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# International comparison of causal relationships among selected social indicators and economic welfare

Yasuaki Aihara
*Iowa State University*

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Yasuaki Aihara

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# CHAPTER I. INTRODUCTION

## History and the Problem

After World War II, international cooperation for reconstruction and development of world economies has been performed mainly for European countries where economies had received serious damages rather than for the so-called "backward areas." This was because those areas had been thought of as less promising areas to achieve economic growth.

This situation continued until around the early 1950s. However, as many areas obtained their independence from European countries, economists and international organizations could no longer be indifferent to the necessity of establishing policies and strategies that would enable the favorable economic growth and social development in those newly-born countries. The substantial foundation of "economic development" roughly coincided with that necessity.

For the newly-independent developing countries, their temporary models of economic development were similar to those already achieved in Western countries, where economies were consuming a large amount of resources to supply materialistic welfare to the people. Thus, in many of the developing countries, the major task of government administrators was to direct their countries in that

direction. Until the mid 1960s, there were government administrators of some countries who believed that giving high priority to quantitative economic growth and achieving higher growth rates of the Gross National Product (GNP) per capita were the right strategies for their countries.

The performance of countries varied widely. Those who had been keeping the highest growth rates (Libya, Iraq, Korea, Hong Kong, etc.) enlarged their economies remarkably, while those mostly in Africa and in Latin America (Rwanda, Burundi, Madagascar, Bolivia, etc.) had recorded almost insignificant or even negative growth rates.

However, the emergence of environmental pollution in developed countries, due to the excessive destruction of natural resources and the frustrations in economic performance of some developing countries, brought the following view to the administrators of the developing countries:

> The concept of catching up must be rejected. Catching up with what? Surely the Third World does not wish to imitate the life styles of the rich nations? It must meet its own basic human needs within the framework of its own cultural values, building development around people rather than people around development (Haq, 1976, p. 2).

Hence, the objectives of development in the countries

have been reformed since the early 1970s. They are now oriented not only to increase GNP per capita to catch up with developed countries, but to other aims related to the realization of social equality such as income distribution, fulfilling basic human needs, etc. In other words, the objectives have changed from growth-oriented to those that put more emphasis on the quality of social or human conditions, i.e., welfare.

The reformation of objectives has required a new function in the field of economic development. The function is to develop a reasonable method to measure how much development or welfare has been achieved in developing countries, and to present it through a reasonable and understandable numeric system. It is needless to say, however, the inherent difficulty to this problem was how to define a rather philosophical concept of "welfare."

As will be introduced in Chapter II, many institutions and research workers have tackled this issue. One achievement was the creation of social indicators, and the other, composite measures of development and welfare. One relatively obvious pattern in generating such indicators and measures was that some research workers totally disregarded economic factors in their system. Their common reasoning for excluding economic factors was

that it was not the amount of products people really need to receive, but the quality of life (i.e., human and social condition aspects). Their view might have been derived from the serious criticism of the fact that too much emphasis had been put on the increase in economic indicators, or from their personal philosophical notion. Hence, they regarded the economic factors as the inputs for enhancing the human and social aspects, not as the final results. This direction of the effects must be recognized as one aspect of this subject. It is quite natural to expect that the more a government expends, then more useful goods and better services will be allocated to areas such as health, security, education, etc., enhancing the values of social indicators that represent these dimensions.

However, the relationship that will mainly be focused upon as the problem in this thesis is not in that direction. The theme of this study is to analyze the opposite relationships. That is, how the improvement in each of the recognizable social conditions causes the increments in individual economic welfare. The discussion of the selection of the aggregate individual economic welfare will be left for a later section. These relationships also deserve to be discussed. Through this opposite direction, the dimensions of social situations

are assumed to be the inputs that organize individual economic welfare. It is not very realistic to assume people directly sense they are benefitted only by the improvement in each dimension of social condition such as welfare or utility, although it may be rational for some researchers to assume this. What people generally receive are the realized services and utilities obtained from goods. The production of those items is guaranteed by the contribution of human and social dimensions, as well as the materialistic capital. In order to observe the mechanisms of the development in countries and to understand similarities or dissimilarities, this type of bilateral approach should be utilized. This study will organize a model to analyze the causal relationships and show the similarities and differences in the causal relationships among the grouped countries empirically.

This kind of analysis is largely affected by the availability of reliable indicators. Data collection has sometimes been interrupted or discontinued due to the lack of a survey technique, the difference in the definitions of objective phenomena, and other administrative inconvenience especially in developing countries. Those data for this issue that have usually been allowed to researchers for analyzing were collected at one point in time or quite discontinuously. These data are not

useless. However, it is more desirable to utilize continuous annual data to take into account the duration and fluctuation of the effects. Thus, this study will focus upon the eleven-year period 1975 through 1985.

## Structure of the Study

This thesis consists of four chapters beyond this Introduction.

In Chapter II, the concepts of social indicators are discussed. The characteristics of indicators, their coverage of concerns, and the advantages in measuring phenomena are argued by reviewing the previous approaches for creating various types of social indicators. The second part discusses the weaknesses of social indicators, composite measures of development, and welfare as the candidates for representing economic welfare. Also, previous works on those measures are discussed critically. This discussion is followed by the selection of the economic welfare measurement analyzed in this project. The third part of Chapter II surveys other relevant works that examined the relationships between the development of a country and its demographic and social development. These works provide some theoretical background required for this study.

Chapter III begins with the selection of the social indicators that capture several important dimensions of

social welfare. The criteria for selection, validity, and other issues are mentioned. Next, information about data sources and classification of countries will be the topics. The second section discusses the theoretical framework that establishes the relationship between the social and economic indicators. This is the part where expectations will be posed.

Chapter IV discusses the empirical analysis of the data. The analysis mainly focuses on the elasticity of economic welfare with respect to each social indicator and their comparison between the groups of countries. The expectations are examined and the similarities and the differences are found.

Finally, Chapter V summarizes the observations and the analysis. Suggestions for further research are made.

# CHAPTER II. CONCEPTUAL FRAMEWORK AND REVIEW OF PREVIOUS WORK

## Social Indicators

The most basic components that organize this study are social indicators. Social indicators had already been used before the change in the objectives of development in developing countries occurred. In those days, the major indicators included the areas mostly related to demographic phenomena. These indicators included birth rates, death rates, life expectancies, etc.

The change in the objectives of countries' development, as stated before, required the indicators to capture more qualitative dimensions of the societies. In that sense, the concept of "social indicators" in the beginning was neither unanimously understood by economists nor statisticians.

Today, the concept of social indicators are defined and understood as follows:

> A social indicator, as the term is used here, may be defined to be a statistic of direct normative interest which facilitates concise, comprehensive and balanced judgments about the conditions of major aspects of a society. It is in all cases a direct measure of welfare and is subject to the interpretation that, if it changes in the 'right' direction, while other things remain equal, things have gone better, or people are 'better off' (U.S., Department of Health, Education, and Welfare, 1969, p. 97).

Over the years, a vast array of research programs have been developed to deal with the allocation of resources among sectors (e.g., education, housing facilities, medical care, etc.) and population categories (e.g., low income groups, the aged, women, migrant workers, etc.). More recently, the negative effects of economic growth (e.g., pollution of natural resources, depletion of fossil energy resources, etc.) have been covered. In the process, the national economic account system that has been used in virtually all of the Western countries and its many successful applications, especially in the field of macroeconomic planning, were often referred to as models of the successful interaction of statistics, planning, and policy-making.

There are several individuals and groups who have made significant contributions to create social indicators systems. Wilson (1973) attempted to develop a comprehensive set of social indicators for the purpose of ascertaining differences in the quality of life, focusing on fifty states of the United States. He chose seventy-two indicators out of an important political document to complete his system. Although this system is useful for politicians to use as a guiding indicator for domestic development, it is not suitable for international application. Terleckyj (1973) adopted an accounting

system (input-output matrix) to calculate probabilities for improving the quality of life. He listed the six goal areas according to the relative importance in public and private budgets. What is peculiar to his system is Terleckyj applied the selected indicators directly to choose concrete socio-political programs. Cantril (1965) divided human life into past, present, and future. Then he set positive and negative human goals and factors that would affect a person's judgment during the three stages of his life. Andrews and Withey (1974) focused especially on the aspects of family, community, and housing to measure and predict general satisfaction with life. The latter two and Abrams (1973) had a common approach, in that they put their emphasis on the most important systems of so-called subjective social indicators, i.e., measures of individual contentment, aspirations, and conceptions of value.

In short, the systems introduced above are suitable for examining relatively small or domestic areas. They are descriptive systems as well as highly prescriptive to the development of the specific local society of interest.

On the contrary, for the study of economic development in the international area, internationally comprehensible and comparable indicator systems were required. For this, some of the international

organizations like the United Nations Economic and Social Council (1974) and OECD (1973) have shown an interest in a more critical selection of data than the above examples, both in general and in specific areas. Since both of the contributions were basically along the same procedural track, OECD's work will be described. OECD's statistical compendia were organized by the three major methods: 1) social accounting, 2) system of social and demographic statistics, and 3) net national welfare measurement. All three have the following goals in common:

> a. to provide guidelines for the development of measures to fill the gaps in existing knowledge about socio-economic conditions;
>
> b. to link various measures so as to provide a picture not only the relevant phenomena, but also of the relationships between them; and
>
> c. to reduce information overload through concentration on relevant indicators and supporting data (OECD, 1976, p. 11).

No attempt will be made here to elaborate on each of these aims. However, it must be recognized that one basic concept exists as a criterion judging the validity of indicators. This is commonly called "social well-being." This term represents the aggregate well-being of individuals. OECD (1976) put particular emphasis upon the word "individuals," to make it much clearer to construct pin-pointed indicators revealing each dimension of well-

being.

In the OECD's work, "social well-being" is captured by nine areas of social concepts and the social indicators are provided for them.

There is still a need for improvement in this system. However, it is necessary to point out some particular advantages of this type of social indicators.

First, they describe some ends or at least some specific inputs that are closely related to the dimensions they represent. For example, daily calorie supply per capita can serve as a representation of the food dimension of the society better than the amount of government expenditure allocated to food policy.

Second, they imply something about the distribution of the particular phenomena. Many of the indicators have the upper limits, say one hundred percent. In this scaling system, it is generally observed that the higher the values of the indicators rise, the smaller the marginal change in the value, since achieving one hundred percent of a certain phenomenon is highly unlikely to happen. Therefore, if the value is very close to the limit, that phenomenon might really be spread among the society.

Utilizing these two advantages, some of the social indicators of OECD's type will be used to represent the

social welfare dimensions in this study.

## Composite Measures of Development

Although social indicators have advantages in representing conditions of specific dimensions of social welfare, they still have some problems. One example of a problem is the social welfare dimension is not the only requirement for the society. It is not quite sufficient to measure a society's degree of contentment only from the social point of view. In any society, people need certain levels of materialistic or economic affluency. Social and economic welfare are in a complementary relationship, rather than in substitute relationship. Thus for proceeding this study, it is necessary to find an adequate indicator to represent an economic dimension. Social indicators, unfortunately, do not represent this.

