P} - 1.20 \left(\frac{P}{H}\right)_G + 0.24 I_G \]
\[ (-2.10) \quad (3.88) \quad (-2.35) \quad (6.70) \]
\[ R^2 = 0.75 \quad d.f. = 33 \quad F = 24.05 \]

1979
\[ Y_G = 0.02 + 0.50 N_G + 0.10 K_G + 0.000000003 Y^2 \]
\[ (3.11) \quad (1.82) \quad (7.04) \quad (2.35) \]
\[ R^2 = 0.74 \quad d.f. = 32 \quad F = 30.18 \]

Table 4—The first four regressions separate the cross-section into high and low per capita income groups. A dummy variable is given the value of one for the lower per capita group of LDCs and zero for the other group. The dummy variable test of sample separation by per capita income differences shows the significance of the separation between low and high income groups in the sample in 1960 and 1979.

Sample Homogeneity: Results from Table 4

The results of the sample separation tests lead one to question the homogeneity of the sample, and ask whether heteroskedastic bias is present.
Tests for sample homogeneity show:

1. Some heteroskedastic bias is also shown in Table 4 by the results of inserting of a squared per capita income term as an independent variable. Its significance shows a non-linear effect caused by the atypical characteristics of the higher per capita income countries. This could perhaps be reduced by removing suspect countries and/or reducing the population level criterion to include more typical LDCs. However, this might bias the sample in another direction if lack of country autonomy due to smallness of size distorts the interpretation of trade statistics, as previously mentioned.

2. Another specification shows a modification of the standard Cobb-Douglas production function specification in growth rate estimation form. The growth rates are average yearly growth rates for the 20 year period. A level of per capita income variable is used in the growth rate specification of the first equation. This controls for differences in per capita income level that would otherwise bias the interpretation of the growth rates in a cross-country sample because of lack of sample homogeneity.

3. The Park Glejser test regresses the square of the regression residual on the variable assumed to represent sample variance. Significance of the coefficient obtained indicates heteroskedasticity. The Park–Glejser test accepts the null hypothesis that heteroskedastic error is present. A Generalized Least Squares regression estimation corrects for the heteroskedasticity. However, the change in coefficients is negligible, indicating that the heteroskedasticity is not extreme. It is concluded that the sample bias in this case is not extreme enough to question the validity of the results.
It is obvious intuitively that the inclusion of a number of countries on the upper fringe of the per capita income range have characteristics not completely homogeneous with the general sample characteristics. Sample homogeneity is never completely attainable in a cross-country sample. Differences between continental placement of the countries and cultural background significantly affect the data.

The Significance of Coefficient Differences Between Cross-Sections

The Chow test is used to determine whether changes in the coefficients of the regression equations are significant or random. Results of the test shows that the difference between the coefficients of the 1960 and the 1979 sample are significant. This allows the statement (following from the observation) that both the population density and the capital/investment coefficients increase in absolute value between the two period. Population density has had an increased negative influence on per capita income levels, while capital/investment has had an increased positive influence on the variation of per capita incomes across the sample between the two cross-sections.

Conclusion

The main objective in this section has been to determine the sign and significance of the partial regression coefficient of population density. This is done to resolve conflicting results from the literature through the use of a more complete specification than the bivariate model usually tested.

In contrast to a number of other empirical studies in the literature, the population density and per capita income relationships estimated here are significantly negative. The difference is attributed to an improved specification of the regression model.
5.6 Production Function and Residual Analysis

Introduction

Use of the production function format establishes a formal analytical model comparable to established methodology. It also enables the insertion of this study's hypothesis into a familiar format, that of growth accounting. This is true, even though the growth accounting methodology is itself a modification of the formal production function model. Indeed, the characteristics of the formal model are stretched from the outset by the level of aggregation of the growth accounting discussion.

In the growth accounting context, the analysis of the Residuals generated from the production function gives specification validation of the mitigating variables. This justifies their use in the interaction model of Part 3 as the final test of the mitigation hypothesis.

The development of the empirical analysis of this section proceeds from the production function format in the following directions:

1. Use of the production function format permits the analysis of interesting production function characteristics. These include the analysis of efficiency changes, input substitutability, and scale economies.

2. The production function efficiency parameter provides a context and an introduction to the discussion of the mitigation hypothesis.
Cobb-Douglas Growth Rate Form

In the Cobb-Douglas Growth Rate Form, the dependent variable, per capita income, and the population and investment variables are in growth rates. Total differentiation of the Cobb-Douglas Production Function of the form:

\[ Y = A K^{\alpha} L^{(1-\alpha)} \]

yields the growth rate form:

\[ \frac{Y^*}{Y} = \frac{A^*}{A} + \alpha \frac{K^*}{K} + (1-\alpha) \frac{L^*}{L} \]

that is suitable for regression estimation.

Cobb-Douglas Log-Log Form

A logarithmic transformation of the Cobb-Douglas Production Function:

\[ Y = A K^{\alpha} L^{(1-\alpha)} \]

yields the estimating form:

\[ \ln \frac{Y}{Y} = \ln A + \alpha \ln K + (1-\alpha) \ln L \]

Table 5
Production Function Results

1960-1980 Cobb-Douglas Growth Rate Form

\[ \begin{align*}
YG &= .02 + .45 \text{ NG} + .11 \text{ KG} \\
&= (3.45) (1.55) (7.57) \\
R^2 &= .70 \\
d.f. &= 35 \\
F &= 25.62
\end{align*} \]

1960 Cobb-Douglas Log-Log Form

\[ \begin{align*}
\ln Y &= 5.57 + .50 \ln N + .29 \ln H + .18 \ln K \\
&= (9.79) (3.31) (1.92) (2.21) \\
R^2 &= .66 \\
d.f. &= 34 \\
F &= 21.92
\end{align*} \]

1979 Cobb-Douglas Log-Log Form

\[ \begin{align*}
\ln Y &= 4.91 + .58 \ln N + .17 \ln H + .27 \ln K \\
&= (4.96) (2.92) ( .91) (2.54) \\
R^2 &= .58 \\
d.f. &= 34 \\
F &= 15.01
\end{align*} \]
Cobb-Douglas Result Discussion

1. Hicks-neutral technological change would be indicated by change in the intercept $A$. The results here, however, show the value remaining substantially the same, indicating no cross-country variation in neutral progress.

2. Non-neutral technological change is indicated in the increase in the $K$ coefficient. Capital-using technological change is seen from the increased share of capital ($K$). Tests of coefficient comparison validity are shown in the Chow test.

3. No scale economies are indicated by the Cobb-Douglas form. By definition, constant returns to scale are prevalent.

4. The elasticity of substitution is defined as 1 in the Cobb-Douglas form.

Results are consistent between both the growth rate and the double log Cobb-Douglas production function form. The land resource variable ($H$) is included explicitly in the log form. In the growth rate form, the contribution of land resources is embedded in the population density growth variable. It is not explicitly shown because of the simplifying assumption that the land resources have not changed over the period.

The CES Production Function

The CES production function is estimated as a non-linear model, removing some of the constraints of the linear Cobb-Douglas forms. Notes on the non-linear estimation procedure are given in an appendix.
Humphries (1976)\textsuperscript{13} notes:

"the marginal product of capital declines during development as capital intensity increases, as one would predict from production theory."

However, she doesn't account for the possibility of capital biased technological change, or specify at what level of development that she expects the decline of marginal product to occur. She further says that the Cobb-Douglas form may not be an appropriate functional form to use in the analysis of growth:

"The Cobb-Douglas form suggests that global possibilities for substitution are considerably wider than might be implied by models such as the Chenery-Strout "two-gap" model. There, the implicit assumption is that the production function is Leontief."

CES estimation makes no assumption concerning the elasticity of substitution, but calculates it as part of the estimation, a decidedly positive trait.

The CES production function is estimated as

\[
\ln Y = \ln (y) - ((v/p)\ln(\delta K)^{-p} + (1-\delta)N^{-p})
\]

The estimated coefficients are shown in Table 6.

In the CES production function constrained to Cobb-Douglas assumptions of neutral scale characteristics and a unity elasticity of substitution, the results replicate the Cobb-Douglas results with the coefficients reversed in magnitude from the unrestricted CES model.

\textsuperscript{13} Humphries (1976) p.352
Table 6

CES Production Function Results

1960
\[ y = 99.9 \quad \nu = .88 \quad \rho = .25 \quad \delta = .62 \]
\[ (87.76)(9.16) \quad (1.68) \quad (3.66) \]

1979
\[ y = 10 \quad \nu = .99 \quad \rho = .32 \quad \delta = .85 \]
\[ (4.99) \quad (7.16) \quad (2.02) \quad (5.87) \]

1960 CES production function constrained to Cobb-Douglas assumptions:
\[ y = 99.56 \quad \nu = .97 \quad \rho = .04 \quad \delta = .36 \]
\[ (77.41) \quad (6.86) \quad (.28) \quad (1.85) \]

R², and F tests are not relevant for non-linear estimation.

---

CES Result Discussion

The results indicate that variation in production levels across countries are explained by:

1. Hicks-neutral technological change between the 1960 and 1980 cross-sections would be indicated by a change in the intercept \( y \) parameter. A decrease in the \( y \) parameter from 100 to 10 indicates that efficiency differences across countries have decreased over the 20 year period. This is due, perhaps to the results of international development programs and the mitigating influences of institutional and structural changes.
These define the efficiency parameter, as shown in Residual disaggregation.

2. non-neutral technological change is indicated by the increase in the K coefficient, indicating capital-using technological change, as seen from the increased share of capital.

3. even though scale economies are permitted by the CES form, the estimation done here shows neutral scale effects. Differences in scale economy factors are not indicated, as $\nu = 1$. This indicates constant returns to scale.

4. the elasticity of substitution sigma ($\sigma$) is approximately .80 as indicated by $\rho = .25$ where $\sigma = 1/(1+\rho)$.

**Comparison of Cobb-Douglas and CES Production Function Results**

Compared to the Cobb-Douglas estimation, the less constrained CES form gives a more realistic picture of the growth process between 1960 and 1980.

1. **Scale**—Rather than assuming constant returns to scale, its test of scale characteristics, the $\nu$ coefficient, shows that constant returns to scale were prevalent.

2. **Elasticity of substitution**—Rather than assuming an elasticity of substitution between factor inputs of 1, the CES estimation calculates a somewhat less elasticity of substitution. In the CES estimation, an elasticity of substitution ($\sigma$) of approximately .75 remains relatively constant over the period.
3. Efficiency Characteristics

A marked decrease in Hicks neutral efficiency differences across countries over the period, apparently implies that capital is now more uniformly available. This is perhaps due to the efforts of international development programs, and the mitigating influences of institutional and structural changes.

4. Factor Shares

1) A marked increase in the share of capital in production over the period, in both the Cobb-Douglas and CES forms, implies the existence of capital-biased technological change. Significance of the increase is shown by the Chow test of the Cobb-Douglas form.

2) The reversal of factor coefficient magnitudes between the Cobb-Douglas and CES forms is probably due to the Cobb-Douglas assumption of a unit elasticity of substitution. Since the CES estimation found neutral scale characteristics, the elasticity of substitution constraint of the Cobb-Douglas model is the only remaining difference. An assumption of a unit elasticity of substitution leads to an underestimation of the capital share, and an overestimation of labor's share in the Cobb-Douglas form. The Cobb-Douglas production function is only a special case of a more general CES production function, with scale and elasticity of substitution coefficients restricted to unity. When a CES production function is constrained to Cobb-Douglas assumptions (neutral scale characteristics and a unity elasticity of substitution), the results replicate the Cobb-Douglas results. That is, the coefficients are reversed in magnitude compared to the unrestricted CES model.
In empirical work, the growth accounting Residual represents that part of the dependent variable which remains unexplained after the explanatory independent variables are accounted for. In theory this unexplained element represents the efficiency parameter (of a Cobb-Douglas production function) incorporating technical and institutional/structural change, as well as the contribution of unmeasured factor inputs, such as those of institutions. Residual analysis is done on all the production function estimation forms. As previously noted, the Residual, in the growth accounting sense is not the residual or error term discussed in econometrics. It includes also the contributions of the intercept which represents the contributions of technology in the growth accounting context.