Composite measures of development and welfare were designed to reflect an economic aspect of a society, as well as to fill the gap between the two separate dimensions. Composite measures are not purely social nor economic. However, examining these measures is a suggestion for making a decision as to the most appropriate measurement for the individual economic welfare to be analyzed in this study.

The definition of composite measures may be confusing with some types of social indicators. However, they are

defined as the measures consisting of the OECD's type social indicators and other economic indicators.

Economists and statisticians have made many attempts to combine different components of socioeconomic indicators (in some cases, only social) taken from the many studies already done on social indicators. Efforts have been made to create new composite measures that would be able to surpass a GNP per capita in approximating the level of development or welfare. Similar to the creation of social indicator systems, subjective criteria for creating composite measures are needed. The following issues are important.

> a. Have the right flows been chosen? (i.e., are the components selected a complete representation of the phenomenon to be measured?)
>
> b. Are these flows adequately reflected in the index? (i.e., is the choice of indicators an adequate reflection of the components?)
>
> c. Are they (components) given appropriate relative importance? (i.e., how have they been weighted?) (Taylor, 1980, p. 28).

The requirement (a) has not been perfectly satisfied. This is mainly due to the lack of data, particularly in developing countries, or of an appropriate indicator such as mental welfare. Other influencing factors are ethnic, geographical, or cultural differences. Statistical deficiencies cannot be attributed to the creators of

composite measures.

Like the investigators for creating social indicators, the contributors for developing composite measures have also been investigated by the research groups of international organizations and economic organizations.

McGranahan et al. (1972) tried to combine economic and social dimensions for measuring development. The project was concerned with the selection of the most appropriate indicators of socio-economic development, the analysis of relationships between these indicators at different levels of development, and the construction of a synthetic index of development which they thought was more representative and sensitive than a GNP per capita to the general development levels. Initially, they provided more than seventy social and economic variables, which were eventually reduced to eighteen highly correlated core variables. The selection was based on the assumption that variables with high intercorrelations, on the average with other development variables are better development indicators than those with a low correlation. Consideration was also given to maintaining some balance between indicators which represented different dimensions of development. The method of best-fitting curves was used to establish the empirical correspondence between the

eighteen core indicators at different levels of development on the basis of cross-national comparisons. The system of correspondence points was used also to determine critical points for converting the indicators to a common scale. A general index of development was then constructed, using a system of shifting weights derived from the degree of correlation of each indicator with other indicators at each level of development. The new idea in this study was the emphasis of the assumption of interdependence between all the variables, and then its application to the weighting procedure.

The study completed by Adelman and Morris (1967) differs from the work by McGranahan et al. (1972) in many respects. The purpose of the Adelman and Morris' study was to gain more precise empirical knowledge about the interdependence of economic and non-economic aspects (particularly institutional) of the development process. This study was intended to provide "semi-quantitative" insights into the variation of the selected variables that were considered by sociologists and political scientists to play an important role in the early stages of development. However, they were not usually dealt with systematically because of the difficulty in the quantification of the substance. As in the study by McGranahan et al. (1972), the authors used factor analysis

to show the interdependence between forty-one social and political variables, and the level of economic development. The same method was also applied to analyze the relation between various aspects of social, political, economic change, and economic growth and modernization in terms of a smaller number of independent factors at three different levels of socio-economic development. Levels of socio-economic development were determined by using scores or factor loadings on a factor representing various aspects of socio-economic structure. The innovation that should be mentioned in this study is the combination of the quantitative variables and the qualitative indicators. However, the application of fourteen political indicators might reduce the reliability of the final indicator in a statistical sense.

On the other hand, measurements of welfare generally measure the areas of interest subjectively. For representative works on the measures of welfare, Drewnowski (1970) created the "Level-of-Living Index" in the United Nations Research Institute for Social Development (UNRISD). His calculation of the indicator was based on "natural units" (represented by social indicators). Natural units take into account the fact that the welfare value of certain outputs may, beyond certain levels or "critical points," differ from their

economic value. Therefore, Drewnowsky defined the critical points for each dimension or component (represented by "unbearable," "inadequate," "adequate," and "affluent"), and then normalized the individual indeces accordingly on a scale from 0-100. In addition, he proposed that notice be made to the extent of the inequality in each component; for example, by multiplying the individual indices by the relevant Gini coefficients. In short, Drewnowski's methods involved a multi-level application of the conventional process of index construction in order to measure "flows of welfare" in real terms. These terms were social indicators, and their combination into a system resulted from the fact that the dimensions and critical points were selected on scientific and political grounds.

These composite measures have their own advantages in filling the gap not covered by pure social indicators.

Next, there is the question of which composite measures or GNP per capita should be utilized in this study. Since composite measures were designed to be more precise in measuring the level of welfare than GNP per capita, there must be a reasonable method to determine how the composite measures differ from GNP per capita in ranking countries.

McGranahan et al. (1972), computed indices for fifty-

three countries. The correlation coefficient between these indices and the GNP per capita of the countries was 0.89. This is significantly higher than the ninety-five percent level. The coefficient obviously indicates that there is no substantial difference between the composite measures devised and GNP per capita in ranking countries. There is no example of a computed index found in Drewnowski's study (1970). However, judging from the component indicators used, it is expected to have the same level of correlation with GNP per capita.

Another disadvantage of the composite measures is that as the procedure for computing indeces becomes more complicated, so does the ambiguity in the values. All of the measures discussed above have somewhat implicit (or explicit) assumptions of "optimal" patterns of socio-economic change, or the so-called "critical points." The use of these notions may sustain their arguments, but it also increases the subjectivity in the final output.

These problems lead us to the question whether the necessity of creating composite indices is really meaningful. It is fairly laborious to identify the necessary social indicators and then convert them into the composite measures. A GNP per capita is not a complete measure, of course, but it has at least four advantages over the composite indices.

First, there is no ambiguity in the method of measuring or aggregation. All components are given in money terms, thus there is no possibility of causing a weighting problem.

Second, similar to the first advantage, even if two composite measures in different years were compared, it is not very clear what the difference in the two values really represents. For example, the level of welfare of a country in one year is given by one kind of composite index as 50, and the level in the following year is 60. In this case, we are at a loss to interpret the meaning of the difference, 10. This is an inherent problem contained in any of the composite measures, since they use an ordinal ranking system. For GNP per capita, which is a cardinal measurement, this problem is manageable.

Third, GNP per capita is understood to include most of the elements that affect production, except the activities in a household sector, which are rather implicit. This means if life expectancy grows, its growth is reflected on production as the improvement in the health of workers. Better health can affect the level of total production. GNP per capita can capture that implicit effect. On the contrary, a composite index cannot be disaggregated any further than its number of components, because it is a function of several component

indicators.

The last advantage is data availability. Unlike composite indicators, the national accounting system has a much longer history. This enables researchers easy access to time-series data which are required for this study.

The advantages pointed out above should not be taken lightly, since they all directly affect the procedural aspect of this study. Thus, it is a rational choice to use GNP per capita of countries as the "proxy" of individual economic welfare.

## The Relationships between Economic and Social Dimensions

The research work dealing with the effects of improvements in social dimensions upon economic welfare (as previously determined, it is represented by GNP per capita) are frequently found in the areas of demography and education. In the demographic approach, researchers focus upon how the reduction in death rate (or infant mortality rate) and a rapid growth of population affect the productivity or output levels. On the other hand, in terms of education, the relationship between the level of education that people have attained and the rates of return that are expected or are actually received is the main issue of the studies. In both types of approaches, the common conclusion reached by many of the researchers

is that lower mortality rate (hence, longer life expectancy), or longer education enhances the quality of human capital, which is reflected as higher outputs.

First of all, the studies on demographic approach are reviewed. The obvious benefit gained from a longer life expectancy is that people can participate in the labor force longer. This means a longer life expectancy chiefly determines the physical time aspect of productivity. The implication is more significant in developing countries where production is likely to be labor-intensive than in highly industrialized countries.

Another benefit gained, especially in the long run, is that longer lives allow people to have higher chances acquiring more knowledge and techniques from on-the-job training and schooling, as investments for future higher productivity and earnings.

However, the assumption found in some studies is contrary to this idea. The researchers assume that if life expectancy becomes longer, the marginal productivity of labor declines as the work force grows relative to capital. This assumption overlooks the accumulation of human capital and other social aspects that are improved by a longer life expectancy.

Coale and Hoover (1958) carried out their study along this "pessimistic" view. They made a model postulating

the change in major demographic indicators in India (including a declining mortality rate). They said that a high rate of increase in population and hence, in the labor force, is not supported by a corresponding increase in investment to maintain the same per capita income. In addition, the population growth induced by the declining mortality increases the dependency burden and thus tends to lower private savings and investment rates. Savings and investment in the public sector also tend to be lower because of a greater burden on public welfare funds for education and health. These analyses, based on the model, led them to conclude that a fall in per capita income is an inevitable consequence of the decline in mortality and the population growth.

Keeley (1976) introduced the Swan-Solow, neoclassical, one-sector model of growth. He revised the model to include elements such as human capital investment, dependency burden, etc. Keeley concluded there was no straightforward tendency like the one observed in the study by Coale and Hoover.

The positive effect given by the improvement in health has been examined empirically. Malenbaum (1968) applied the simple regression-type analysis to examine twenty-two countries in Africa, Asia, and Latin America. The independent variables chosen were: $X_e$, percent labor

force in agriculture; $X_3$, pounds of commercial fertilizer per acre; $X_4$, infant deaths per one thousand live births; $X_5$, population per physician; and $X_6$, illiteracy. Then, he regressed them upon $X_1$, the value of agricultural output. The following is the relationship Malenbaum found:

$$X_1 = 133 + \underset{(2.2)}{0.344X_2} + \underset{(0.73)}{0.038X_3} - \underset{(2.7)}{0.13X_4} - \underset{(3.8)}{0.00095X_5} - \underset{(0.25)}{0.024X_6} \qquad R^2 = 0.62$$

(t-ratios in parentheses)

As Malenbaum assumed initially, $X_4$ and $X_5$ showed inverse relationships with $X_1$. Moreover, these two health variables accounted for eighty percent of the total variation, while almost twenty percent was explained by the labor input variable, and only less than two percent by illiteracy. He concluded that changes in observed output could not adequately be explained by changes in the input of labor and capital, when these were measured as quantities of labor and capital without allowance for quality change.

Ram and Schultz (1979) used regression analysis to determine the relationship between the gains in total productivity in the health and technical change variables.

The data were from India during 1951 through 1971. The preliminary analysis showed that 36.3 percent and 19.3 percent of the total percentage increase in output were not explained by other factors in each decade, respectively. Using infant mortality rate only, there was a twenty-eight percent variation in the unexplained parts. Ram and Schultz pointed out possible statistical questions to justify their results. One possibility was the limitation due to a small number of observations. Another was the endogeniety of mortality change. Despite these possibilities, it seems natural to conclude that the decline in mortality has some significant effects upon the improvement in productivity.

Finally, a study on the effects of education on productivity is reviewed. In checking educational effects, a dependent variable is usually the level of the workers' income or a rate of return. They should not necessarily be taken synonymously with GNP per capita, since former concepts include some elements peculiar to individual.

Psacharopoulos (1981) made an international comparison of rates of return using forty-four countries. According to the analysis, the rate of return for primary education was higher in the lower income countries than in the higher income countries. This is because the average

educational attainment is relatively low in the lower income countries; hence, the significance of primary education is greater than in higher income countries. Also, the rate of return is generally lower for higher education than for primary and secondary levels. Higher education has an average of about ten percent rate of return.

The studies discussed here found that, in general, improvements in health or a higher participation in schooling would enhance output. It is probable that an improvement in health status has a positive effect upon worker's productivity or level of output. This means the study by Coale and Hoover is less persuasive than other empirical analyses because they neglected the significance of human capital improvement.

Therefore, the preliminary expectation about the pattern of estimated coefficients as discussed in the following chapter for this study will support the positive effects of social improvements.

# CHAPTER III. THE DATA AND THE MODEL SPECIFICATION

## Selection of Social Indicators

Based upon the discussion in Chapter II, this section will select the social indicators, which represent several social welfare dimensions. Hence, it is necessary to point out some important criteria that must be satisfied.

First, the represented concepts must be easily judged for direction of change associated with more welfare. This is the most important requirement, since the indicators must approximate the level of "well-being" of the society. In this sense, for example, birth rate is not an adequate indicator because the meaning of new births could be positive to the parents, but negative to society, where it is very crowded or people are suffering from hunger.

Second, the concept must be broadly accepted or observed in many countries. Due to differences in climate, religion, and other cultural variations, some of the indicators are not necessarily appropriate for an international comparison.

Third, the indicators must represent the very core of the welfare of a society. This means the indicators must reflect the basic factors essential for people to live. An indicator such as death rate by automobile accidents could satisfy the first condition. However, the concept

is not related to the core part of welfare, but is influenced by the number of automobiles used in that society.

Fourth, the indicators should represent the phenomena that are quantitative. Although it was discussed earlier that welfare is a kind of ordinal concept, the ambiguous elements must be eliminated to make a statistical analysis possible.

And finally, the indicators should be available continuously with a certain level of reliability. Generally, indicators with high availability are those with relative reliability. Indicators discontinuously recorded tend to be biased or to have some incorrectness. In this study, continuous availability is desirable to apply an econometric analysis.

The indicators that meet all of the above conditions are: 1. infant mortality rate, 2. life expectancy at age one, 3. daily calorie supply per capita, and 4. primary school enrollment ratio. Each indicator is explained below.

1. Infant mortality rate: This indicator gives the number of infants who died before they reached age one per one thousand live births. The implication of this indicator is that in any society, people are happy to have their babies survive rather than die. It means that a

reduction of this rate brings more well-being to the society, while an increase does not. An infant mortality rate can represent the health aspect of a society, namely that for children. It suggests something about the availability of clean water supply and the condition of sanitation systems, since these conditions are very critical for infants to survive.

2. Life expectancy at age one: Generally, life expectancy of people in a country is given by the number of years during which infants at age zero are expected to live. However, life expectancy at age zero overlaps the concept of infant mortality rate. Thus, an adjustment is required to ascertain the value at age one. To adjust life expectancy, the following formula will be used.

$$E_1 = [E_0 - 1 + Q_0(1 - K_0)] / (1 - Q_0)$$

where, $E_1$ = life expectancy at age one
$E_0$ = life expectancy at age zero
$Q_0$ = infant mortality per one thousand live births
$K_0$ = estimated average length of life of infants in a country who died before age one (approximately 0.2)

Although the actual difference between two expectancies is not very large, this adjustment has conceptual importance in a statistical sense. The implication of this indicator is to represent the health

dimension of adults in a country.

The phenomenon captured by this indicator, unlike the other three, may not be very objective and observable. In a society where people are expected to live seventy years, there are more older and healthier people than in a country where people are expected to live forty years. Hence, this indicator is more suggestive when it is used for making a comparison between countries rather than to be presented alone.

3. Daily calorie supply per capita: This indicator determines the nutritional and food supply condition of a society. It is represented by the food supply that is converted into calorie equivalent measured by the percentage of the required daily calorie intake of people in a society. The requirement of daily calories of each country differes slightly, since it involves other physiological elements of the people in a country.

4. Primary school enrollment ratio: An improvement in an educational dimension of a society is measured by this indicator. It is an estimate of the number of people enrolled in primary schools. This is expressed as a percentage of children at standard school-age (generally considered as those between six and eleven years old). The difference in the educational systems are reflected in the ratios given.

Although any other indicators cannot satisfy all the requirements mentioned above, these four indicators are the most reliable ones. Hence, the analysis will be meaningful and cover adequate dimensions of social and human welfare.

For each of the four indicators, eleven observations will be collected. They cover the years between 1975 and 1985. It is true that eleven years is not long enough to fully reflect the advantage of a time-series approach, however, this is the maximum length of period from which sufficiently reliable data could be obtained.

As expected, the correlation among these four indicators was very high, thus the possibility of multicollinearity exists. But since it is not possible to have other indicators or to reduce the number of indicators, there is no effective way to avoid multicollinearity.

Compared to the social indicators, however, the conversion of GNP per capita from local currencies into US dollars is not always easy. Artificial overvaluation of exchange rates are likely to happen in developing countries. In this study, a formula which was created by the World Bank will be used for conversion.

$$E_{t-2,t} = 1/3\ [E_{t-2}\{(P_t\ P_{t-2,u})/(P_{t,u}\ P_{t-2})\} + E_{t-1}\{(P_t\ P_{t-1,u})/(P_{t,u}\ P_{t-1})\} + E_t]$$

$$Y_{t,u} = Y_t\ /\ (N_t\ E_{t-2,t})$$

where, $E_{t-2,t}$ = weighted exchange rate for year t
$E_t$ = annual average exchange rate (local currency/US dollar) for year t
$P_t$ = local GNP deflator for year t
$P_{t,u}$ = US GNP deflator for year t
$Y_{t,u}$ = GNP per capita of a country measured in US dollars
$Y_t$ = current total GNP in local currency for year t
$N_t$ = mid-year population of a country for year t

The next issue is the classification of countries. The number of countries where data are available and relatively reliable is eighty-five. Countries such as Eastern European centrally planned economies where GNP per capita cannot be estimated accurately due to the differences in the economic accounting system, Middle Eastern and North African oil-producing countries where the level of GNP per capita is determined mainly by the factors that are generally independent from social and human welfare dimensions, and those having very small populations (less than one million) are excluded.

The classification of eighty-five countries is based upon the level of their GNP per capita in 1985. There are seventeen developed countries (DCS), where GNP per capita is more than or equal to US$6,000; sixteen as upper middle income countries (UMC), where GNP per capita is between

US$1,600 and US$5,999 (several countries whose GNP per capita was more than US$6,000 are classified in this group due to a common economic convention); twenty-six as lower middle income countries (LMC), where GNP per capita is between US$400 and US$1,599; and twenty-six as least developed countries (LDC), having GNP per capita of less than US$400. The last two classes are subdivided into two each, depending upon the income rankings of the countries involved. These six groups will be used as the units for a comparison in the empirical analysis section. For reference, names of the countries that belong to each group are given below.

DCS: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Federal Republic of Germany, Italy, Japan, Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom, and the United States

UMC: Argentina, Brazil, Greece, Hong Kong, Hungary, Israel, Korea, Malaysia, Mexico, Panama, Singapore, Spain, Trinidad and Tobago, Uruguay, Venezuela, and Yugoslavia

LMC1: Cameroon, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Nigeria, Paraguay, Peru, Syria, Thailand, Tunisia, and Turkey

LMC2: Bolivia, Cameroon, Dominican Republic, Honduras, Indonesia, Ivory Coast, Morocco, Mauritania, Nicaragua, Papua New Guinea, Philippines, and Zimbabwe

LDC1: Benin, Central African Republic, Ghana, Haiti, India, Kenya, Pakistan, Senegal, Sierra Leone, Somalia, Sri Lanka, Sudan, Tanzania, and Zambia

LDC2: Bangladesh, Burma, Burkina Faso, Burundi, Madagascar, Malawi, Mali, Nepal, Niger, Togo, Uganda, and Zaire

## Theoretical Framework and Model Specification

Using the indicators selected, a set of model equations will be specified in this section.

First of all, the constitution of the indicators is examined. The indicators are functionally represented as follows:

$$M = f_M(G_M, NI, S; X_M) \quad (1)$$

$$L = f_L(G_L, M, NA; X_L) \quad (2)$$

$$C = f_C(G_C; X_C) \quad (3)$$

$$E = f_E(G_E; X_E) \quad (4)$$

$$Y = f(K, LB, TC; X) \quad (5)$$

where, $M$ = infant mortality rate
$G_M$ = government expenditure on medical care, especially for infants
$NI$ = amount of nutrition available for infants
$S$ = degree of cleanliness of the society (availability of sanitation, accessibility to clean water, etc.)
$X_M$ = other factors affecting M
$L$ = life expectancy at age one
$G_L$ = government expenditure on medical care, especially for adults
$NA$ = amount of nutrition available for adults
$X_L$ = other factors affecting L
$C$ = daily calorie supply per capita

$G_C$ = government expenditure on promoting food supply
$X_C$ = other factors affecting C
E = primary school enrollment ratio
$G_E$ = government expenditure on primary education
$X_E$ = other factors affecting E
Y = gross national product per capita
K = physical capital
LB = labor force
TC = level of technology
X = other factors affecting Y

Among the factors determining the values of indicators, NI and NA are approximated by a daily calorie supply per capita, C. Although NA is generally greater than NI, the difference is not taken into consideration here. Also, measures for $G_M$, $G_L$, $G_C$, and $G_E$ are difficult to obtain. Hence, for GNP per capita, Y is used as a single proxy for each factor. For this approximation, there is an implicit assumption that for each kind of expenditure and the level of GNP of the countries are positively correlated. The variable S in equation (1) is a relatively important factor for determining the level of infant mortality rates; however, in this study, it will be included in other factors, $X_M$.

Of the four factors of production in equation (5), the labor force variable, LB, and the technology, TC, are further decomposed into the following factors:

$$LB = g(M, L, C, E; Z_1) \qquad (6)$$

$$TC = h(E; Z_e) \qquad (7)$$

where, M = infant mortality rate
L = life expectancy at age one
C = daily calorie supply per capita
E = primary school enrollment ratio
$Z_1$ = other factors affecting LB
$Z_e$ = other factors affecting TC

M and L determine quantitative aspects of the labor force. C has an effect upon the physical quality of workers, and E governs the area of knowledge and creativity of workers. Judging from the areas of social indicators, physical capital, K, is a more economic factor than LB and TC, which are influenced by social and human capital aspects. Thus, K is an exogenous variable.

In the second step, it is essential to reconsider the nature of the phenomena measured by the social indicators. The phenomena of interest, as compared with the economic dimension, do not change their conditions very rapidly. As will be observed later, the yearly changes in the indicators are generally small. This fact suggests that it takes a certain time period until the desired changes occur, after the variables affecting that indicator have changed. Thus, in this study, a time-lag concept will be incorporated into the econometric model.