14. Hagen and Hawrylshyn (1969): "If one interprets the least-squares analysis not as an estimation of the production function but rather as something more akin to a factor analysis in which $R^2$ indicates the proportion of variance explained by the independent variables. One could interpret the value of $1-R^2$ in the equations including only economic inputs as in some sense a measure of the relative importance of technical change broadly defined in explaining growth rates. However, as the value of $1-R^2$ includes all the errors of measurement and "badness of fit" and is particularly upward biased by the unsatisfactory nature of the proxy for capital one is forced to use, there is a strong implication that capital is in some sense more productive marginally in LDCs. We do not, however, call these coefficients estimates of marginal productivity. That is what they would be if we assumed that $K/Y$ has the same value across our sample. Nevertheless, it seems acceptable to consider the changes of the coefficient from one time period to the next and over a different sample as being reflective of the direction of change of marginal productivity, in which case the implication of the analysis is that the marginal productivity of capital is higher in the LDCs."
The purpose of disaggregating the Residual is to gain a specification verification of the "growth source" mitigating variables to be used in the interaction testing to follow in Part 3.

The procedure for this section is:
1. to estimate the size of the Residual as a percentage of the dependent variable.
2. to estimate the portion of the Residual attributable to institutional/structural elements.

The Residuals
1. For the Cobb-Douglas production function double log form:

\[ \ln Y = \alpha_1 + \alpha_2 \ln N + \alpha_3 \ln K \]

the Residual is: \( \ln Y - \alpha_2 \ln N - \alpha_3 \ln K \)

2. An estimation of the Residual in more traditional growth accounting form is:

\[ (Y/P)G = \alpha_1 + \alpha_2 NG + \alpha_3 KG \]

the Residual = \( YG - \alpha_2 NG - \alpha_3 KG \)

If the effects of institutional and structural change are separate from the technical changes embodied in capital and labor quantities, then by definition, the analysis of the Residual captures these effects.
Table 7

Production Function Residual Determinants

1960 OLS

\[
\ln \text{RES} = 1.83 + 0.03 \ln R + 0.04 \ln A + 0.004 \ln F + 0.01 \ln L + 0.05 \ln MT
\]

\[
(99.37) \quad (4.14) \quad (4.88) \quad (3.16) \quad (2.01) \quad (x)
\]

\[d.f. = 31\]

\[R^2 = 0.62\]

\[F = 37.67 \text{ for } 1,30 \text{ d.f.}\]

1979-OLS

\[
\ln \text{RES} = 1.59 + 0.04 \ln R + 0.05 \ln A + 0.07 \ln F + 0.03 \ln L + 0.02 \ln MT
\]

\[
(22.27)(3.15) \quad (4.26) \quad (x) \quad (1.82) \quad (3.27)
\]

\[d.f. = 31\]

\[R^2 = 0.54\]

\[F = 6.89 \text{ for } 1,30 \text{ d.f.}\]

1960-CES

\[
\ln \text{RES} = 1.46 + 0.04 \ln R + 0.10 \ln A + 0.009 \ln F + 0.02 \ln L + 0.05 \ln MT
\]

\[
(47.82)(3.20) \quad (8.01) \quad (3.99) \quad (1.78) \quad (x)
\]

\[d.f. = 31\]

\[R^2 = 0.74\]

\[F = 4.61 \text{ for } 1,30 \text{ d.f.}\]

1979-CES

\[
\ln \text{RES} = -0.24 + 0.16 \ln R + 0.24 \ln A + 0.40 \ln F + 0.17 \ln L + 0.11 \ln MT
\]

\[
(-0.48)(1.57) \quad (3.17) \quad (x) \quad (1.66) \quad (2.25)
\]

\[d.f. = 31\]

\[R^2 = 0.35\]

\[F = 6.38 \text{ for } 1,30 \text{ d.f.}\]

T statistics for restricted coefficients are shown as (x), meaning invalid. Hypothesis F tests are invalid because of the restriction. The F statistics shown are for the test of the restricted coefficient value.

The regressions here show that the production function Residuals can be explained in a significant way by the institutional and structural variables. This supports their use in the interaction test of Part 3.
Residual Analysis: Efficiency Parameters and Mitigating Variables

Whereas the production function estimations explain the variation in per capita incomes across countries in terms of capital and labor factor inputs, the growth accounting Residuals generated from those estimations can be disaggregated in terms of the institutional/structural variables of which they are composed. The Residual of the 1960 to 1980 growth rate specification of the Cobb-Douglas production function is not used here. It is not compatible with the levels of the mitigating variables measured at a point in time.

The Residual explains variation in per capita income growth not attributable to traditional factor inputs. The Residuals are regressed on the mitigating institutional/structural variables chosen for this study:

The mitigating variables explain about 60 per cent of the Residual. Considering that traditional factor inputs explain about 67 per cent of total income, these results produce a combined $R^2$ in excess of 80 per cent in measuring the total contributions to total income. The Residual itself accounts for about 35 per cent of the unexplained part of the production function regressions. The mitigating variables isolated here together explain about 65 per cent of the Residual. Thus the mitigating variables together are shown to contribute about 22 per cent of the total sources of per capita income growth.

15. in terms of $R^2$ of Table 7 regressions
16. in terms of $1 - R^2$ of Table 5 regressions
The explanatory capacity of the Residual is comparable to the Solow study, which concluded that a large percentage of productivity increase in the United States came from factors other than capital accumulation.

The regression of the production function Residuals on the mitigating institutional and structural variables produces coefficients that are significant at the 5 per cent level. These results verify the mitigating variables as determinants of the growth accounting Residual that has been shown by Denison (1957) to be an important source of economic growth.

**Econometric Concerns**

1. In absence of convincing reasons to the contrary, the mitigating Residuals are estimated in log-linear form. This functional form is confirmed by the likelihood ratio test, as shown in the econometric testing appendix.

2. The same econometric issue surfaces in this exercise as in the informal modified production function based regressions of Part 1. Either the degree of multicollinearity between the institutional structural variables makes empirical disaggregation of the Residual difficult, or the degree to which the production function variables are correlated with some of the institutional/structural variables underestimates the Residual. It is likely, for example, that part of the technological change effects are drawn into the coefficients of the capital input by specification bias in the original production function estimation.
Attempts are made to disentangle these relationships. A combination of Ridge-Regression and coefficient restriction are used to determine whether one might have confidence in the results under some conditions. The objective is to justify the specification of mitigating variables for testing in the interaction model of Part 3 of this chapter. A discussion of the Ridge Regression technique is given in the econometric test appendix of this study.

Regardless of the econometric problems involved, it is clear that the institutional/structural change variables are present in the Residual, in addition to the contributions of technical change. Together, these two groups are the components of "Technology". The neutral element of technological change are captured in the efficiency parameter of the production function.
5.7 The Income/Population Relationship Over Time

The interaction test is done in a pooled regression format in which the interaction between the population density variable and the mitigating variables is tested. The way this is done is to include each of the variables individually, and an additional variable—in which the two variables of interest are multiplied together to form an interaction term. The objective of the interaction test is to determine the direction of change over time in the partial regression coefficient of one explanatory variable compared to the other one. The sign of the interaction coefficient shows whether the coefficients of the individual variables change in different directions over time. The significance of the interaction coefficient shows whether that relationship is consistent enough to be statistically significant. This is as strong an indication of causality as is possible in the regression format. That is, the increase of one coefficient is sufficiently correlated with the decrease in the other coefficient to be statistically significant, implying that one caused the other. The increase or decrease occurs over the time dimension added by the pooling of time series information with the initial cross-section regression. In the case at hand, vis a vis the population density coefficient, the partial derivative of per capita income with respect to population density in the cross-section, is reduced by institutional and structural change over time.
The interaction model explains mitigation over time for the group of countries, as a result of increasing institutional/structural efficiency.

The form of this test was specified as:

\[ \ln \frac{Y}{P} = \beta_1 + \beta_2 \frac{P}{H} + \beta_3 M + \beta_4 \left( \frac{P}{H} \right) M \]

where \( M \) is the mitigating variable to be tested.

This interaction model tests the effect of \( \left( \frac{a}{Y/P} \right) / \left( \frac{a}{P/H} \right) \) as a result of increasing levels of \( M \). Other variables may be added to the interaction model to improve the specification. However, the interaction mechanics are defined "without respect to the addition of other variables."\(^{17}\) The interaction relationships in a regression equation hold true regardless of what other explanatory variables are included in the equation. Other explanatory variables may be included for completeness. For example, an investment variable is added to complement the institutional/structural change variables. However, the issue of full and complete specification is not at stake for the purposes of the interaction model, compared to the specification completeness essential to the usual regression equation.

The interpretation of the regression is as described, that is, the effect of an increasing \( M \) over time upon the total effect of population density \( \frac{P}{H} \) upon per capita income.

---

In other words, over time, the partial derivative of per capita income with respect to population density changes in opposite directions from the partial derivative of per capita income with respect to the mitigating variable. The former becomes smaller and less significant, while the latter increases. This effect is captured by the coefficient of the interaction term. By comparing the cross-country population density coefficient with its counterpart in the pooled interaction model, one can see the decline in the population density coefficient that econometrically defines mitigation.

The sign of the interaction coefficient depends upon the interaction relationship of the two individual variables, separate from their combined form in the interaction term. Where \( Y/P \) is per capita income, \( M \) is the mitigating variable, and \( P/H \) is the population density in the form:

\[
\ln \frac{Y}{P} = \beta_1 + \beta_2\frac{P}{H} + \beta_3M + \beta_4(\frac{P}{H}M)
\]

an inverse relationship between the mitigating and the population density change effects can be substantiated in two different cases:

1) where the two individual variable coefficients are of opposite signs, the interaction coefficient will be positive:

\[
\ln \frac{Y}{P} = \beta_1 - \beta_2\frac{P}{H} + \beta_3M + \beta_4(\frac{P}{H}M)
\]

2) where the two individual variable coefficients are of the same sign, the interaction term coefficient will be of the opposite sign:

\[
\ln \frac{Y}{P} = \beta_1 + \beta_2\frac{P}{H} + \beta_3M - \beta_4(\frac{P}{H}M)
\]
It is sufficient for the validation of the mitigation effect that the interaction term coefficient be of opposite sign from the population density coefficient. However, it could be of the same sign, if the population density coefficient is small, insignificant, and negative, the mitigating variable positive, and the interaction variable coefficient negative.

The interpretation of the T statistic for significance is the same in both cases. An absolute value in the vicinity of two is sufficient for significance at the 5 per cent level, but perhaps not necessary. Kmenta\textsuperscript{18} suggests the use of an F test that can show in some cases a coefficient is significant even with failure of the T test. He notes also that when one of the interaction coefficients has a significant T statistic, the significance of F test hypothesis verification will always be confirmed.

The best functional form was found to be an exponential form of the type shown. Its fit was sufficiently better to resolve the ambiguity of functional form apparent between cross-section regressions. It is speculated that the injection of the time-dimension through the pooling process emphasizes the curvature of the functional form. The only literature referring to such a curvature is in the Low-Level Equilibrium Trap discussion where such a functional form is shown for lowest per capita income observations. Apparently the imposition of a time dimension on top of the cross-country model means that as the explanatory variables increase in magnitude, the effect upon per capita income is of the shape implied by the exponential form, for countries at this level of economic development.

\textsuperscript{18} Kmenta (1971) p.455
The shape of the curve reminds one of the savings share of income curve at the less-developed end of the Neo-Classical Model diagram used by Nelson (1956) to show a low-level equilibrium trap. Indeed work by Hazledine (1977) shows that for a sample of many of the same countries, some elements of the "trap" exist. This possible explanation for the difference in functional form is at once reasonable and consistent with other empirical work in the literature.

**Interaction Model Sample Requirements**

The test of the mitigation hypothesis requires a pooled cross-section time-series data set, (the 36 country data set pooled with the 1960, '65 '70, '75 and '79 data to capture the 20 year trend). A cross-section sample, at a point in time, cannot test the change (over time) of per capita income with respect to population density, as a function of structural and institutional variables. Likewise, a time series with no cross country variation in economic structures and institutions, cannot measure the differential relative effects of these variables (change over time of per capita income with respect to population density). Both time and country variation are required for the tests, hence the data pooling.
Use of the pooling procedure has been discussed by a number of writers. Chenery (1968) has made some comments concerning its use in development models\textsuperscript{19}. One issue is the comparability of a group of countries spanning the development spectrum with the time-path of development for a single country. This use of data pooling is a concession to data availability for LDC's. Ideally, one would like a time series for one country with sufficient observations to analyze the development process through regression analysis. Since sufficient data are not available, observations from hopefully similar countries are pooled to obtain the degrees of freedom necessary for regression analysis. It is crucial that the differences in the cross country regression structure be kept to a minimum. If it is suspected that there are enough differences between the countries such that the coefficients of the variables across countries may be regarded as random, then the pooling procedure must be questioned, and special procedures followed.\textsuperscript{20}

However, the purpose of data pooling here is not the same as that just described. The cross-country variance is acknowledged. The purpose of the pooling technique as used here is to show, given the cross-country variation, how that variation changes over time, when time series for each country are added to the cross-section.