Assume that a current value of $A_t$ depends upon the historical duration of a variable Z. Using a standard representation, $A_t$ is written as:

$$A_t = \beta_0 Z_t + \beta_1 Z_{t-1} + \ldots + \beta_k Z_{t-k}.$$

There is no instantaneous method to detect how the magnitude of βs varies depending upon t-i (i = 0, ..., k). For estimating the pattern of behavior for βs, suggestions have been made by Fisher (1937), Almon (1965), and other contributors. The common pattern for βs is that size declines as k becomes larger. Thus, it is reasonable to include recent Zs when the length of the lag is limited. This idea should be recognized as a general assumption for making the econometric model.

Due to the severe restriction on the length of available time-series, it is assumed that indicator $A_t$ is affected only by the values for year t-1 of itself and those of other variables. For example, $A_t$ is affected by $A_{t-1}$ and the values of other variables for year t-1. The lagged dependent variable permits a slow transition of the conditions.

Hence, in addition to the variables which influences each indicator in equations (1) through (4), each indicator is largely determined by its past values.

Incorporating the lagged dependent variables, the new equations are:

$$M_t = f_M(Y_{t-1}, M_{t-1}, C_{t-1}; X_M) \quad (1')$$

$$L_t = f_L(Y_{t-1}, M_{t-1}, L_{t-1}, C_{t-1}; X_L) \quad (2')$$

$$C_t = f_C(Y_{t-1}, C_{t-1}; X_C) \quad (3')$$

$$E_t = f_E(Y_{t-1}, E_{t-1}; X_E). \quad (4')$$

Using the estimates obtained by the four equations above, equation (5) becomes:

$$\begin{aligned} Y_t &= f(K, LB, TC; X) \\ &= f[K, g(M_{t-1}, L_{t-1}, C_{t-1}, E_{t-1}; Z_1), \\ &\qquad h(E_{t-1}; Z_2); X] \\ &= f(M_{t-1}, L_{t-1}, C_{t-1}, E_{t-1}; X) \end{aligned} \quad (5')$$

In equation (5'), it is assumed that f represents the Cobb-Douglas production function. Thus, using the data measured by natural logs, the regression coefficients obtained are interpreted as elasticity coefficients.

The third step completes a set of econometric models. Since the time-series data for the indicators are not stationary (having a slight upward or a downward trend), trend terms are incorporated into the models. This adjustment leads to the following equations:

$$\ln M_t = \alpha_M + \beta_{10}T + \beta_{11}\ln Y_{t-1} + \beta_{12}\ln C_{t-1} + \mu_{Mt} \quad (8)$$

$$\begin{aligned} \ln L_t = \alpha_L &+ \beta_{20}T + \beta_{21}\ln Y_{t-1} + \beta_{22}\ln M_{t-1} \\ &+ \beta_{23}\ln L_{t-1} + \beta_{24}\ln C_{t-1} + \mu_{Lt} \end{aligned} \quad (9)$$

$$\ln C_t = \alpha_C + \beta_{30}T + \beta_{31}\ln Y_{t-1} + \beta_{32}\ln C_{t-1} + \mu_{Ct} \quad (10)$$

$$\ln E_t = \alpha_E + \beta_{40} T + \beta_{41} \ln Y_{t-1} + \beta_{42} \ln E_{t-1} + \mu_{Et} \quad (11)$$

$$\ln Y_t = \alpha + \beta_0 T_1 + \beta_1 \ln M_{t-1} + \beta_2 \ln L_{t-1} + \beta_3 \ln C_{t-1} + \beta_4 \ln E_{t-1} + \mu_t \quad (12)$$

where, $T$ = year (1976-1985)
$T_1$ = year (1977-1985)

When equations (8) through (11) are fitted by ordinary least squares (OLS), several problems may arise.

The main problem is that in equations (8) through (11), the lagged dependent variable (such as $\ln M_{t-1}$ for estimating $\ln M_t$) is most likely correlated with the disturbance of the equation. This violates the assumption necessary for efficient and consistent OLS estimation. There are two possible cases that need to be considered.

The first possibility is when there is no significant autocorrelation among the residuals. Under this condition and with large samples, a simple OLS method would produce consistent and asymptotically efficient estimates.

The second possibility is the case when the standard first-order autocorrelation exists; i.e.,

$$\mu_t = \rho \mu_{t-1} + \epsilon_t$$
$$\epsilon \sim N(0, \sigma_\epsilon^2)$$
$$E(\epsilon_i \epsilon_j) = 0 \quad (i \neq j).$$

In this case, generalized least squares (GLS) method can be applied to obtain good estimates for the

coefficients.

Statistical tests to check the significance of the ps, the autocorrelation coefficients, are required to judge which application of the estimation is best. The ps are estimated for each country by applying OLS. The test statistic used is the one proposed by Durbin (1970b):

$$h = p\{ N / [1 - N V(\alpha)]\}^{0.5}$$

where, p = estimated first-order autocorrelation coefficient
N = number of observations
$V(\alpha)$ = the estimated variance of the OLS estimate of the coefficient of the lagged dependent variable

The test statistic is distributed as a standard normal. However, if the denominator within the brackets becomes less than zero, tests cannot be performed. In that case, the equations will be fitted assuming that $p \neq 0$, and apply GLS estimation.

Tables 1 through 4 present the results of the estimation of the coefficients. For all the dependent variables, a large share of the variation is explained with the one-year lagged value of a few regressors. The implication of these relationships is, as mentioned before, the phenomena measured by the social indicators do not change very quickly. This characteristic is common to all of the indicators used here.

Table 1. Estimated causal relationships for infant mortality rates ($\ln M_t$)

| Groups | a | T | $\ln Y_{t-1}$ | $\ln M_{t-1}$ | $\ln L_{t-1}$ | $\ln C_{t-1}$ | $\ln E_{t-1}$ |
|---|---|---|---|---|---|---|---|
| DCS | .758 | -.001 | .004 | .902* | | .252* | |
| | (.20)[a] | (-.48) | (.25) | (35.9) | | (3.33) | |
| | d.f. = 165 $R^2$ = .99 | | | | | | |
| UMC | -8.816 | .005 | -.035 | .980* | | -.064 | |
| | (-1.70) | (1.80) | (-1.88) | (60.4) | | (-.90) | |
| | d.f. = 155 $R^2$ = .99 | | | | | | |
| LMC1 | -4.644 | .003 | -.039 | .990* | | -.009 | |
| | (-.68) | (.73) | (-1.44) | (44.5) | | (-.11) | |
| | d.f. = 135 $R^2$ = .99 | | | | | | |
| LMC2 | 1.691 | -.001 | -.012 | .981* | | .017 | |
| | (.41) | (-.40) | (-.73) | (46.2) | | (.32) | |
| | d.f. = 115 $R^2$ = .99 | | | | | | |
| LDC1 | .037 | -.001 | .003 | .994* | | .004 | |
| | (.05) | (-.09) | (1.09) | (38.5) | | (.42) | |
| | d.f. = 135 $R^2$ = .99 | | | | | | |
| LDC2 | -.007 | .001 | .004 | .838* | | -.267* | |
| | (-.01) | (1.45) | (.62) | (101.5) | | (-13.9) | |
| | d.f. = 115 $R^2$ = .99 | | | | | | |

[a] t-ratios in parentheses.

*$\alpha$ < .05.

Table 2. Estimated causal relationships for life expectancies at age one ($lnL_t$)

| Groups | a | T | $lnY_{t-1}$ | $lnM_{t-1}$ | $lnL_{t-1}$ | $lnC_{t-1}$ | $lnE_{t-1}$ |
|---|---|---|---|---|---|---|---|
| DCS | .278 | .001 | .002 | -.009* | .814* | .013 | |
| | (.57)[a] | (.89) | (.82) | (-2.44) | (17.6) | (1.28) | |
| | d.f. = 164 | $R^2$ = .99 | | | | | |
| UMC | -.111 | .001 | -.002 | -.005* | .923* | -.004 | |
| | (-.20) | (.90) | (-.70) | (-2.77) | (35.1) | (-.57) | |
| | d.f. = 154 | $R^2$ = .99 | | | | | |
| LMC1 | 2.064 | -.001 | .006 | -.006 | .930* | -.010 | |
| | (1.94) | (-1.66) | (1.36) | (-1.54) | (38.0) | (-.75) | |
| | d.f. = 134 | $R^2$ = .99 | | | | | |
| LMC2 | -.46 | .001 | .002 | -.009 | .930* | .013 | |
| | (-.39) | (.62) | (.36) | (-1.00) | (28.6) | (.86) | |
| | d.f. = 114 | $R^2$ = .99 | | | | | |
| LDC1 | 1.867 | -.001 | 1.8E-6 | -.033* | .870* | 5.9E-6 | |
| | (3.1E3) | (-2.0E3) | (.79) | (-1.0E4) | (8.2E4) | (.64) | |
| | d.f. = 134 | $R^2$ = .99 | | | | | |
| LDC2 | -1.775 | .001 | -.012* | -.015* | .919* | 1.6E-6 | |
| | (-8.6E3) | (1.1E5) | (-1.3E4) | (-1.3E4) | (1.8E5) | (.56) | |
| | d.f. = 114 | $R^2$ = .99 | | | | | |

[a] t-ratios in parentheses.

*$\alpha < .05$.

Table 3. Estimated causal relationships for daily calorie supplies per capita ($lnL_t$)

| Groups | a | T | $lnY_{t-1}$ | $lnM_{t-1}$ | $lnL_{t-1}$ | $lnC_{t-1}$ | $lnE_{t-1}$ |
|---|---|---|---|---|---|---|---|
| DCS | 3.400 | -.001 | .001 | | | .882* | |
| | (1.53)[a] | (-1.23) | (.09) | | | (24.0) | |
| | d.f. = 166 | $R^2$ = .99 | | | | | |
| UMC | 2.428 | -.001 | -.009 | | | .970* | |
| | (1.22) | (-1.10) | (-1.49) | | | (37.4) | |
| | d.f. = 156 | $R^2$ = .99 | | | | | |
| LMC1 | 1.870 | -.001 | .001 | | | .956* | |
| | (.64) | (-.57) | (.06) | | | (26.9) | |
| | d.f. = 136 | $R^2$ = .99 | | | | | |
| LMC2 | .935 | -.001 | -.013 | | | .884* | |
| | (.26) | (-.09) | (-1.00) | | | (19.9) | |
| | d.f. = 116 | $R^2$ = .99 | | | | | |
| LDC1 | 4.598 | -.002 | -.028* | | | .804* | |
| | (9.36) | (-7.18) | (-13.7) | | | (44.7) | |
| | d.f. = 136 | $R^2$ = .99 | | | | | |
| LDC2 | -1.499 | .001 | -4.1E-7 | | | .904* | |
| | (-8.0E3) | (1.0E4) | (-.51) | | | (3.8E5) | |
| | d.f. = 116 | $R^2$ = .99 | | | | | |

[a] t-ratios in parentheses.

*$\alpha < .05$.