\textsuperscript{19} Chenery and Taylor (1968)
*"Development Patterns: Among Countries and Over Time"
 p.415: "time series analyses of growth paths support the underlying hypothesis that universal factors affecting all countries are reflected in the intercountry patterns."
 p.416: the combination of time-series and cross-section analysis provides a useful basis for determining the significance of technological change and other sources of variation over time.

\textsuperscript{20} Swamy (1970): random coefficient model
Therefore the use of random coefficient techniques are not appropriate. The pooling estimation form chosen performs the sufficient task of limiting the heteroskedastic and autocorrelative bias affecting the residuals, so that the integrity of the individual observations is retained.

**Interaction Testing of Mitigating Variables**

Regression estimations of the Residual and each of the mitigating variables are shown in the following section.

While the significance of coefficients for sample separated equations for the early and later half of the full sample period is tested later in this chapter, the regressions are included here, for comparison of the coefficients with the full sample results.

1. **The Residual**

Using the results of Part 2, the production function Residual is tested as a mitigating factor. Here, the institutional and structural variables are taken as a group, incorporated in the Residual of a traditional production function with only capital and labor inputs. An interaction test between population density and the Residual shows significant mitigation of negative population density effects upon per capita incomes across countries over time. The production function Residual used here is the Cobb-Douglas growth rate form Residual. It captures production relations over the time period, making it compatible with the pooled data.
### Table 8

**Interaction Model Mitigation Results**


<table>
<thead>
<tr>
<th>Period</th>
<th>Country Type</th>
<th>Time Series</th>
<th>Equation</th>
<th>$R^2$</th>
<th>d.f.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960-70</td>
<td>36-country</td>
<td>3 time series</td>
<td>$\ln Y/P = 5.65 - .03 P/H + .94 M + .02 ((P/H)*M) + .0001 I/Y</td>
<td>.99</td>
<td>102</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(269.39) (-8.91) (35.12) (5.07) (.94)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1970-80</td>
<td>36-country</td>
<td>3 time series</td>
<td>$\ln Y/P = .38 - .03 P/H + 1.07 M + .03 ((P/H)*M) + .0001 I/Y</td>
<td>.95</td>
<td>102</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(2.43) (-9.98) (37.78) (7.22) (1.52)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1960-80</td>
<td>36-country</td>
<td>5 time series</td>
<td>$\ln Y/P = 5.14 - .04 P/H + .89 M + .02 ((P/H)*M) + .001 I/Y</td>
<td>.97</td>
<td>175</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(291.81) (-12.91) (40.5) (7.64) (55.36)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Residual (identified as the variable M) taken as a whole is used in the interaction model prior to disaggregating it into its components. The Residual used is the one generated from the Cobb-Douglas growth rate form, where the production function variables are measured in average yearly growth rates, making it more appropriate for use with the time series of mitigating variables.

The mitigating variables are disaggregated from the Residual, which contain institutional/structural change efficiency elements. These variables measure over time:

1. rural to urban structural shifts (R)
2. the increase in agricultural efficiency (A)
3. the increase in literacy (L)
4. the increase in financial efficiency through financial deepening (F)
5. the increase in the proportion of manufactured to total exports (MT)
Table 9
Rural to Urban Structural Shift


1960-70: 36-country 3 time series
\[
\ln Y/IP = 5.46 - .16 P/H + .60 R + .31 ((P/H)\times R) + .004 I/Y + .24 L \\
R^2 = .99 \\
(54.89) (-5.22) (2.01) (4.34) (10.46) (1.98) d.f. = 102
\]

1970-80: 36-country 3 time series
\[
\ln Y/IP = 5.49 - .12 P/H + 1.07 R + .19 ((P/H)\times R) + .002 I/Y + .38 L \\
R^2 = .99 \\
(89.98) (-6.01) (5.80) (4.51) (9.27) (3.08) d.f. = 102
\]

1960-80: 36-country 5 time series
\[
\ln Y/IP = 5.22 - .08 P/H + 1.69 R + .13 ((P/H)\times R) + .001 I/Y + .72 L \\
R^2 = .97 \\
(72.44) (-5.12) (7.74) (4.72) (3.90) (5.53) d.f. = 174
\]

Rural to urban structural shift

The rural-urban structural shift results (where R equals the percentage of the labor force outside of agriculture), by interpretation of the interaction term, show mitigation of population density constraints to the economic growth process. This can be interpreted as saying that those processes motivating the shift, that is, the creation of economic opportunities in urban areas, coupled with increased efficiency in the agricultural sector, contribute to per capita income growth, in spite of population density increase effects.

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Table 10
Agricultural Efficiency


1960-70: 36-country 3 time series
\[
\ln Y/P = 5.40 - .03 P/H + .06 A + .01 ((P/H)*A) + .006 I/Y + 3.40 MT
\]
\[
(84.03) (-1.52) (2.21) (1.45) (10.35) (2.50)
\]
\[R^2 = .99 \quad d.f.=102\]

1970-80: 36-country 3 time series
\[
\ln Y/P = 5.85 + .01 P/H + .06 A - .006 ((P/H)*A) + .002 I/Y + .93 MT - .76 C
\]
\[
(89.90) (1.25) (3.74) (-1.94) (6.80) (.99) (-10.57)
\]
\[R^2 = .99 \quad d.f.=101\]

1960-80: 36-country 5 time series
\[
\ln Y/P = 5.51 + .02 P/H + .08 A - .006 ((P/H)*A) + .002 I/Y + 1.81 MT
\]
\[
(125.74) (2.15) (5.22) (-2.16) (7.92) (2.28)
\]
\[R^2=.99 \quad d.f.=174\]

The A variable measures agricultural efficiency. C is a dummy variable showing that former British Colonies did less well as a group in terms of agricultural efficiency. The interpretation of the agricultural efficiency results also shows mitigation of population density restraints to the economic growth process from the interaction term. Of interest is Bizien (1979)\(^21\)

"The model result that seems to us counterintuitive is that regardless of the production function's elasticity of substitution, a labor-augmenting improvement in agricultural production techniques reduces desired fertility."

The implication is that this change not only reduces the influence on population density on per capita income through mitigation, but also reduces the direct effect by reducing the rate of population density increase.

\(^{21}\) Bizien (1979) p.146

1960-70: 36-country 3 time series

\[ \ln \frac{Y}{P} = 5.31 - .09 P/H + .65 F + .16 (P/H \times F) + 1.66 R + .004 I/Y \]

\[ (71.25) (-4.38) (2.83) (3.11) \]

\[ R^2 = .99 \quad d.f. = 102 \]

1970-80: 36-country 3 time series

\[ \ln \frac{Y}{P} = 5.41 - .08 P/H - .02 F + .10 (P/H \times F) + 1.76 R + .002 I/Y \]

\[ (77.69) (-.85) (-.08) (2.62) \]

\[ R^2 = .99 \quad d.f. = 102 \]

1960-80: 36-country 5 time series

\[ \ln \frac{Y}{P} = 5.21 - .04 P/H + .11 F + .04 (P/H \times F) + .001 I/Y + 2.02 R \]

\[ (108.13) (-2.89) (.97) (1.33) \]

\[ R^2 = .99 \quad d.f. = 174 \]

The \( F \) variable measures the effects of financial deepening. The financial deepening variable shows significant mitigation effects, but gives the weakest results of the mitigating variables, probably due to an omitted source of variation in the sample. From analysis of the data set, there is an apparent tendency for former members of the British Empire to have a higher ratio of \( M_2/GDP \) than would be expected for their level of development. Use of a dummy variable to control for this characteristic is shown to improve the results by controlling for this anomaly. This is shown in sample separation tests to follow.
Table 12

Literacy


1960-70: 36-country 3 time series

\[
\ln Y/P = 5.11 - .04 P/H + .12 L + .04 ((P/H)*L) + .003 I/Y + 1.63 R
\]

\[
(93.90) (-2.37) (.91) (1.47) (9.89) (7.42)
\]

\[R^2 = .99 \quad \text{d.f.} = 102\]

1970-80: 36-country 3 time series

\[
\ln Y/P = 5.33 - .04 P/H + .31 L + .03 ((P/H)*L) + .002 I/Y + 1.42 R
\]

\[
(52.45) (-2.07) (1.48) (.82) (8.46) (8.78)
\]

\[R^2 = .99 \quad \text{d.f.} = 102\]

1960-80: 36-country 5 time series

\[
\ln Y/P = 5.09 - .03 P/H + .42 L + .06 ((P/H)*L) + .00001 I/Y + 1.87 R
\]

\[
(67.26) (-2.27) (3.00) (2.93) (4.84) (10.54)
\]

\[R^2 = .94 \quad \text{d.f.} = 174\]

The literacy variable in the interaction model measures the effects of increasing literacy levels upon per capita income and population density. The consistency and strength of the literacy variable as a mitigating influence is evident from the results. The growth of literacy, and education in general in LDCs, is a result of institutional changes in broad cultural and economic values. The development of a skilled labor force through the growth of human capital is a later result of the initiating institutional changes. The literacy variable is positively correlated with the change in production emphasis from rural to urban. This indicates that literacy, which was less important in a traditional agricultural setting, becomes more important to the development of the institutional infrastructure associated with manufacturing and foreign trade.

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Table 13
Manufactured Trade


1960-70: 36-country 3 time series

\[
\ln Y/P = 5.18 - .04 \frac{P}{H} + 2.60 \text{MT} + .42 (\frac{P}{H} \times \text{MT}) + 1.56 R + .004 \frac{I}{Y}
\]

\[
(95.83) (-3.09) (2.85) (2.02) (9.50) (13.03)
\]

\[ R^2 = .99 \quad \text{d.f.}=102 \]

1970-80: 36-country 3 time series

\[
\ln Y/P = 5.40 - .03 \frac{P}{H} + 10.26 \text{MT} + .41 (\frac{P}{H} \times \text{MT}) + 1.71 R + .002 \frac{I}{Y}
\]

\[
(95.83) (-3.09) (11.30) (2.02) (9.50) (13.03)
\]

\[ R^2 = .99 \quad \text{d.f.}=102 \]

1960-80: 36-country 5 time series

\[
\ln Y/P = 5.20 -.005 \frac{P}{H} + 3.28 \text{MT} + .11 (\frac{P}{H} \times \text{MT})+ 2.08 R + .002 \frac{I}{Y}
\]

\[
(90.99) (-.49) (5.74) (3.11) (15.27) (2.56)
\]

\[ R^2 = .94 \quad \text{d.f.}=174 \]

The MT variable measures trade in manufactured goods. Structural change in the form of export increases shows a significant contribution to per capita income growth. Indeed, fortuitous timing in policy decisions regarding exports (institutional change) shows that the change in export emphasis from primary to manufactured goods enabled the contribution to occur with even greater success than would otherwise have been possible. This was noted in a case study of the Korean economy.
Summary of Interaction Model Results

The interaction testing provides an important part of the mitigation hypothesis test. The interaction test results show that the significant partial relationships between the mitigating variables and per capita income, as opposed to those between population density and per capita income, change in opposite directions. This result, as measured by the interaction term, is significant for most of the mitigating variables, and of the expected sign for hypothesis confirmation.

Test of Mitigation-Investment Substitution

What is the degree to which institutional/structural changes and investment are complements or substitutes? That is, where economic growth is occurring, do we find these two factors occurring together equally, or do we find that they can substitute for each other?

In this case the mitigating Residual and the investment variables are combined into an interaction variable. It is shown that across countries over the time period, there was significant substitution found between mitigation and increased investment. That is, in those countries which experienced per capita income growth, increased investment made significant contributions, but there was a significant degree to which otherwise insufficient investment was compensated for by mitigating changes.
Table 14
Investment/Mitigation Substitution

1960-80: 36-country 5 time series

\[
\ln Y/P = .91 - .03 P/H + .006 I/Y + .72 M + .0006 (I*M) \quad R^2 = .99
\]

(6.36) (-6.18) (5.48) (32.90) (5.24) \quad d.f.= 175

The results show that both investment and the mitigating institutional/structural variables make positive and significant contributions to the increase of per capita income levels over time. However, the coefficient of the interaction variable shows that over the time period across countries, there are significant levels of substitution between investment and the mitigating variables. This implies that where investment goods are not available for some reason, with respect to increasing per capita incomes, the mitigating effects of institutional and structural change can somewhat substitute for lack of investment. Thus where economic growth occurred, varying combinations of investment and mitigating variables are responsible for the growth. The possibility of partial substitution for inadequate investment by mitigating changes is an additional conclusion of this study, helpful in explaining the intermediary determinants of the population density and per capita income relationship.
5.8 **Sample Separation**

To determine the significance of results shown by separating the sample in several interesting ways, dummy variable testing is done to determine the significance of sample separation. A dummy variable is given the value of one for the lower per capita group of LDCs and zero for the other group. For the separation of continents two dummy variables are used. The first takes a value of one for the Asian sub-sample, and zero otherwise. The second dummy variable is given a value of one for the African countries and a zero value otherwise. This enables one to separate the continental variance in results by interpretation of the dummy variable coefficients. The colonial influence sample separation is done in the manner of the per capita income separation, such that the former colonial countries have a dummy value of one, and the rest of the sample has a value of zero.

**Sample Separation by Per Capita Income Grouping**

When the 36 country sample set is divided between high and low per capita income countries, the 180 observation pooled cross-section time series data set shows a clear trend between low and high per capita income countries of the set. In accordance with the hypothesis, the pooled interaction results show population density having a stronger negative influence in the low per capita income set. Accordingly, the mitigating variables show a stronger positive effect in the high per capita income set of LDCs.
Table 15
Sample Separation by Per Capita Income Group

\[ \ln Y/P = 5.37 - .04 P/H + .96 M + .02 ((P/H)*M) + .0003 I/Y - .27 Dum \]
\[ R^2 = .98 \]
\[ (267.27)(-9.16) \quad (66.32)(7.38) \quad (1.03) \quad (-11.45) \]

\[ \ln Y/P = 5.73 - .04 P/H + .47 R + .11 ((P/H)*R) + .001 I/Y + .77 L - .82 Dum \]
\[ R^2 = .98 \]
\[ (70.60)(-3.21) \quad (2.28) \quad (3.98) \quad (9.75) \quad (7.33) \quad (-12.16) \]

\[ \ln Y/P = 6.07 + .05 P/H + .05 A - .004 ((P/H)*A) + .001 I/Y + 2.26 MT - 1.02 Dum \]
\[ R^2 = .90 \]
\[ (73.88)(5.09) \quad (4.69)(-1.82) \quad (7.44) \quad (3.91) \quad (-11.24) \]

\[ \ln Y/P = 5.67 - .01 P/H + .56 L + .05 ((P/H)*L) + .001 I/Y + .80 R - .81 Dum \]
\[ R^2 = .99 \]
\[ (91.53)(-1.19) \quad (4.99)(2.11) \quad (9.93) \quad (4.42) \quad (-12.47) \]

\[ \ln Y/P = 5.59 + .009 P/H + .15 F + .01 ((P/H)*F) + 1.52 R + .001 I/Y - .70 Dum \]
\[ R^2 = .99 \]
\[ (65.61)(.72) \quad (1.56)(.48) \quad (9.24) \quad (9.41) \quad (-8.54) \]

\[ \ln Y/P = 6.04 + .05 P/H + 4.04 MT - .21 ((P/H)*MT) + .03 A + .001 I/Y - 1.03 Dum \]
\[ R^2 = .99 \]
\[ (87.32)(6.18) \quad (7.38)(-4.63) \quad (5.34) \quad (9.07) \quad (-12.56) \]

\[ \ln Y/P = 5.67 + .02 P/H + 2.26 MT - .11 ((P/H)*MT) + 1.31 R + .002 I/Y - .79 Dum \]
\[ R^2 = .97 \]
\[ (68.90)(2.47) \quad (3.29) \quad (8.48) \quad (7.90) \quad (-9.88) \]

A dummy variable given the value of 1 for the low income section shows significant differences. Comparison between the high and low per capita income sample divisions shows gains in agricultural efficiency to be of main importance to the lower per capita income sample. The higher per capita income sample has relatively greater contributions from literacy improvements, financial deepening and manufactured trade. This supports the analysis of Paul Kuznets (1977) in describing the sources of Korea's economic growth. Population density coefficients are less negative in the higher per capita income sample. The interaction terms correspondingly, show the divergence in change between the change in population density coefficients and the institutional/structural coefficients.
Table 16
Sample Separation by British Colonial Influence

\[
\ln Y/P = 2.22 - .01 P/H + .97 M + .02 ((P/H)^M) + .0004 I/Y - .01 Dum
\]
\[R^2=.99 \quad (220.03)(-12.66)(385.75)(11.16) \quad (2.50) \quad (-1.61)
\]

\[
\ln Y/P = 5.52 -.03 P/H + .79 R + .08 ((P/H)^R) + .001 I/Y + .59 L - .56 Dum
\]
\[R^2=.99(101.70)(-4.12)(4.31) (3.59) \quad (10.46) \quad (5.70) \quad (-13.74)
\]

\[
\ln Y/P = 5.77 +.04 P/H + .07 A -.007 ((P/H)^A) + .001 I/Y + 2.48 MT -.87 Dum
\]
\[R^2=.96 \quad (99.95)(4.67) (5.06) \quad (-2.82) \quad (7.30) \quad (3.91) \quad (-13.55)
\]

\[
\ln Y/P = 5.77 -.02 P/H + .36 L +.04 ((P/H)^L) + .001 I/Y + 1.03 R -.67 Dum
\]
\[R^2=.97(103.87)(-1.97)(3.61) (2.30) \quad (10.68) \quad (6.93) \quad (-14.82)
\]

\[
\ln Y/P = 5.47 -.02 P/H +.08 F +.02 ((P/H)^F) +1.50 R + .001 I/Y -.68 Dum
\]
\[R^2=.94(127.15)(-.21) (.95) (2.30) \quad (12.85) \quad (9.96) \quad (-11.73)
\]

\[
\ln Y/P = 5.79 +.04 P/H +4.03 MT -.23 ((P/H)^MT) +.03 A +.001 I/Y -.90 Dum
\]
\[R^2=.94(108.82)(5.15) (5.45) \quad (-4.49) \quad (4.68) \quad (7.16) \quad (-14.82)
\]

\[
\ln Y/P = 5.53 +.01 P/H +2.24 MT -.09 ((P/H)^MT) +1.37 R +.001 I/Y -.77 Dum
\]
\[R^2=.95(284.70)(1.41) (3.75) \quad (-2.12) \quad (15.77) \quad (7.93) \quad (-20.07)
\]

The degrees of freedom are 173 for each regression but the first with 174.

A dummy variable (equal to 1) controlling for British colonial influence shows significant negative explanatory power. The results show that former British colonies are significantly distinguished from the rest of the sample. The differences are perhaps attributable to a uniformly higher population density than the rest of the sample, and at least one characteristic institutional structural difference. It has been noted in work with the data set that the former British colonies have a relatively higher level of the \( M_2/GDP \) measure of the \( F \) variable that is not reflected in per capita income levels. The dummy variable is especially strong in its influence on financial deepening and the development of manufactured trade. It was observed that both of these variables had consistently higher levels in former British colonies, that were not accompanied with an expected higher per capita income.
Whether this phenomenon is explained by the British colonial influence, or is due to cultural phenomena indigenous to those areas is unknown.

Separation by Continental Area

The division of the sample into continental areas shows that the Asian countries have had greater success in implementing the mitigation concept. The Asian countries experience the most mitigation as seen in the relative strengths and significance of the interaction coefficients. The Asian countries as a group have experienced the most economic growth over the whole sample. The Asian country sample shows the strongest mitigation as well as population density effects. Associated with their growth has also been a stronger role of external development aid channelled through the ASEAN and Asian Development Bank organizations. The existence of these organizations, in itself represents the mitigating essence of institutional change.

The African and the South American countries have had less success. It is speculated that this is the result of indigenous political peculiarities and certain geophysical characteristics. Likely candidates of these might be the great inequality in political power between groups in both areas, the extent of mountainousness and unfertile rain forest in South America, and the degree of desertification and land infertility in Africa. While overall population density poses a constraint on economic growth, apparently the degree of dispersion of arable land is also important.
Table 17
Sample Separation by Continental Area

\[ \ln \frac{Y}{P} = 2.24 - .01 P/H + .97 M + .002 ((P/H) \times M) - .00004 \frac{I}{Y} - .04 D_1 + .002 D_2 \]
\[ R^2 = .99 \quad (186.75)(-10.71)(345.71)(8.76) \quad (-1.74) \quad (-5.38) \quad (.34) \]

\[ \ln Y/P = 5.63 - .04 P/H + .59 R + .11 ((P/H) \times R) + .001 \frac{I}{Y} + .74 L - .79 D_1 - .21 D_2 \]
\[ R^2 = .99 \quad (68.33)(-3.79)(2.85)(4.66) \quad (10.21) \quad (6.69) \quad (-10.71) \quad (-3.19) \]

\[ \ln Y/P = 5.92 + .04 P/H + .06 A - .007 ((P/H) \times A) + .002 \frac{I}{Y} + 3.05 MT - 1.09 D_1 - .37 D_2 \]
\[ R^2 = .93 \quad (88.90)(5.07)(4.93)(-3.07) \quad (8.31) \quad (5.11) \quad (-13.76) \quad (-6.20) \]

\[ \ln Y/P = 5.61 - .009 P/H + .41 L + .07 ((P/H) \times L) + .002 \frac{I}{Y} + .91 R - .85 D_1 - .19 D_2 \]
\[ R^2 = .99(63.20)(-.99)(3.49)(3.98) \quad (9.75) \quad (4.98) \quad (-10.29) \quad (-2.57) \]

\[ \ln Y/P = 5.48 + .002 P/H + .06 F + .02 ((P/H) \times F) + 1.54 R + .001 \frac{I}{Y} - .77 D_1 - .09 D_2 \]
\[ R^2 = .92(73.45)(.23)(.67)(.88) \quad (10.20) \quad (9.60) \quad (-9.92) \quad (-1.33) \]

\[ \ln Y/P = 5.95 + .05 P/H + .488 MT - .26 ((P/H) \times MT) + .03 A + .001 \frac{I}{Y} - 1.12 D_1 - .39 D_2 \]
\[ R^2 = .93(95.10)(6.35)(7.22)(-6.01) \quad (4.22) \quad (8.47) \quad (-14.83) \quad (-6.60) \]

\[ \ln Y/P = 5.63 + .01 P/H + 2.51 MT - .11 ((P/H) \times MT) + 1.22 R + .001 \frac{I}{Y} - .87 D_1 - .19 D_2 \]
\[ R^2 = .93(76.20)(1.63)(3.35)(-2.05) \quad (8.31) \quad (8.45) \quad (-12.42) \quad (-3.06) \]

the degrees of freedom = 172 for each regression
Dummy variables are D_1 (1 = Asia) and D_2 (1 = Africa)

(text continued) An index might be formed by adding the degree of arable land dispersion to the population density variable. However, this might unduly complicate the variable's interpretation, and so, has not been done.

The African countries show the reverse situation from that of the Asian countries. Africa shows the strongest effect of population density constraints with minimal mitigating effects. The mitigation in Africa has been less and the negative effects of population density stronger.
The South American sample results are somewhat ambiguous. South America shows little mitigation relationship between population density and institutional/structural variables. With the exception of manufactured trade and rural to urban shift, traditional growth sources such as investment and increased education seem to be most important.

The sample division testing supports and emphasizes the general results, showing that greater mitigation occurred in those countries of the LDC sample which have experienced greater economic growth.

Significance of Coefficient Changes Between Time Periods

When the 36 country sample set is divided into pre- and post 1970 samples, differential strengths among the mitigating variables at different points in the sample period are indicated, in addition to the declining significance of population density. Some of the mitigating variables are relatively stronger early in the period and decline in importance, where others increase in value and significance over the entire period. Rural to urban changes and the increase in agricultural efficiency show mitigating effects (against population density) that increase over the growth process in aiding per capita income growth. While the most important mitigating factor may vary depending upon country-specific conditions, as well as its stage of development, the results of testing support the hypothesis advanced.