Table 4. Estimated causal relationships for primary school enrollment ratios ($lnE_t$)

| Groups | a | T | $lnY_{t-1}$ | $lnM_{t-1}$ | $lnL_{t-1}$ | $lnC_{t-1}$ | $lnE_{t-1}$ |
|---|---|---|---|---|---|---|---|
| DCS | -3.278 | .002 | -.006 | | | | .779* |
| | (-1.61)[a] | (2.06) | (-.63) | | | | (19.8) |
| | d.f. = 166 | $R^2$ = .99 | | | | | |
| UMC | .447 | .001 | -.001 | | | | .882* |
| | (.25) | (.06) | (-.29) | | | | (29.0) |
| | d.f. = 156 | $R^2$ = .99 | | | | | |
| LMC1 | 3.690 | -.002 | -.001 | | | | .914* |
| | (1.17) | (-1.03) | (-.10) | | | | (37.3) |
| | d.f. = 136 | $R^2$ = .99 | | | | | |
| LMC2 | 3.290 | -.002 | .001 | | | | .938* |
| | (.66) | (-.59) | (.07) | | | | (51.3) |
| | d.f. = 116 | $R^2$ = .99 | | | | | |
| LDC1 | 1.853 | -.001 | -.005 | | | | .995* |
| | (1.72) | (-1.65) | (-1.18) | | | | (24.3) |
| | d.f. = 136 | $R^2$ = .99 | | | | | |
| LDC2 | 3.172 | -.002 | -8.1E-7 | | | | .970* |
| | (1.8E4) | (-1.7E4) | (-1.08) | | | | (2.3E6) |
| | d.f. = 116 | $R^2$ = .99 | | | | | |

[a] t-ratios in parentheses.

*$\alpha < .05$.

The model, unfortunately, does not work very well for LDC1 and LDC2. In estimating $\ln L_t$, $\ln C_t$, and $\ln E_t$, some independent variables have very small coefficients and small t-ratios. Thus, a revised model for these groups of countries are as follows:

For LDC1,

$$\ln L_t = \alpha_L + \beta_{e0} T + \beta_{e1} \ln M_{t-1} + \beta_{ee} \ln L_{t-1} + \mu_{Lt}. \quad (13)$$

For LDC2,

$$\ln L_t = \alpha_L + \beta_{e0} T + \beta_{e1} \ln Y_{t-1} + \beta_{ee} \ln M_{t-1} + \beta_{e3} \ln L_{t-1} + \mu_{Lt} \quad (14)$$

$$\ln C_t = \alpha_C + \beta_{30} T + \beta_{31} \ln C_{t-1} + \mu_{Ct} \quad (15)$$

$$\ln E_t = \alpha_E + \beta_{40} T + \beta_{41} \ln E_{t-1} + \mu_{Et}. \quad (16)$$

The reason why most of the modified equations do not have GNP per capita as the independent variable is important in revealing the situation of the countries in LDCs. In those countries, the absolute amount of expenditure is less than those in higher income countries. Thus, even if the governments have policies to improve a certain social dimension, the amount of budget allocated for that purpose may not be enough to make a significant change in the indicator. In addition, it is pretty likely that in those countries, political instability harms the efficient functioning of the government. Hence, it invites the absence of the policy implementation for social welfare advancement. Therefore, it must be useful

to expect that fraction of GNP per capita which gives some favorable effects upon the improvement of the phenomena as measured by the social indicators. However, as far as the econometric specification used in this study can determine, such effects are negligible in LDCs. Table 5 shows the modified estimation of the causal relationships.

The equations defined above are now substituted into the equation (12). Thus, equation (12) can be described as follows:

For DCS, UMC, LMC1, and LMC2,

$$\begin{aligned} \ln Y_t = \alpha + \beta_0 T &+ \beta_1 [f_M(Y_{t-2}, M_{t-2}, C_{t-2}; X_M)] \\ &+ \beta_2 [f_L(Y_{t-2}, M_{t-2}, L_{t-2}, C_{t-2}; X_L)] \\ &+ \beta_3 [f_C(Y_{t-2}, C_{t-2}; X_C)] \\ &+ \beta_4 [f_E(Y_{t-2}, E_{t-2}; X_E)] + \mu_t . \end{aligned} \tag{17}$$

For LDC1,

$$\begin{aligned} \ln Y_t = \alpha + \beta_0 T &+ \beta_1 [f_M(Y_{t-2}, M_{t-2}, C_{t-2}; X_M)] \\ &+ \beta_2 [f_L(M_{t-2}, L_{t-2}; X_L)] \\ &+ \beta_3 [f_C(Y_{t-2}, C_{t-2}; X_C)] \\ &+ \beta_4 [f_E(Y_{t-2}, E_{t-2}; X_E)] + \mu_t . \end{aligned} \tag{18}$$

For LDC2,

$$\begin{aligned} \ln Y_t = \alpha + \beta_0 T &+ \beta_1 [f_M(Y_{t-2}, M_{t-2}, C_{t-2}; X_M)] \\ &+ \beta_2 [f_L(Y_{t-2}, M_{t-2}, L_{t-2}; X_L)] \\ &+ \beta_3 [f_C(C_{t-2}; X_C)] \\ &+ \beta_4 [f_E(E_{t-2}; X_E)] + \mu_t . \end{aligned} \tag{19}$$

When these equations are fitted, there still exists the possibility of a serial correlation. Testing a serial correlation in these equations requires a standard Durbin-Watson statistic, since the equations do not have a lagged

Table 5. Estimated causal relationships for LDCs

| Groups | a | T | $\ln Y_{t-1}$ | $\ln M_{t-1}$ | $\ln L_{t-1}$ | $\ln C_{t-1}$ | $\ln E_{t-1}$ |
|---|---|---|---|---|---|---|---|
| LDC1 | | | | | | | |
| $\ln L_t$ | 1.867 | -.001 | | -.033* | .870* | | |
| | (1.09)[a] | (-.69) | | (-3.30) | (25.9) | | |
| | d.f. = 126 | $R^2$ = .99 | | | | | |
| LDC2 | | | | | | | |
| $\ln L_t$ | -1.776 | .001 | -.012* | -.015* | -.919* | | |
| | (-1.37) | (1.65) | (-2.02) | (-2.21) | (28.0) | | |
| | d.f. = 115 | $R^2$ = .99 | | | | | |
| LDC2 | | | | | | | |
| $\ln C_t$ | -1.500 | .001 | | | | .904* | |
| | (-.44) | (.57) | | | | (20.5) | |
| | d.f. = 126 | $R^2$ = .99 | | | | | |
| LDC2 | | | | | | | |
| $\ln E_t$ | 3.171 | -.002 | | | | | .970* |
| | (.74) | (-.70) | | | | | (93.4) |
| | d.f. = 117 | $R^2$ = .99 | | | | | |

[a] t-ratios in parentheses.

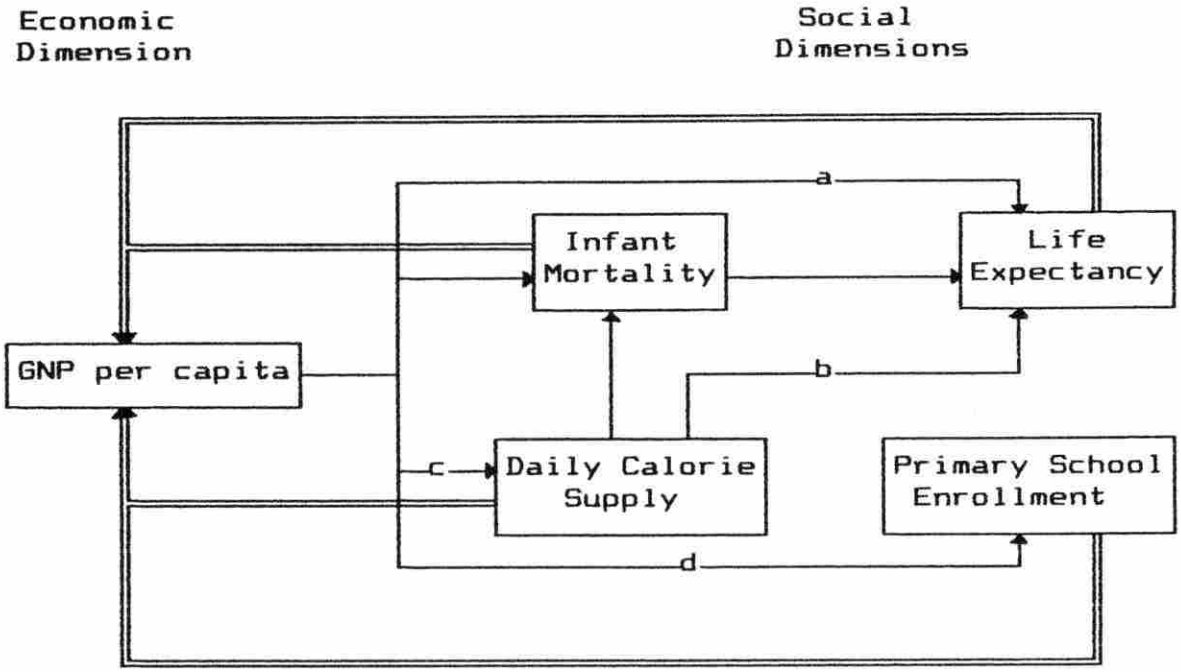
*$\alpha < .05$.

dependent variable.

For the visual convenience, Figure 1 is presented to show the causal relationships established above.

Before discussing the empirical analysis, it is necessary to delineate how GNP per capita of groups of countries will respond to the changes in the each of the social indicators selected as the independent variables.

First expectation is the sign of the estimated coefficients. The social indicators used in this study satisfy all the required conditions discussed in the first part of this chapter. All indicators, except the infant mortality rate, bring more social welfare when they have higher values; and likewise infant mortality rate when it has lower values. What is expected here is that these characteristics will similarly be reflected upon the changes in GNP per capita of the countries. It was stated before why both social and economic dimensions would be treated in this study as a complementary relationship in satisfying the requirements for human lives. It directly implies that the direction of change in the indicators representing the improvement in the social welfare dimensions must coincide with the positive changes in GNP per capita. Hence, it is expected that the estimated coefficients for life expectancy, daily calorie supply per capita, and primary school enrollment ratio have positive




———— : The internal causal relationships that are to be determined initially [equations (8)-(11), and (13)-(16)]

a : equations (9) and (14) only

b : equation (9) only

c : equation (10) only

d : equation (11) only

═══ : The causal relationships that are the principal interests of the study [equations (17)-(19)]

Figure 1. Possible causal relationships among the indicators

signs, while infant mortality rate has negative. If the signs of the coefficients prove this classification within an adequate significance level, this expectation will be considered reasonable.

The second expectation, related to the first, is that the magnitude of the estimated elasticities with respect to each social indicator for the higher income countries are generally greater than those for the lower income countries. This expectation is derived from the fact that all social indicators used in this study have the values of maxima or minima in a practical sense; and ultimate values are usually attained by the higer income countries. Thus, it becomes less likely to observe an increase or a decrease in the values of indicators than in the changes in GNP per capita, the dependent variable. On the contrary, the opposite is true for the lower income countries, where the level of the values of the social indicators is far from the maxima or the minima. This difference creates greater elasticity coefficients in magnitude for the higher income groups, and the smaller coefficients for the lower income countries.

However, it is important to understand the following. Even if the higher income countries receive larger coefficients than the lower income countries, it does not necessarily imply that dimension is more important for the

higher income countries than for the lower income countries. Because, as income levels of countries increase, the actual effects of the social welfare dimensions become less important. Thus, the level of GNP per capita becomes more independent from the social dimensions. Therefore, in interpreting the large elasticities for the higher income countries, careful treatment is recommended.

The second point was introduced in Chapter II, Psacharopoulos found that the rates of return from primary education was higher in the lower income countries than in the higher income countries. This observation hints that in the lower income countries, the meaning of the basic social and the human requirement has a greater implication than in the higher income countries. If this is true for all the independent variables, the magnitude of elasticities must rise again as the level of GNP goes down. Thus, it is possible to expect that the changes in the magnitude of the coefficients will show a slight U-shaped curve as the level of GNP per capita changes.

Both of these expectations are rather a priori issues and have not been explicitly analyzed yet by economists. Thus, the following empirical analysis should be taken as one way to sustain the above expectations.

# CHAPTER IV. EMPIRICAL ANALYSIS

## Overall Estimation

Before discussing the results of the estimation in detail, it is desirable to delineate the general tendency with which GNP per capita of the countries react to the changes in the social indicators. Table 6 provides the estimates of coefficients from an overall fitting.

Table 6. Overall estimation of elasticities of GNP per capita with respect to each social indicator

| | a | T | $\ln M_{t-1}$ | $\ln L_{t-1}$ | $\ln C_{t-1}$ | $\ln E_{t-1}$ |
|---|---|---|---|---|---|---|
| $\ln Y_t$ | −14.984 | .004 | −.820* | 2.458* | 1.402* | −.054 |
| | (−1.11)[a] | (.65) | (−9.94) | (8.35) | (7.26) | (−.88) |

d.f. = 759 $R^2$ = .99 SSE = 175.98

[a]t-ratios in parentheses.

*$\alpha$ < .05.

The expectations stated in Chapter III for the signs of the coefficients are generally supported by these estimates. A reduction in infant mortality rates promotes higher GNP per capita highly significantly, while longer life expectancies and higher daily calorie supply have positive effects upon the level of GNP. These three types of effects imply that the physical environment of people

is an important determinant of economic welfare of countries. This suggests that the social and the economic dimensions of the societies cannot be separable.

The fourth variable, the primary school enrollment ratio, does not have a significant coefficient. The importance of education, as revealed by the study of Psacharopoulos, is significant in determining peoples' income levels. However, that relationship does not seem to be directly reflected in the levels of GNP per capita.

The overall estimation of cofficients is suggestive in interpreting the effects of the independent variables. Since the degree of the causal relationships between the variables and GNP per capita vary depending upon the levels of GNP, overall estimation does not necessarily give good estimates if a substantial number of countries are positioned apart from the estimated regression line. Thus, it is more useful to classify the countries into several groups, depending upon their income levels. So far, the internal causal relationships have been estimated by groups. This was assumed a priori, that the coefficients obtained by the group estimation were different from those by the overall estimation. However, in order to examine the effects of the social indicators upon GNP per capita, it is important to test whether the estimated elasticites of GNP per capita with respect to

each social indicator by the group estimation are significantly different from those by the overall estimation. Unless the coefficients are different from the overall estimates, the grouping of countries becomes meaningless. The testing procedure is shown in the Appendix. The statistics in Table 6 and 7 produce $F = 48.91$, which is statistically significant with a higher than ninety-nine percent confidence. Thus, it is meaningful to perform the separate estimation by the groups. In the following sections, comparisons will be made to show the differences and the similarities in the pattern of responses of the GNP per capita of the countries to the improvement in social welfare dimensions.

## Group Comparisons

### Infant mortality rate

Figure 2 gives a clear idea that GNP per capita and infant mortality rate of countries have a negative relationship at almost all income levels. The negativity of the coefficients, shown in Table 7, is universal for all country groups, although some coefficients are not statistically significant. This is evidence that a reduction in the infant mortality rate causes a positive increase in GNP per capita.

Among the coefficients of the upper five groups, DCS had the largest magnitude. As expected before, as the

Table 7. Estimated elasticities of GNP per capita ($\ln Y_t$) with respect to each social indicator for six groups

| Groups | a | T | $\ln M_{t-1}$ | $\ln L_{t-1}$ | $\ln C_{t-1}$ | $\ln E_{t-1}$ |
|---|---|---|---|---|---|---|
| DCS | -39.597 | .020 | -.427* | 3.220 | .311 | -1.093* |
| | (-3.85)[a] | (3.31) | (-3.41) | (1.32) | (1.76) | (-2.22) |
| | d.f. = 147 | $R^2$ = .99 | SSE = 7.96 | | | |
| UMC | -58.194 | .026 | -.338* | 5.289* | .006 | -1.288* |
| | (-2.77) | (2.39) | (-4.99) | (5.59) | (.02) | (-3.30) |
| | d.f. = 138 | $R^2$ = .99 | SSE = 14.21 | | | |
| LMC1 | -44.219 | .022 | -.128 | 1.498* | -.120 | .311* |
| | (-2.26) | (2.39) | (-1.01) | (2.83) | (-.42) | (3.69) |
| | d.f. = 120 | $R^2$ = .99 | SSE = 7.94 | | | |
| LMC2 | -13.009 | .001 | -.325* | 1.572* | 2.660* | -.101 |
| | (-.54) | (.11) | (-2.75) | (2.78) | (6.73) | (-.42) |
| | d.f. = 102 | $R^2$ = .99 | SSE = 9.71 | | | |
| LDC1 | -65.352 | .036 | -.031 | -.481 | .407 | .150 |
| | (-3.27) | (3.62) | (-.23) | (-1.19) | (1.03) | (1.36) |
| | d.f. = 120 | $R^2$ = .99 | SSE = 9.40 | | | |
| LDC2 | -31.310 | .021 | -.578* | -.819 | .424 | -.085 |
| | (-1.36) | (1.75) | (-2.98) | (-1.19) | (1.16) | (-1.11) |
| | d.f. = 102 | $R^2$ = .99 | SSE = 9.19 | | | |

[a] t-ratios in parentheses.

*$\alpha < .05$.

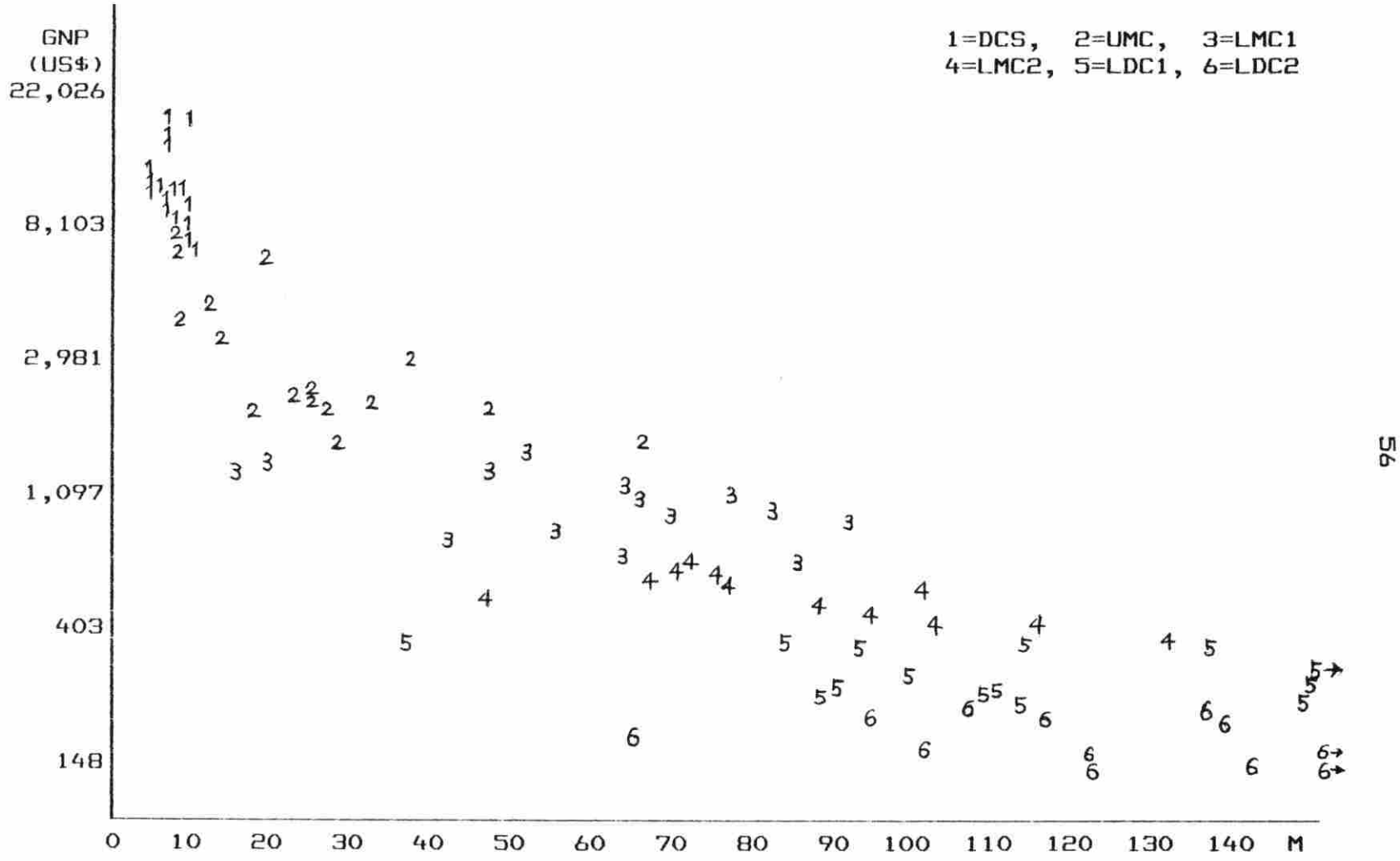



Figure 2. A profile of the relationship between GNP per capita and infant mortality rates in 1985

infant mortality rate approaches zero, it becomes less likely to achieve a further marginal reduction as compared to higher rates. However, it is very difficult to determine whether this magnitude really implies the significance in infant mortality rate reduction is greater in DCS than in other groups. In developed countries where styles of production in many fields of industries are highly mechanized and the age at which individuals begin to participate in the labor force is relatively high, hence younger children's participation in the labor force is only trivial (or sometimes officially prohibited). This fact suggests that infant mortality rates may not be very important elements in determining the level of GNP per capita in developed countries. The views supported by a large magnitude and by the industrial structure are contradictory though. What can be inferred from this estimate of elasticity is that in DCS, the level of GNP per capita is relatively sensitive to the reduction in infant mortality rates.