Chow tests of the population density coefficients show a significant decline in the value of the partial regression coefficients between the two time periods. These tests are described in greater detail in the econometric testing appendix.
Table 18

1960-70
\[
\ln Y/IP = 5.65 - 0.03 P/H + .94 M + .02 ((P/H)*M) + .0001 I/Y
\]
(269.39) (-8.91) (35.12) (5.07) (.94)
\[
\ln Y/IP = 5.46 - .16 P/H + .60 R + .31 ((P/H)*R)+ .004 I/Y + .24 L
\]
(54.89) (-5.22) (2.01) (4.34) (10.46) (1.98)
\[
\ln Y/IP = 5.40 - .03 P/H + .06 A + .01 ((P/H)*A) + .006 I/Y + 3.40 MT
\]
(152.65) (-1.52) (1.45) (9.35) (2.50)
\[
\ln Y/IP = 5.11 - .04 P/H + .12 L + .04 ((P/H)*L) + .003 I/Y + 1.63 R
\]
(93.90) (-2.37) (.91) (1.47) (9.89) (7.42)
\[
\ln Y/IP = 5.31 - .09 P/H + .65 F + .16 ((P/H)*F) + 1.66 R + .004 I/Y
\]
(71.25) (-4.38) (2.83) (3.11) (9.26) (13.53)
\[
\ln Y/IP = 5.18 -.04 P/H + 2.60 MT + .42 ((P/H)*MT) + 1.56 R + .004 I/Y
\]
(95.83) (-3.09) (2.85) (2.02) (9.50) (13.03)
\[R^2 = .99 \text{ and d.f.} = 174 \text{ for each but the first equation with d.f.} = 175\]

1970-80
\[
\ln Y/IP = .38 - .03 P/H + 1.07 M + .03 ((P/H)*M) + .0001 I/Y
\]
(2.43) (-9.98) (37.78) (7.22) (1.52)
\[
\ln Y/IP = 5.49- .12 P/H + 1.07 R + .19 ((P/H)*R)+ .002 I/Y + .38 L
\]
(89.98) (-6.01) (5.80) (4.51) (9.27) (3.08)
\[
\ln Y/IP = 5.85 +.01 P/H + .06 A - .006 ((P/H)*A)+.002 I/Y + .93 MT - .76 C
\]
(89.90) (1.25) (3.74) (-1.94) (6.80) (.99) (-10.57)
\[
\ln Y/IP = 5.33 -.04 P/H + .31 L + .03 ((P/H)*L) + .002 I/Y + 1.42 R
\]
(52.45) (-2.09) (1.48) (.82) (8.46) (8.78)
\[
\ln Y/IP = 5.41 -.08 P/H - .02 F + .10 ((P/H)*F) + 1.76 R + .002 I/Y
\]
(77.69) (-4.85) (-.08) (2.62) (14.45) (13.27)
\[
\ln Y/IP = 5.40 -.03 P/H + 10.26 MT+.41 ((P/H)*MT) + 1.71 R + .002 I/Y
\]
(95.83) (-3.09) (11.30) (2.02) (9.50) (13.03)
\[R^2 = .99 \text{ and d.f.} = 174 \text{ for each but the first equation with d.f.} = 175\]

and \[R^2 = .95, \text{ and the third equation with d.f.} = 173, \text{ where C is a dummy variable representing British colonial influence.}\]
Analysis of the early and later period results gives the following points of comparison, providing additional support of the mitigation hypothesis:

1. between the early and later samples, the population density coefficients became less negative.

2. the contribution of the institutional/structural variables increased in magnitude from the first through the second period. The change in the distribution of rural/urban labor and the increase in agricultural efficiency in the earlier period, were joined by increased contributions of financial deepening and manufactured trade in the second period.

3. the interaction term coefficients maintain about the same level of magnitude and significance.

5.9 Summary of Empirical Results

The consensus of the results is that the process of economic growth for LDCs is characterized by a mitigation of population density constraints to growth, by the implementation of appropriate institutional and structural changes. This explains the variation in economic growth across LDC countries.

In regression work that has improved the specification over previous work found in the literature, the negative partial regression coefficient of per capita income, with respect to population density across countries, was found to increase markedly in negativity between 1960 and 1980.
However, in a pooled interaction model, the effects of institutional and structural change variables interacting with population density conditions over the 1960-80 time period show no increase and some decrease in the population density coefficients:

1. In cross-country LDC regressions institutional/structural variables show a positive and significant correlation with per capita incomes and a population density coefficient that is strongly negative. Cross section regressions done for the beginning and the end of the period show population density coefficients increasing markedly in absolute value (becoming more negative) across countries. This means that across countries population density differences were more negatively correlated with per capita incomes at the end of the period than at the beginning. Population density effects were becoming more negative and significant determinants of per capita incomes. In the cross country regressions the population density variable is negative and significant at the 5 per cent level. The mitigating variables show significant positive correlations with per capita income across countries.

2. Combined with time-series data in a pooled sample that shows change in the foregoing cross-country relationships over time, the interaction results show that the institutional/structural variable changes in the opposite direction from the population density coefficient. This means that as the partial effect of institutional and structural change upon per capita income increases, the partial effect of population density change upon per capita income decreases, in a statistically significant way.
Comparing the result of the Part 1 cross-section regression with the result of the Part 3 interaction test gives the result for the test of the mitigation hypothesis. In the cross-section results the population density coefficient is negative, relatively large in absolute value, and significant. Over time, as shown in the pooled regression, the population density coefficient declines in absolute value. It becomes less negative and less significant, correlated with increases in the levels of the mitigating variables. This is measured through the interaction test. By the decline in importance of population density over time, where it is correlated with an increase in mitigating variables, the mitigation hypothesis is shown to be fully supported.

Compared to the cross-section relationships across countries, with the addition of the time dimension in the pooled sample:

where countries change their institutional and structural characteristics, the population density effects declines in negativity and significance. The population density coefficients become more negative and significant determinants of per capita income.

This result defines and thus confirms the mitigation hypothesis. This test confirms the "mitigation hypothesis" that institutional and structural changes over time can lessen or "mitigate" the negative economic effects of population density growth.

In sum, the results favor the hypothesis of the mitigating activity of the variables tested, and support the hypothesis that institutional and structural change can reduce the influence of population density constraints to some extent, aiding in the growth process.
The implications of these results strongly support the hypothesis that technical change alone is not responsible for economic growth. Further, the original definition of technological change, which included the contributions of institutional structural components, in addition to the technical changes embodied in capital goods, is substantiated.

In the production function format, institutional and structural change is measured as efficiency differences. The Cobb-Douglas and CES forms estimated for 1960 and 1979 both support the hypothesis that efficiency differences caused by institutional/structural factors explain per capita income differences across LDCs. Perhaps due to the success of development programs, these efficiency differences have declined since 1960. Testing of the production function Residuals confirms the identity of the mitigating variables as the efficiency factors.

The interaction model gives a direct test of the mitigation hypothesis. Across countries the partial relationship of population density with respect to per capita incomes is negative and significant at the 5 per cent level. Over time, in the presence of institutional and structural change, the negative cross-country relationship between population density and per capita incomes becomes less negative and less significant in most cases, for tests of the individual mitigating variables. The structure of the test is such that it shows the effect on the population density coefficient of an increase in the mitigating variable in question.

Sample separation tests show that the influence and significance of population density decline as incomes rise across countries. Also, geographic differences of a minor order show up when the sample is divided by continental location.
CHAPTER VI
CONCLUSION, COMMENTS, AND CAVEATS

6.1 Summary

The particular kind of economic underdevelopment common to LDCs, traceable to exogenously introduced public health improvements, makes the development context for 20th Century LDCs different from that of the development of European countries in the 19th Century. In modern LDCs, increased population growth rates and densities have caused a variety of constraints upon economic growth. Per capita incomes have grown slowly or not at all in many LDCs.

Concern over the effects of population growth and density upon per capita incomes is justified in LDCs, where capital scarcity is a hindrance to the economic growth process. However, as suggested in this study, the ability to make effective institutional and structural changes can, to some extent, mitigate the population effects and lessen their negative influence upon the economic growth process.

This study has presented a hypothesis of how institutional and structural change in LDCs can reduce the constraints created by the burgeoning of population densities in the 20th century. The mitigation of these constraints is shown empirically through regression analysis. Results show that compared to the cross-country variations in per capita income attributable to population densities, over time where institutional and structural change occurs, the population density effects become significantly less severe. This fact, which has been called the mitigation effect in this study, explains the ability of some LDCs to experience economic growth, while others have not.

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6.2 Qualifying Notes and Discussion

Theoretical Notes

The major qualification to the results, which are in themselves quite satisfactory, is the lack of specific prescriptive power for individual countries, given the fact that the cross-country sample homogenizes many cultural and situation-specific differences between LDCs. Nonetheless the mitigation hypothesis goes far in explaining why institutional and structural changes are important for LDCs attempting to make the transition to the "virtuous circle" of developed countries.

The pursuit of institutional effectiveness and efficient factor allocation over economic sectors occurs in the "second best" world of transactions costs and government policy. Given the interrelationships of institutions and structural characteristics, according to second best theory, guidelines for global optimality are compromised by shortcomings in any one sub-element of the global system. The possibility of negative cross-effects between policies must also be weighed. How far the pursuit of one "mitigating policy" should be pursued must consider these cross-effects and the global optimum sought. For example an excessive rural to urban shift in sectoral production may result in social external costs of "urban blight", and may bring about an actual decline in the effectiveness of urban institutional infrastructure. Due to national income accounting procedures, gross national product would also not reflect these social costs. Fortunately some of the elements of global institutional/structural effectiveness are sufficiently discreet and separable such that appropriate guidelines are relatively determinate.
The "equilibrium interest rate policy" for the effectiveness of financial institutions is one example. Policies affecting the structural distribution of production, through subsidies, taxes, and tariffs, on the contrary, must be handled with extreme care. This is true both with respect to the direct economic effects of the policies and the side-effects upon related institutional and structural characteristics. The presence of "second best" reality is neither an excuse for "laissez faire" in the presence of institutional inadequacy, nor for the rigidity of a command economy. It requires an integrated search for a global optimality of institutional effectiveness and structural characteristics, within the complexities of the world of economic activity.

The transition made from the low levels of per capita income which define LDCs, is evidenced by the reduction of population density influence through the mitigation process. The success of "mitigation" in correcting factor disequilibrium (in the Eckaus sense), shows itself in the decline of efficiency differences between countries, as determined by production function analysis. The association between population density constraints upon the level and growth of per capita income, when institutional changes have been made, is circumstantial evidence of the mitigation hypothesis' validity.

Econometric Notes

The most important empirical caveats in this study are predictably the level of aggregation and the ability to capture the simultaneous and interactive nature of institutional/structural change variables. As Solow (1957) has noted, the interest of the questions posed by a model can justify otherwise unacceptable levels of aggregation.
Despite the aggregate nature of the institutional change variables used in the empirical study, their contribution to the growth process across LDC countries, and through time, shows economic significance. The concessions to aggregation made here appear justified, for the results are instructive and supportive of the theoretical hypothesis posed.

The choice of variables is often a concession to the reality of information and data scarcity. This is true whether one refers to the choice of per capita income to represent economic development level, or \( M_2 \)/GDP to represent the level of financial development. But two relevant facts support the analysis presented in this study:

1. The specification used here is a substantial advance over the bivariate models seen in the previous economic literature.
2. The variables chosen here have been used elsewhere in published articles in accepted journals. Exceptions are the capital stock and growth variables, for which an estimation method was designed, based on previously accepted methods.

The limitations of multicollinearity encountered in the extension of specification from earlier literature models may bias the relative contributions of the chosen variables to some degree, but does not question their justification as specified variables. The specification of the mitigating variables is justified originally on theoretical grounds and supported empirically. The completeness of specification is as great as data availability permits.

The empirical model is not excessively large or complex and the number of LDCs is limited by reasonable criteria. The empirical test structure is circumscribed by the definition of the hypothesis.
The interactive model has the advantage of providing a simple test of the hypothesis. The mitigating variables are few in number, but they have the advantage of being economically sound, compared to the político-socio-economic indexes used as proxies for economic development determinants in the Adelman (1968) study.

The temptation to apply conclusions drawn from cross-country relationships to individual countries' path of change through time is fraught with warning. However, a number of prominent authors (e.g. Chenery, Suits) have stated that within limits, such a formulation is reasonable and empirically supported. The analogy between the structure of the cross-section development spectrum of countries and the growth time-path of one country for the purposes of theoretical comparison is justifiable. Extending this conclusion to the pooling of data between cross-sections and time series is also justifiable, given the theoretical analogy, and given the fact that for most LDCs, sufficiently extensive and complete time series data are not available. However, the purpose in this study is not to pretend that a pooled data set represents the experience on one country over time. Rather it is to show change in cross-country variation when time series information is added to the model. This purpose is thus less at risk to receive the usual pooled data criticisms.

1. Higgs (1980): "'Surely, any history of an economy's growth will today be no more, and no less than a parable agreed upon.' Growthmen could do worse than to employ a parable that has at least some cross-sectional consistency with the evidence of economic history."
Hypothesis tests (T and F statistic tests) ascertain the validity of the regression coefficients. Sample separation is done to check the heuristic reasonableness of the results, and is tested by dummy variable analysis for significance.

The question of causality is an econometric question relating to two levels of discussion:

1. Statistically, regression estimation shows correlation and does not prove causality. However, with the use of coefficient and hypothesis test procedures, significance tests give a valid regression analysis in a practical sense.

2. This abstracts from the metaphysical level of discourse where Proof as an Absolute measure would find all statistical results trivial.

While this type of model defies the same exactitude, for example, as demand analysis, the value of modelling these phenomena is considerable, and relatively new to the literature on population and economic development. It is thought that the approach presented in this study goes beyond the saving-consumption trade-off effect, which has been the major credible effect described in the literature to date. It is also more tangible than the socio-political studies which rely on variables such as indices of political stability.

Countries where more detailed data are available should benefit from this aggregate example in viewing the relative effects of differing institutional and structural change scenarios. The importance of institutional environment and the sectoral distribution of economic activity applied to specific development situations should be of interest for policy-makers in LDCs.
6.3 Findings, Implications, Contributions

The findings of this dissertation:

1. confirm the importance of population density growth as a major factor inhibiting the development process in LDCs.
2. discuss, in a production function and growth accounting context, the effect and measurement of institutional and structural change in mitigating population density inhibitions to economic growth.
3. show the function and measurement of institutional and structural change through a number of economic variables.

It is found that the negative effects of high population density levels, significantly associated with low levels of per capita income across LDCs, can be reduced in influence through appropriate institutional and structural change. This suggests the prerequisite of viable institutional arrangements and appropriate structural changes for economic activity to generate economic growth.

The implications of this dissertation are:

1. that increasing population density levels should be a concern for LDCs, contrary to some current suggestions in the literature.
2. that institutional and structural change can act in ways similar to technical change to promote growth in LDCs.
3. that the management of economic institutions and the guidance of appropriate structural change can somewhat mitigate the initially adverse effects of increasing population densities in LDCs.
Table 19
Economic Growth and Mitigation by Country Rank

<table>
<thead>
<tr>
<th>Rank by Economic Growth Index</th>
<th>Rank by Mitigation Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Korea</td>
<td>1. Portugal</td>
</tr>
<tr>
<td>2. Portugal</td>
<td>2. Brazil</td>
</tr>
<tr>
<td>3. Brazil</td>
<td>3. Pakistan</td>
</tr>
<tr>
<td>5. Ecuador</td>
<td>5. Algeria</td>
</tr>
<tr>
<td>6. Indonesia</td>
<td>6. Ecuador</td>
</tr>
<tr>
<td>7. Malaysia</td>
<td>7. Malaysia</td>
</tr>
<tr>
<td>8. Turkey</td>
<td>8. Turkey</td>
</tr>
<tr>
<td>10. Egypt</td>
<td>10. Columbia</td>
</tr>
<tr>
<td>11. Columbia</td>
<td>11. Thailand</td>
</tr>
<tr>
<td>12. Pakistan</td>
<td>12. Tanzania</td>
</tr>
<tr>
<td>15. Philippines</td>
<td>15. Nigeria</td>
</tr>
</tbody>
</table>

Thirteen out of fifteen of the countries ranked by average yearly economic growth also occur in the ranking by mitigation over the 1960-1980 period. The indices for economic growth and mitigation are the values for the per capita income growth and mitigation (M) variables.
The implications of this study suggest that greater attention be paid by economic development planning both toward population density growth policy and effective institutional and structural change, to improve the per capita income status in LDCs. Indeed in recent development programs, where attention has been paid to these elements, economic growth has resulted. The extended modelling and methodology of the topic presented in this paper, makes a significant contribution to the literature on the relationship between population and income characteristics (under various specifications), and the potential for economic growth and development in LDCs.

The contributions of this dissertation are:

1. a new viewpoint on the population density and national per capita income relationship, extending the literature on the general issue of population effects upon economic conditions.

2. a closer inspection of the components of technological progress, as disaggregated from a growth accounting Residual derived from the efficiency parameters of a production function. This extends the growth accounting literature to an application for LDCs.

3. a view of new possibilities for development efforts in LDCs, through the implementation of appropriate structural and institutional changes, that reduce the influence of population density upon economic conditions. This is called the "mitigation hypothesis". Its implications extend the economic development literature.

4. a novel empirical technique in the estimation of capital stock, and a discussion of means to reduce the bias of cross-country differences in regression analysis.
APPENDIX A
TESTING AND CORRECTIVE PROCEDURES

Hypothesis Confidence Testing: testing done on estimation procedures.

**OLS**

T test of individual variables

F test of hypothesis validity—tests whether all coefficients are not significantly different from zero.

Park-Glejser test for sample heteroskedasticity—with GLS correction

Chow Test of coefficient comparability

**Non-linear:** CES production function estimation

T test of parameter coefficients

**Pooled regressions**

The interaction model is used to test the significance of coefficients, under the hypothesis that the interacting variables have opposite sign effects upon the dependent variable. The T test is used to test the significance of parameter coefficients. The F test of hypothesis validity tests whether all coefficients are not significantly different from zero. However, the presence of significant T tests in the interaction model make the construction of F tests unnecessary, as noted by Kmenta (1971). The use of dummy variables adds precision to the sample separation methodology by the ability to test the significance of the sample separation without separating the sample, thus maintaining the full degrees of freedom.
Functional form, Autocorrelation, Multicollinearity, and Specification

A sequence of tests is used to gain information about the regressions:

1. **Likelihood Ratio Tests**, in the general case allows the testing of hypotheses about regression parameters using the ratio of restricted and unrestricted likelihood functions to see the compatibility of the information contained in the hypotheses and the sample. This involves testing the null hypothesis $H_0$ against hypothesis $H_1$ to reject the null hypothesis if the critical value of the test statistic is greater than some critical value that is determined for a given significance level for the random variable with $(T-K)$ degrees of freedom.

   The particular form of the likelihood ratio test used here is the one used by White and Savin (1978) to test the linearity of functional form. When the null hypothesis ($H_0$) is true and certain regularity conditions are satisfied, the statistic has a limiting chi-square distribution with $q$ degrees of freedom, where $q$ is the number of additional restrictions imposed by ($H_0$). It tests the hypothesis that disturbances are independent given a certain functional form. Acceptance of the null hypotheses indicates appropriateness of linear or log-linear form, depending upon which is tested for. Rejection of the null hypotheses shown by significant $T$ statistics of the test results, implies non-linearity of functional form. The test shows that Durbin-Watson test statistics indicating autocorrelation, may instead be caused by inappropriate functional form.
The results of this test here are to accept the null hypothesis $H_0$, confirming the linearity of functional form in the per capita income/population density relationship for the equations tested. The log-linear form shows the best fit of the data. The likelihood ratio statistics from regressions specified under a number of functional forms (linear (L), autoregressive (AR), Extended Box-Cox (BC), Box-Cox Autoregressive (BCEA) are used to generate a test statistic that is then evaluated by $T$ statistic. The Likelihood Ratio Test tests hypotheses about the values of $\rho$ and $\lambda$ to distinguish between possibilities of incorrect functional form and/or autocorrelation, when a Durbin-Watson test yields unacceptable test statistics. The test statistic is $T=2[L(Q)-L(W)]$ where $L(Q)$ is the maximum of the likelihood function over $Q$ and $L(W)$ is the maximum of the likelihood function over $W$.

Test criteria involve statements about $\rho$ and $\lambda$ that are conditional, general, or joint hypothesis tests:

$C(\lambda)$ is the conditional test that $\lambda = 0$ or 1 (linear, log-linear respectively) given $\rho = 0$ or 1 (linear, log-linear respectively). Q is the likelihood ratio yielded by the Extended Box-Cox estimation. W is the likelihood ratio given by the linear or log-linear estimation.
\( G(\lambda) \) is the general and unrestricted test that \( \lambda = 0 \) or \( 1 \) (linear, log-linear respectively). \( Q \) is the likelihood ratio yielded by the Extended Box-Cox with autocorrelation correction. \( W \) is the likelihood ratio given by regular Cochrane-Orcutt autocorrelation estimation.

\( C(\rho) \) is the conditional test that \( \lambda = 0 \) or \( 1 \) (linear, log-linear respectively) given \( \rho = 0 \) or \( 1 \) (linear, log-linear respectively). \( Q \) is the likelihood ratio given by regular Cochrane-Orcutt autocorrelation estimation. \( W \) is the likelihood ratio given by the linear or log-linear estimation.

\( G(\rho) \) is the general and unrestricted test that \( \lambda = 0 \) or \( 1 \) (linear, log-linear respectively). \( Q \) is the likelihood ratio yielded by the Extended Box-Cox with autocorrelation correction. \( W \) is the likelihood ratio given by the Extended Box-Cox estimation.

\( J(\lambda, \rho) \) is the joint test that either or both \( \lambda \) and \( \rho = 0 \) or \( 1 \) (linear, log-linear respectively). \( Q \) is the likelihood ratio yielded by the Extended Box-Cox with autocorrelation correction. \( W \) is the likelihood ratio given by the linear or log-linear estimation.
Table 20
The Likelihood Ratio Test

1)  
\[ C(\lambda) \ 2 \ [ (-193 \ BC) \ - \ ( -193 \ Linear)] = 0 \]
\[ G(\lambda) \ 2 \ [ (-207 \ BCEA) \ - \ ( -212 \ AR)] = 0 \]
\[ C(\rho) \ 2 \ [ (-212 \ AR) \ - \ ( -193 \ Linear)] = -19 \]
\[ G(\rho) \ 2 \ [ (-207 \ BCEA) \ - \ ( -193 \ BC)] = -14 \]
\[ J(\lambda,\rho) 2 \ [ (-207 \ BCEA) \ - \ ( -193 \ Linear)] = -14 \]

2)  
\[ C(\lambda) \ 2 \ [ (-16 \ BC) \ - \ ( -18 \ Linear)] = 2 \]
\[ G(\lambda) \ 2 \ [ (-24 \ BCEA) \ - \ ( -24 \ AR)] = 0 \]
\[ C(\rho) \ 2 \ [ (-24 \ AR) \ - \ ( -18 \ Linear)] = -6 \]
\[ G(\rho) \ 2 \ [ (-24 \ BCEA) \ - \ ( -18 \ Linear)] = -6 \]
\[ J(\lambda,\rho) 2 \ [ (-24 \ BCEA) \ - \ ( -16 \ BC)] = -8 \]

linear=(L)
autoregressive=(AR)
Extended Box-Cox=(BC)
Box-Cox Autoregressive=(BCEA)

1) Test of the functional form:
\[ \ln Y/P = f (\ln P/H, \ln I/N, \ln R, \ln A, \ln F, \ln L, \ln MT) \]
for T = T statistic, where T=2[L(Q)-L(W)], and the numbers are log of likelihood function values. The T value of 0 for G(\lambda) is sufficient to accept the null hypothesis of log-linear functional form.

2) Test of the functional form: \[ \ln M = f (\ln R, \ln A, \ln F, \ln L, \ln MT) \]
for T = T statistic, where T=2[L(Q)-L(W)], the numbers are log of likelihood function values.

The T value of 0 for G(\lambda) is sufficient to accept the null hypothesis of log-linear functional form.
2. It is apparent that multicollinearity exists between some of the mitigating variables. The high partial correlations between the A and L variables with the R variable, and between the F and MT variables suggest that the results would be more accurate if the multicollinearity could be corrected. Ridge regression procedures show a marked improvement in the coefficient T statistics except for the F variable, confirming the specification. The ridge estimation method attempts to solve the multicollinearity problem by adding a fixed scalar (k) to each of the diagonal elements of cross product of the explanatory variables before inverting it. The RR estimator minimizes the weighted residual sum of squares. It shrinks the generalized least squares estimates to the null vector. The ridge regression was performed at k = .9.