UMC also had a negative coefficient significantly different from zero. This group includes various types of countries, but many of them are known as the newly-industrialized countries (NICS). Looking at the styles of production in those countries, the pattern of production is more labor intensive than in DCS. In that sense, it is

not strange that this group has a greater coefficient in magnitude than DCS. In any case, the coefficient of this group also gives a slight exaggeration.

The magnitude of the coefficients shows a gradual decline as the level of GNP per capita declines, with the exception for LMC2 and LDC2. One possible way to explain the magnitude of the coefficients is to relate them to the style of production of the countries involved. In those countries, farming and household production generally dominate the source of the total national production, which depends heavily upon the labor force of small children. The dominance of such industries implies that the lower the infant mortality rate, the more secured for societies to obtain necessary labor force for production. In other words, lower infant mortality rates increase the number of young labor force supplied. This also enhances the vitality of workers that may affect productivity. Thus, negative large elasticities reflect that relationship. Consequently, it concludes that although the magnitude of elasticities for DCS, LMC2, and LDC2 are all large, but the implication given by the latter two are different from that by DCS.

Life expectancy at age one

Figure 3 provides a profile of the relationship between GNP per capita and life expectancies at age one of

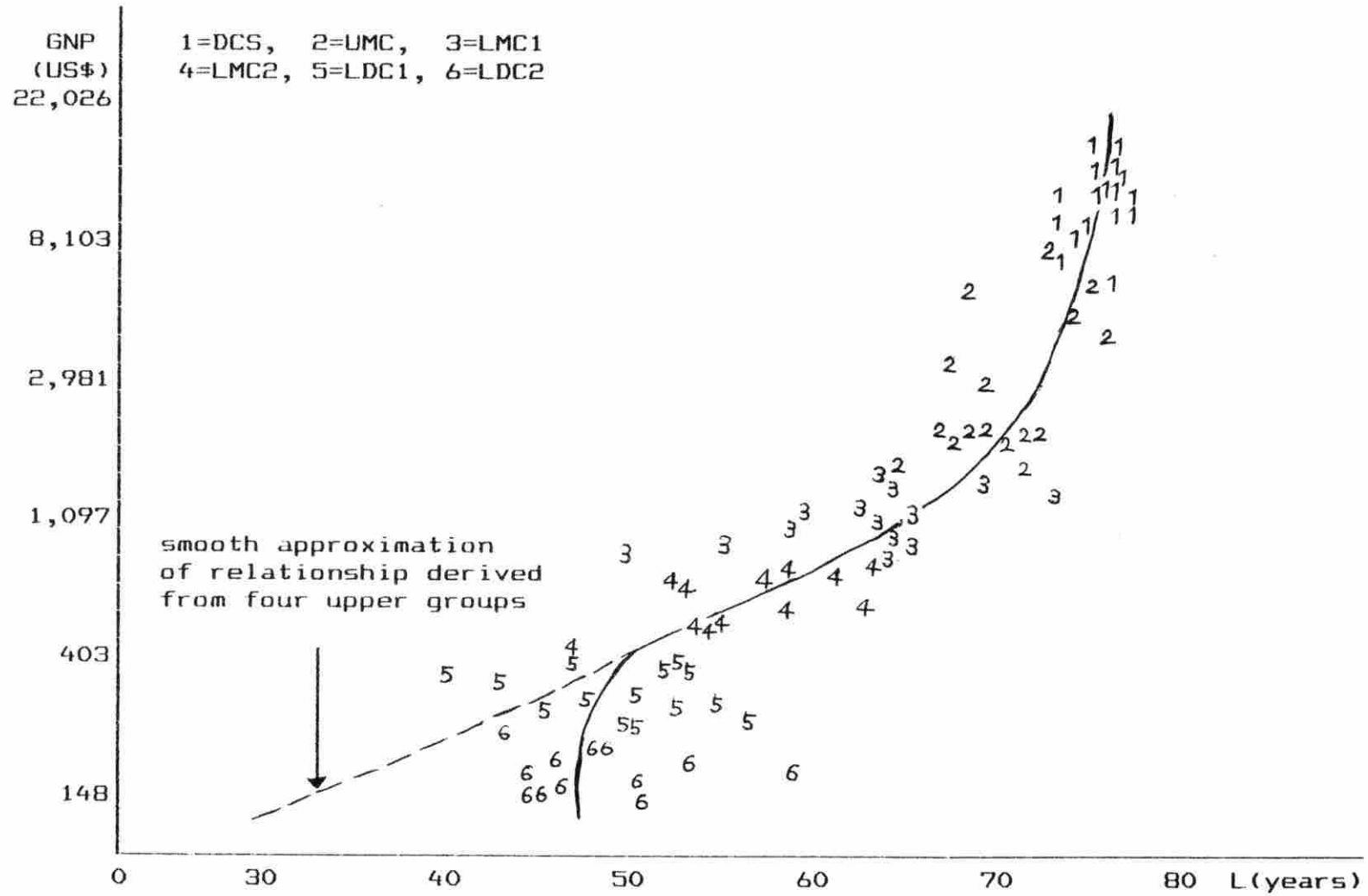



Figure 3. A profile of the relationship between GNP per capita and life expectancies at age one in 1985

the countries. The curve, similar to that of infant mortality rate, does reach the practical limit; that is, about eighty years as GNP goes up. From this profile, it is found appropriate that the expected sign of the elasticities is not fully supported by the estimates presented in Table 6. Out of the six coefficients, two of them are negative. In terms of the magnitude of the coefficients, they follow the pattern of gradual decline as expected before, with one exception, UMC.

First of all, the elasticity coefficient for DCS is much greater than unity, but not statistically significant. An appropriate interpretation is that even though life expectancies seem to affect the GNP as compared to the effects of the other variables, the substantial effects are not very large. The values of the life expectancies for countries in DCS have not changed very much during the period covered in this study. However, the GNP has been increasing greatly. Like the estimate for elasticity with respect to infant mortality rates for this group, the elasticity with respect to life expectancies also involves a kind of an algebraical exaggeration.

UMC has the largest coefficient among the six groups. The pattern of the behavior of GNP per capita is basically the same as DCS. Yet, the t-ratio shows a coefficient is

significant. Therefore, even though life expectancies are not changing and the elasticity is large, the degree of importance of this dimension in determining the level of economic welfare is somewhat larger than for DCS.

The groups LMC1 and LMC2 are only those that are receiving preferable but not exaggerated effects of life expectancies upon their GNP per capita. In Figure 3, both indicators show a clear proportionality, proving the importance of the improvement in life expectancies in promoting higher levels of output. The pattern of production of the countries involved in LMC1 and LMC2 are located in the middle of the DCS and LDCs, thus requiring a lot of human capital to support uncompleted mechanization in production. In this sense, the estimates of elasticities should be taken as showing the true effects.

For groups LDC1 and LDC2, the effects are negative. The coefficients for both are not very significant, but there are some negative effects. The coefficients obviously say that the causal relationships between life expectancies and GNP are different from those in other higher income groups. Graphically, Figure 3 shows the smooth approximation of relationship between life expectancies and the GNP per capita, as derived from the upper four groups, does not fit the LDCs. Furthermore,

the coefficients show as life expectancy increases, a slight reduction in the GNP per capita occurs. This negative causal relationship turns positive near the border of LMC2 and LDC1. The level of the GNP at the turning point is approximately US$400-500 as of 1985. A couple of interpretations are derived from this phenomenon. One, as of 1985, regardless of the level of the GNP per capita, life expectancy of the groups are at least close to forty-five years or more. Another, although the longer life expectancy is expected to give positive effects upon the level of the GNP, the effects cannot statistically be recognized until the level of the GNP of a country reaches close to US$400-500 or higher.

However, it cannot be concluded that shorter human lives increases the ecomomic welfare to these countries. In all countries examined in the study by Ram and Schultz (1979), it was a common observation that a reduction in mortality caused an increase in total economic output. Some of the countries they examined are included in LDCs. It must be recognized that although the total output may have risen due to a reduction in infant mortality rates, the per capita output did not rise significantly (or decrease) in the countries examined here. A reduction in mortality rates not only causes greater vitality and a longer life span, realized by higher productivity, but

also a rapid increase in population in the countries where the birth rates remained quite high. Unless the rate of increase in total GNP is higher than the population, reduction in GNP per capita cannot be avoided. In this sense, as of 1985 US$400-500 seems to be the approximate level of GNP per capita at which the rate of increase in total GNP began to exceed the rate of increase in population caused by lowering infant mortality rates.

From the above discussion, the six groups are classified into three types depending upon the pattern of the responses to the changes in the life expectancies. The first type includes DCS and UMC, whose GNP per capita is relatively independent from their life expectancies. The second type has LMCs which react consistently to changes in life expectancy. The third type includes LDCs. They received a slightly negative effect to the changes in the life expectancy.

The examination of the effects given by both infant mortality rates and life expectancy reveals that especially in the LDCs, the levels of economic welfare are influenced more by a reduction in the infant mortality rate than by longer life expectancy. This is further evidence that children's participation in the labor force is important in low income countries.

Daily calorie supply per capita

The profile presented in Figure 4 shows that unlike the previous two indicators, daily calorie supplies per capita have a rather weak association, suggesting the causal relationship between them and GNP per capita may not be very strong. There are several reasons explaining this. First, the association appears weak because foods consumed in one country are determined not only by the agricultural conditions and issues of trading, but also by the cultural aspects. For example, people in some countries avoid the consumption of beef, pork, etc. because of their religion. Second, the values are given in percentages of the daily requirement set for each country. In some countries the amount of calories are same, but the percentages may differ from one to another. Third, although daily calorie supply per capita is thought to be one of the core measurements to represent social welfare dimensions, this dimension should be thought principally as improving the health dimension. Thus, instead of giving the effects upon the economic welfare directly, daily calorie supplies tend to affect it indirectly through improvements in the health dimension. This means the effects by daily calorie supplies per capita could be one step weaker than the effects by the previous indicators.