A linear restriction was imposed as a correction to the remaining biased coefficient. T tests of the restricted coefficient are invalid. However, F tests of the restriction showed this coefficient to be appropriate. F tests of the equation are not valid by reason of the restriction. But T tests of the coefficients show coefficient significance at the 5 per cent level for all coefficients but the restricted F variable, and L, which is significant at the 10 per cent level. While the somewhat contested characteristics associated with ridge regression would not make it an acceptable procedure to be used to validate a hypothesis, that it is acceptable to use as a test of specification. For a regression showing the determinants of per capita income across countries, specification improvement is indicated from the addition of the mitigating variables.
3. Sample homogeneity—The Park Glejser test for heteroskedasticity rejects the hypothesis of no heteroskedasticity. This result implies that there is some heteroskedasticity caused by a few of the countries at the upper end of the per capita income spectrum, whose characteristics do not well fit the overall typical profile of LDCs. The result is confirmed also by the insertion of a squared per capita income term as an independent variable. Its significance shows a non-linear effect caused by the atypical characteristics of the higher per capita income countries.

The Park Glejser test regresses the square of the regression residual on the variable assumed to represent sample variance:

\[
\text{Park Glejser} = \text{for } Y = \alpha + \beta X + \epsilon
\]

regress \( \epsilon^2 \) on \( X \) variable: obtaining a significant coefficient indicates heteroskedasticity.

Table 21

<table>
<thead>
<tr>
<th>Park Glejser Test</th>
</tr>
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<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>1) ( \epsilon^2 = .31 - .000005 \frac{I}{N} )</td>
</tr>
<tr>
<td>(6.96) (3.12)</td>
</tr>
<tr>
<td>2) Generalized Least Squares Correction for Heteroskedasticity</td>
</tr>
<tr>
<td>( \ln \frac{Y}{P} = .50 - .16 \ln \frac{P}{H} + .64 \ln I/N )</td>
</tr>
<tr>
<td>(1.14) (-2.03) (13.97)</td>
</tr>
<tr>
<td>3) ( \ln \frac{Y}{P} = .11 - .16 \ln \frac{P}{H} + .68 \ln I/N )</td>
</tr>
<tr>
<td>(0.27) (-2.38) (15.98)</td>
</tr>
</tbody>
</table>

Significance of the coefficient obtained the Park Glejser test for heteroskedasticity in 1) indicates some heteroskedasticity.
A Generalized Least Squares regression estimation using the variance of the L variable for the W diagonal corrects for the heteroskedasticity. Correction for heteroskedasticity by Generalized Least Squares, however, when compared to the Ordinary Least Squares Regression shows little difference. However, the change in coefficients is almost negligible, indicating that the heteroskedasticity is not extreme.

4. **Chow Test**

The Chow Test of coefficient comparability. To compare the coefficients of variables used in two different regressions, asking statistically whether the subsets of coefficients are equal. An analysis of covariance is used. One regression has n observations used to estimate p parameters. The other regression has an additional m observations. The general form of the test is:

\[
A = \text{the residual sum of squares of } n+m \text{ deviations of the dependent variable from the regression estimated by } n+m \text{ observations, with } n+m-p \text{ degrees of freedom.}
\]

\[
B = \text{the residual sum of squares of } n \text{ deviations of the dependent variable from the regression estimated by the first } n \text{ observations, with } n-p \text{ degrees of freedom.}
\]

\[
C = \text{the residual sum of squares of } m \text{ deviations of the dependent variable from the regression estimated by the second } m \text{ observations, with } m-p \text{ degrees of freedom.}
\]

The ratio of \((A-B-C)/p\) to \((B+C)/(n+m-2p)\) is distributed as \(F(p, n+m-2p)\) under the null hypothesis that both groups of observations belong to the same regression model.
Table 22
Chow Test

1)
1960
\[ \ln Y/P = 4.09 - .17 \ln P/H + .66 \ln I/N - .10 \ln K/N \]
\[ (10.75)(-1.50) \quad (5.94) \quad (-1.32) \]
\[ R^2 = .69 \]
\[ d.f. = 31 \]
\[ F = 24.09 \]

1979
\[ \ln Y/P = 6.01 - .29 \ln P/H + .91 \ln I/N + .28 \ln K/N \]
\[ (7.14)(-1.70) \quad (3.77) \quad (3.15) \]
\[ R^2 = .49 \]
\[ d.f. = 31 \]
\[ F = 10.07 \]

2)
1960
\[ \ln Y = 5.57 + .50 \ln N + .29 \ln H + .18 \ln K \]
\[ (9.79)(3.31) \quad (1.92) \quad (2.21) \quad (t) \]
\[ R^2 = .66 \]
\[ d.f. = 31 \]
\[ F = 21.92 \]

1979
\[ \ln Y = 4.91 + .58 \ln N + .17 \ln H + .27 \ln K \]
\[ (4.96)(2.92) \quad (.91) \quad (2.54) \quad (t) \]
\[ R^2 = .58 \]
\[ d.f. = 34 \]
\[ F = 15.00 \]

3)
1960-70: 36-country 3 time series
\[ \ln Y/P = 5.46 -.16 P/H + .60 R + .31 ((P/H)*R) + .004 I/Y + .24 L \]
\[ (54.89)(-5.22) \quad (2.01) \quad (4.34) \quad (10.46) \quad (1.98) \quad d.f. = 102 \]

1970-80: 36-country 3 time series
\[ \ln Y/P = 5.49 -.12 P/H + 1.07 R + .19 ((P/H)*R) + .002 I/Y + .38 L \]
\[ (89.98)(-6.01) \quad (5.80) \quad (4.51) \quad (9.27) \quad (3.08) \quad d.f. = 102 \]

For the Part 1) of the empirical work, the Chow Test test for
regression pair 1) above shows an F statistic of 6.86 with 4, 64 d.f.,
compared to a critical value of approximately 2.53, rejecting the null
hypothesis of similar regression structures for the two cases.
For the Part 2) Chow Test test of regression pair 2) above shows an F statistic of 3.88 with 4, 64 d.f., compared to a critical value of approximately 2.53, rejecting the null hypothesis of similar regression structures for the two cases.

For the Part 3) Chow Test test of regression pair 3) above shows an F statistic of 10.89 with 6, 196 d.f., compared to a critical value of approximately 2.10, rejecting the null hypothesis of similar regression structures for the two cases.

5.

Table 23
Sample Separation by Continents Without Dummy Variables

<table>
<thead>
<tr>
<th>Continent</th>
<th>Equation</th>
<th>R²</th>
<th>t-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asia</td>
<td>df=54: ln Y/P = 2.28 -.02 P/H +.51 M +.004 ((P/H)*M) +.001 I/Y -.57 C</td>
<td>.99</td>
<td>(7.26)(-60) (11.65)(.87) (3.53) (-6.33)</td>
</tr>
<tr>
<td></td>
<td>df=56: ln Y/P = 4.40 +.01 P/H + 2.98 R +.05 ((P/H)*R)</td>
<td>.99</td>
<td>(25.43)(.52) (5.74) (1.17)</td>
</tr>
<tr>
<td></td>
<td>df=56: ln Y/P = 4.53 + .05 P/H +.004 A - .0001 ((P/H)*A)</td>
<td>.84</td>
<td>(17.91)(3.42) (3.31) (-1.77)</td>
</tr>
<tr>
<td></td>
<td>df=54: ln Y/P = 4.34 +.04 P/H +.20 A -.007 ((P/H)*A) + 1.34 L +.0008 I/Y</td>
<td>.99</td>
<td>(56.61)(5.46) (4.58) (-2.74) (8.28) (2.61)</td>
</tr>
<tr>
<td></td>
<td>df=54: ln Y/P = 4.82 +.02 P/H +.41 A -.001 ((P/H)*A) -.34 C +.0009 I/Y</td>
<td>.96</td>
<td>(43.18)(2.08) (7.53) (-3.99) (-4.94) (1.33)</td>
</tr>
<tr>
<td></td>
<td>L not solved</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>df=54: ln Y/P = 4.69 +.05 P/H +.45 F -.02 ((P/H)*F) +.13 A +.008 I/Y</td>
<td>.77</td>
<td>(36.27)(4.01) (2.37) (-.97) (4.05) (2.16)</td>
</tr>
<tr>
<td></td>
<td>df=54: ln Y/P = 4.22 +.04 P/H + 3.42 MT -.16 ((P/H)*MT) +.04 A + 2.21 I/Y</td>
<td>.90</td>
<td>(53.15)(5.12) (2.18) (-2.07) (10.86) (6.12)</td>
</tr>
</tbody>
</table>

C is a dummy variable for British colonial influence, taking the value of 1 for former British colonies.
Table 24 (continued)

<table>
<thead>
<tr>
<th>Continent</th>
<th>Equation</th>
<th>df</th>
<th>R²</th>
<th>t statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>ln (Y/P = 2.11 - .86 P/H + .59 M + .11 ((P/H)*M))</td>
<td>56</td>
<td>.92</td>
<td>(2.50) (-2.12) (4.72) (1.91)</td>
</tr>
<tr>
<td></td>
<td>ln (Y/P = 2.19 - .54 P/H + .55 M + .07 ((P/H)*M) + .001 I/Y - .19 C)</td>
<td>54</td>
<td>.98</td>
<td>(4.64) (-2.27) (7.89) (1.97) (3.16) (-4.65)</td>
</tr>
<tr>
<td></td>
<td>ln (Y/P = 5.50 - .30 P/H + 1.20 R + .49 ((P/H)*R) + 1.88I/Y + .71 L)</td>
<td>76</td>
<td>.76</td>
<td>(76.85) (-6.13) (4.99) (5.09) (8.16) (4.56)</td>
</tr>
<tr>
<td></td>
<td>ln (Y/P = 5.38 - .02 P/H + .11 A - .004 ((P/H)*A) + .05 L + .004 I/Y)</td>
<td>54</td>
<td>.87</td>
<td>(54.09) (-.91) (2.60) (-.36) (3.8) (12.11)</td>
</tr>
<tr>
<td></td>
<td>ln (Y/P = 5.41 - .02 P/H + .11 A - .004 ((P/H)*A) - .01 C + .004 I/Y)</td>
<td>56</td>
<td>.85</td>
<td>(59.76) (-.75) (2.41) (-.39) (-.34) (12.15)</td>
</tr>
<tr>
<td></td>
<td>ln (Y/P = 5.75 - .04 P/H + .48 L + .11 ((P/H)*L))</td>
<td>56</td>
<td>.99</td>
<td>(59.38) (-.44) (1.97) (.64)</td>
</tr>
<tr>
<td></td>
<td>ln (Y/P = 5.26 - .08 P/H + .21 F + .05 ((P/H)*F) +1.91 R + 2.19 I/Y)</td>
<td>54</td>
<td>.99</td>
<td>(77.68) (-2.88) (1.08) (.89) (7.99) (8.01)</td>
</tr>
<tr>
<td></td>
<td>ln (Y/P = 5.20 - .03 P/H - 1.01 MT +.27 ((P/H)*MT) +.02 A + 2.29 I/Y)</td>
<td>56</td>
<td>.81</td>
<td>(59.71) (-1.40) (-.37) (.98) (6.67) (6.16)</td>
</tr>
<tr>
<td>South America</td>
<td>ln (Y/P = 1.27 - .30 P/H + .73 M + .03 ((P/H)*M))</td>
<td>56</td>
<td>.93</td>
<td>(3.61) (-3.28) (16.36) (2.93)</td>
</tr>
<tr>
<td></td>
<td>ln (Y/P = 5.77 - .28 P/H + .79 R + .32 ((P/H)*R) + 2.21 I/Y + .68 L)</td>
<td>54</td>
<td>.99</td>
<td>(23.49) (-2.04) (1.87) (1.55) (6.29) (3.93)</td>
</tr>
<tr>
<td></td>
<td>ln (Y/P = 6.10 - .08 P/H - .002 A + .0007 ((P/H)*A) + .82 L + .002 I/Y)</td>
<td>54</td>
<td>.99</td>
<td>(68.86) (-2.13) (-.27) (1.38) (6.32) (11.02)</td>
</tr>
<tr>
<td></td>
<td>ln (Y/P = 5.33 + .37 P/H +2.20 L - .40 ((P/H)*L))</td>
<td>54</td>
<td>.91</td>
<td>(10.83) (1.49) (3.16) (-1.15)</td>
</tr>
<tr>
<td></td>
<td>ln (Y/P = 5.36 - .06 P/H +.13 F +.02 ((P/H)*F) + 2.14 R + 1.80 I/Y)</td>
<td>54</td>
<td>.87</td>
<td>(28.19) (-.81) (.24) (.06) (10.40) (4.42)</td>
</tr>
<tr>
<td></td>
<td>ln (Y/P = 5.99 + .07 P/H + 4.74 MT -.94 ((P/H)*MT) +.0005 A + 1.76 I/Y)</td>
<td>54</td>
<td>.86</td>
<td>(45.92) (1.53) (2.03) (-.96) (6.19) (4.91)</td>
</tr>
</tbody>
</table>

Structural differences between continents are tested and shown significant by the dummy variable technique shown earlier in the text. The inclusion of interaction regressions by continent allows one to inspect differences in coefficients between continents that identify the structural differences.
APPENDIX B

ESTIMATION TECHNIQUES FOR REGRESSION ANALYSIS

The SHAZAM econometric package is used for the analysis done here.

**OLS:** Ordinary least squares estimation is appropriate for the multivariate cross-section regression in generating unbiased and efficient linear estimators.

**Non-Linear:** The non-linear regression capabilities of SHAZAM to estimate the CES production function are taken advantage of. The usual methods of non-linear estimation programs are discussed by Humphries\(^1\).

**Pooled Time Series-Cross Section Regressions:** The SHAZAM package performs a cross-sectionally heteroskedastic, time series autocorrelated regression. The choice of constraining same rho values for each cross-section was used. This method was found to be the most practicable due to the occasional computational difficulties in finding stable rho values in the pooled data estimation. A Generalized Least Squares procedure is used to estimate the model described in Kmenta\(^2\).

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1. Humphries (1976) p.349 notes: "nonlinear regression programs are based on a systematic trial and error approach designed to find the maximum likelihood estimators. The computer is asked to calculate the value of the relevant likelihood function for a number of different combinations of the parameter values until the maximum value is found. The values of the parameters corresponding to this maximum of the likelihood function are the maximum likelihood estimates with their desirable asymptotic properties. The application of the maximum likelihood method is contingent on the assumption that the error terms are normally distributed. If we do not want to make this assumption, then we can obtain our estimates by minimizing the sum of squared deviations of the observed values from the fitted values of the dependent variables, that is by the least squares method. The estimates obtained by the nonlinear least squares method are exactly the same as the maximum likelihood estimates whenever the maximization of the likelihood function is achieved by the minimization of the sum of squared deviations of the observed from the fitted y."

APPENDIX C

DATA SOURCES

WBDR is the World Bank Development Report
IFS is International Financial Statistics by International Monetary Fund

Production Variables

1) \( Y/P \) WBDR, 1978, 1981, Table 1 Basic Indicators

\[ Y \text{ calculated: } Y = (Y/P) \times P \]

\( (Y/P)G \) WBDR, 1981, Table 1 Basic Indicators

\( YG \) WBDR, 1981 calculated from Tables 1 \((Y/P)G\) and 17 \((PG)\)


\( H \) FAO Production Report, 1982-arable land

\( PG \) WBDR, 1981, Table 17 Population Growth

\( N \) WBDR, 1981, Table 19 Labor Force

\( NG \) WBDR, 1981, Table 19 Labor Force

3) \( I/Y \) WBDR, 1978, 1981, Table 5 Structure of Demand

\( IG \) WBDR, 1981, Table 4 Growth of Consumption and Investment

\( K \) calculated from WBDR, 1981 Tables 1, 5, and 17

\( KG \) calculated from WBDR, 1981 Tables 1, 5, and 17

Mitigating Variables

1) \( R \) WBDR, 1978, 1981-Labor Force Table

2) \( A \) WBDR, 1978, 1981-Structure of Production Table

3) \( MT \) WBDR, 1978, 1981-Structure of Demand Table

WBDR, 1978, 1981-Structure of Merchandise Exports Table

4) \( L \) WBDR, 1979, 1982-Education Table

5) \( F \) IFS 1982 Country Tables line 35 \( L = M_2 \), line 99b = GDP

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NOTES

COMMENTS ON EMPIRICAL TOPICS

Growth Rate Functional Form

Variables expressed as percentages or growth rates are not given log form. Since they begin as percentages, they are compatible in interpretation with unit variables expressed in log form. This is not a matter of theory, but a matter of practical choice between functional forms.

Mathematically Generated Data

Assuming data source validity, the mathematical generation of data should be acceptable. An example of this would be the interpolation of valid growth rate data to generate variable level data for missing years, or the use of growth rates to forecast or project backward in time to estimate data points not available. Such interpolations may be more accurate than inserting missing data from another data source, avoiding error from lack of standardization commonly found between sources.

Measurement and Reporting Error

Assuming the correct choice of variable specification, measurement error is a secondary order of significance. For example, the value of correcting population density figures by attempting to standardize for land agricultural productivity far outweighs the possibility of measurement and reporting error in arable land figures. Due to other partially unmeasured factors such as weather and erosion, tending to degrade existing levels of arable land, the arable land correction tends to error, if any, in a conservative way, by undercorrecting.
Number of Sources

Other things equal, fewer sources are preferable with respect to the standardization of data.

Sample Heterogeneity: Controlling for Cross-country Effects

These methods are useful only when sufficient variation over the sample means that homoskedasticity is violated, a possible circumstance in cross-section regressions over many countries.

1. Use of Non-Linear Terms: Suits and Sommers¹, and Chenery and Taylor (1968) discuss the use of quadratic terms, indicating that progressively richer nations tend to make smaller marginal contributions. The non-linear income term allows for the decline in elasticities with rising per capita income levels noted in most industrial sectors. This formulation avoids the necessity of subdividing the sample by per capita income level. However, in some cases sample separation is desirable in its own right.

2. Use of a Per Capita Income Level Control Variable

A method similar in effect to the use of quadratic terms, for regression variables in growth rate form, is the insertion of a per capita income level variable. This allows an interpretation of coefficients holding initial per capita income levels constant.

1. Suits and Sommers (1971) p.122
3. Growth Index Calculation

A more extreme but logical extension of the quadratic and per capita income level control variable methods noted, is an index method combining the relevant information into one variable, essentially as an interaction term. For regression work other than where the usual growth rate specification is defined (e.g. the growth rate form of the Cobb-Douglas Production Function), a form of growth index is suggested to eliminate cross-country biasing of growth rates interpretations. This method was devised to correct the unexplained perverse results obtained by some authors using growth rates of literacy, financial deepening and the like. It is thought that the means presented here provides an improvement to the cross-country use of growth rates. The rationale for the growth indexation is to standardize the meaning of growth rates with respect to initial levels across the sample of countries. This is analogous to the standardization of measurement units through the use of elasticities. The objective is give each unit of change an equivalent value across countries. To give an example:

- Starting from 1, an increase of 1 unit gives a 100 per cent increase.
- Starting from 10, increase of 1 unit gives a 10 per cent increase.
- Starting from 100, an increase of 1 unit gives a 1 per cent increase.

The idea is to construct an index that gives a unit increase the same value from any starting point. The way chosen to do this is to multiply each growth rate figure from the example by its initial level value. The result not only has the desirable quality of standardizing the meaning of the growth rates across the sample, but provides a way of incorporating the information of a variable's level and growth rate into one index.
Simultaneity

As noted in Chapter I, the demographic transition theory was used to suggest a substantial simultaneity between economic growth and demographic factors. However a re-investigation of the data shows considerable variation across cases. Browning (1982)\(^1\) discusses the potential interaction between income growth and demographic growth:

"The seriousness of any simultaneity bias depends on the magnitude and direction of the other causal relationship, if it exists. The magnitude of the effect of income on population growth is quite small. Utilizing an estimate made by Chenery and Syrquin (1975)\(^2\), an increase in the income growth rate of 1 per cent over a 5 year period would lower the the population growth rate by .03 per cent."

One would expect that in the future, rising incomes and greater certainty in survival rates will have an endogenous effect of reducing desired fertility in LDCs, thus stabilizing, or perhaps reducing population growth rates. However, for the time period and sample of countries in this study, such effects are not likely to have significantly affected the population variable in question, population density. Thus simultaneity bias is likely to be small.

\(^1\) Browning (1982) p.51-52
\(^2\) Chenery and Syrquin (1975) p.59
Simultaneous and lagged effects of the institutional/structural variables is a valid consideration that has been investigated to some extent, in an earlier version of this study. However, for the purpose of demonstrating the mitigation hypothesis, these effects are of a secondary order of importance and are somewhat peripheral to the empirical testing of the hypothesis. Therefore, that work has not been included here, but suffice it to say, with the exception of the education variable that has some reputation as a luxury good (for the wealthy) in LDCs, the causal directions favor the specification used here. Indeed, the growth accounting format conceived of as the "sources of growth" defines the expected causal relations.

**Time period**

1960 through 1979 is twenty years. This is equivalent, in this study, to saying the 1960 to 1980 time period, written 1960-80.

**Time Series vs. Cross-Section Emphasis**

Browning (1982) notes the long run—short run differences in response of income growth to demographic growth, evidenced in time series vs. cross-section. He attributes the differences to the structure of the models. However there are certainly economic explanations for the differences: such as the intermediary effects of institutional and structural changes over time. Given comparability of cross-country and time series relationships as discussed by Chenery (1969), a pooled data set gives an interesting portrayal of these intermediary institutional and structural change effects over time, across the sample set of countries.
Demographic Transition refers to the observed development sequence of events in which birth rates begin to decline. It is noted that the demographic transition is not directly related to income growth, as its incidence has been seen to precede, follow, or occur pari passu with economic growth. Thus it is more likely related to a change in cultural institutions.

Economic development adds to the concept of economic growth the institutional environment necessary to make economic growth a self-sustaining process, and welfare considerations such as the distribution of income.

Factor disequilibrium, imbalance in factor proportions, and factor sub-optimum are terms used to express the same concept regarding the failure of markets to clear and make Neoclassical quantity/price adjustments.

Economic growth refers to a prolonged rise in per capita income.

Induce, Necessitate, Demand, are used similarly in the literature
Institutions are sets of behavioral rules ranging in formality from informal customs to written laws governing economic behavior. Increases in their effectiveness in minimizing economic exchange costs can mitigate economic market disequilibria caused by rapid population density growth. Institutions are sometimes defined by the infrastructure providing their services. Thus for example, a university is an "institution" of higher learning, or a bank is a financial "institution". This definition, however, is not useful for the purposes of this study. It is the definition of any given institution to be effective for a specific population density range.

Institutional change, the changing of behavioral rules, explicit or implicit, which govern economic activity. These behavioral rules range in explicitness from unwritten social mores to legal contracts.

Institutional efficiency is defined as an institution's ability to perform its institutional function (with efficiency giving a "least cost" connotation).

Institutional effectiveness adds to institutional efficiency the capacity to resolve conflicts in such a way that institutions can be modified when necessary to retain efficiency.
LDCs or "Less Developed Countries" are countries with per capita incomes ranging from 2 to 100 times less than "Developed Countries". Typically these countries are "traditional" non-western cultures, colonized by western countries, having rather recently gained political and economic autonomy.1

The mitigation of population growth effects is the reducing of the influence of negative population growth effects, reducing the partial derivative of population level with respect to income. Rather than a direct change in $a(Y/P)/a(P/H)$, mitigation comes from a change in the influence of $P/H$ on $Y/P$ because of covariance with institutional and structural change, increasing the values of the mitigating variables over time. Population density effects then constitute less severe an obstacle to income growth.

Monetization of value is defined as increases in the proportion of economic exchange using money rather than goods as a measure of value.

Output, Income are used interchangeably to standardize interpretation between the regression and the production function models.

Population pressure is the accepted literature terminology for the effects of the increasing ratio of population to resources.

1. Kuznets (1965): p.176—chapter entitled: "Present Underdeveloped Countries and Past Growth Patterns" "By underdeveloped countries we mean those with a per capita product so low that material deprivation is widespread and reserves for emergency and growth are small."
Population levels, to be meaningful in cross-country comparisons, are here defined as population per unit of arable land (this corrects for inter-country land fertility differences and controls for country size variation). Population growth increases population density levels. Population density increases, retard economic growth by outmoding institutional regimes. Population density growth increases the demand for institutional change directly, but has no direct causal link to increasing the supply.

Residual, residual: Residual, in the "growth accounting" sense and the sense used here is not the residual or error term discussed in econometrics. It includes also the contributions of the intercept which represents the contributions of technology in the "growth accounting" terminology. The growth accounting Residual represents that part of the dependent variable which remains unexplained after the production function variables are accounted for. In theory this unexplained element represents the efficiency parameter (of a Cobb-Douglas production function) incorporating technical and institutional/structural change, as well as the contribution of unmeasured factor inputs, such as those of institutions.

Structural change is defined in this study as change in the composition of output by production sector in a country, as well as associated movements of labor between sectors, and changes in the use (e.g. between domestic consumption and export) of the product.
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