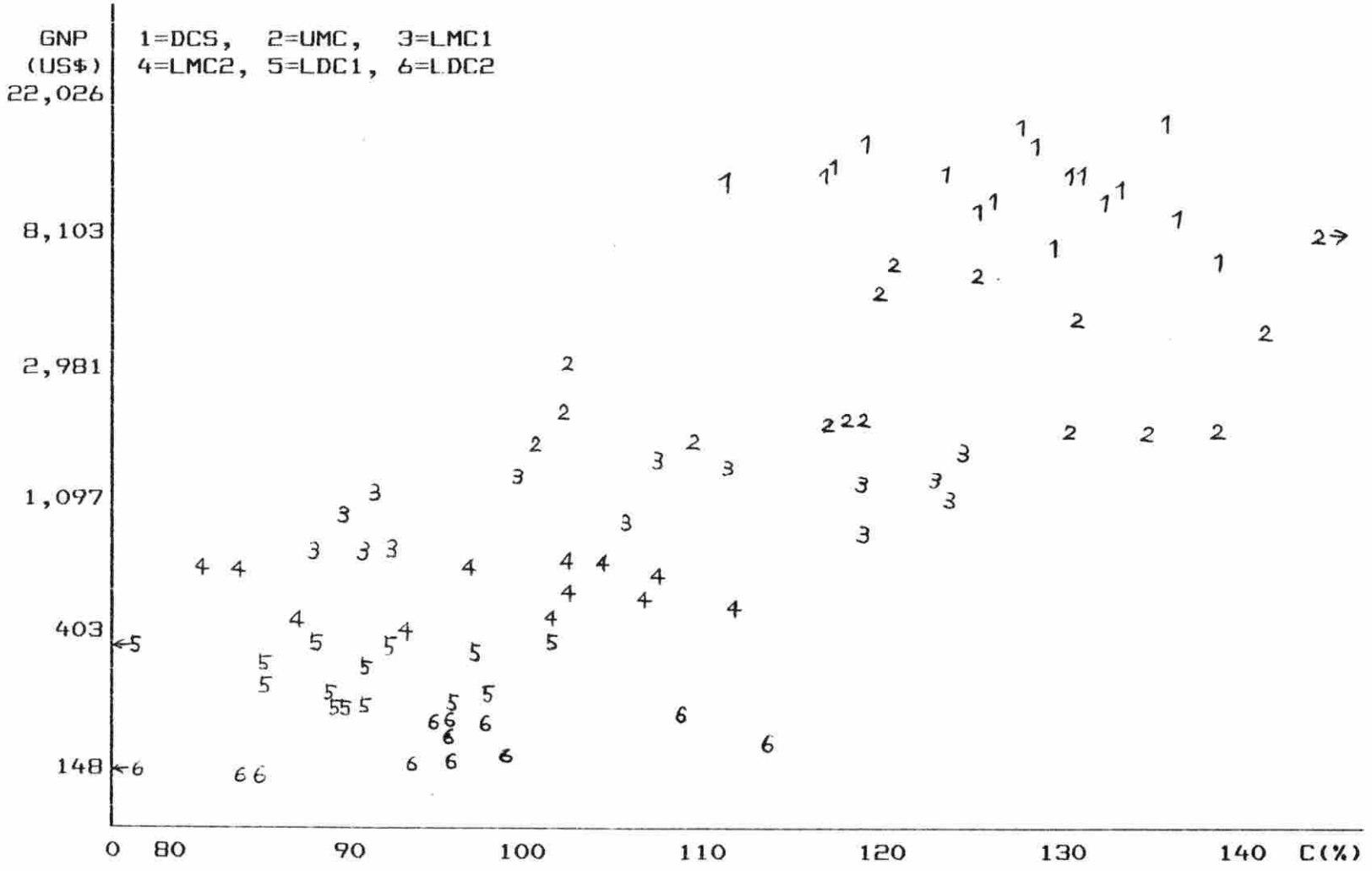



Figure 4. A profile of the relationship between GNP per capita and daily calorie supplies per capita in 1985

A particular characterization of the coefficients obtained in Table 7 is not easy. All groups but LMC1 have positive effects. LMC2 shows the highest significance. These coefficients indicate that regardless of the income level of countries, there is no significant difference in the effects of the increase in daily calorie supplies.

Furthermore, as Figure 4 shows, a substantial number of countries have values higher than one hundred percent. However, the effects of the daily calorie supplies in the group with constantly more than one hundred percent of the daily requirements such as DCS are not much different from the effects in the groups with less than the daily requirements.

Primary school enrollment ratio

A profile is shown in Figure 5 for the primary school enrollment ratio. There is a clear relationship between the GNP per capita and the enrollment ratios. This suggests that the higher the enrollment ratios, the higher the level of the GNP. Another clear pattern is shown in the lower income countries. The variance of the enrollment ratios is greater than in higher income countries.

However, the actual estimates of elasticities present a difficulty in proving the above expectations.

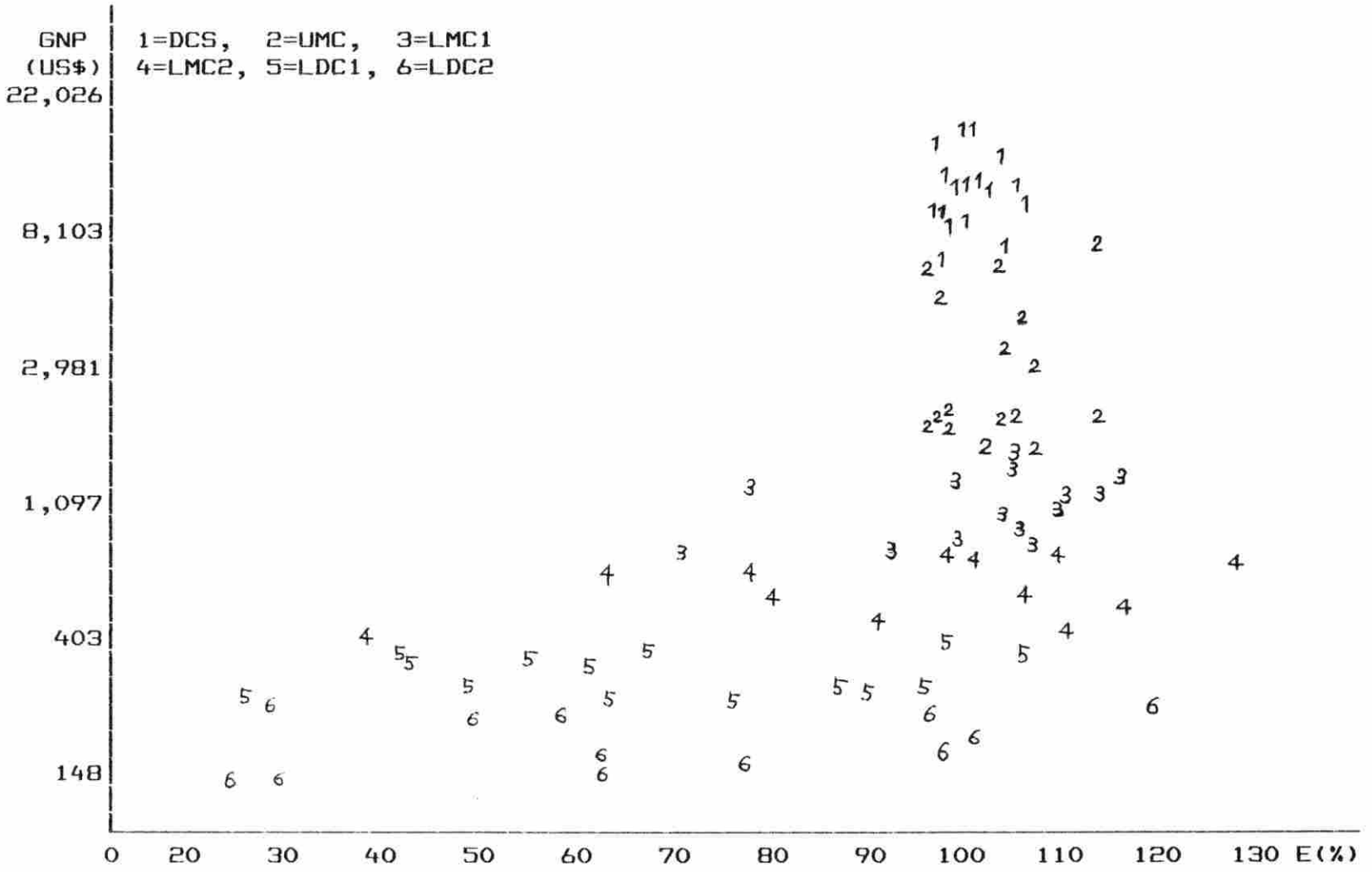



Figure 5. A profile of the relationship between GNP per capita and primary school enrollment ratio in 1985

A positive effect is significant only in LMC1, and there is a slightly ambiguous, positive effect in LDC1. In the other groups, the effects are negative, with statistical significance only for DCS and UMC. It is not correct to conclude that the significant negative effects in DCS and in UMC indicate that higher enrollment leads to the lower GNP.

In DCS, the pattern of the effects is somewhat complicated. As shown in Table 8, among the seventeen countries, Australia, Canada, France, Italy, New Zealand, and the United Kingdom recorded enrollment ratios higher than one hundred percent. These countries, except Australia, Canada, and France have relatively low levels of GNP as compared with those of Finland, Norway, Sweden, Switzerland, and the United States, who have slightly lower enrollment ratios. This relationship was the major cause for a negative coefficient. Enrollment ratios higher than one hundred percent seen from a different perspective imply that pupils who are not within the standard age groups (usually six to eleven years old) are thought to have missed their opportunities to be educated at their desired ages due to some reasons. It infers that those countries constantly having enrollment ratios higher than one hundred percent are not implementing their educational systems universally. On the other hand, the

Table 8. Average primary school enrollment ratios in developed countries 1977-1985[a]

| Country | Enrollment Ratio (%) | Country | Enrollment Ratio (%) |
|---|---|---|---|
| Australia | 106.5 | Japan | 99.7 |
| Austria | 99.5 | Netherlands | 99.1 |
| Belgium | 100.0 | New Zealand | 104.1 |
| Canada | 101.3 | Norway | 99.6 |
| Denmark | 99.4 | Sweden | 98.9 |
| Finland | 93.0 | Switzerland | 92.4 |
| France | 107.8 | United Kingdom | 102.7 |
| Federal Republic of Germany | 100.4 | United States | 99.1 |
| Italy | 101.8 | | |

[a]World Bank. World Development Report, 1979-1987.

latter group of countries that have enrollment ratios close to one hundred percent could be interpreted as almost perfectly accepting children at the desired age group to their primary education. It is generally difficult to explain reasons for a difference in the levels of the GNP though, the above difference in the primary education could be the one.

In UMC, the pattern of the effects is the same as in DCS, but it has a greater magnitude and a higher significance.

In lower income groups, there is neither an obvious pattern of relationships between GNP and enrollment ratios nor a U-shape in the magnitude of the coefficients. In all the countries, except LDC1, the effects of primary school education are ambiguous. In other words, it can be concluded that education does not enhance production explicitly. This contradicts the common notion in lower income countries that primary education is important as an element for economic development. Yet, the ambiguity of the effects can be interpreted as the following. The labor force required for the production in the lower income countries needs to be more quantitative-oriented rather than qualitative-oriented. From this point of view, it becomes more profitable to participate as a labor force than to go to school. Because of the variation in

domestic conditions, this reasoning may not universally be applicable. However, the demand for a labor force for farming and household production must be one reason for making the effects of the enrollment ratios to be less explicit, especially in the lower income countries.

# CHAPTER V. SUMMARY AND SUGGESTIONS

## Summary of Observations

The empirical analysis in Chapter IV supported the first expectation. That is the improvements in social welfare dimensions represented by the four social indicators generally affect an individual economic welfare dimension as represented by GNP per capita in the expected ways. For the second expectation, no clear pattern was observed to determine why there is a gradual decline in the magnitude of the elasticities and U-shaped transition of the magnitude of the coefficients.

Among the four indicators, infant mortality rate was the only variable that had the effects with an expected sign at all levels of GNP per capita. The magnitude of the coefficients differed between groups, reflecting differences in the style of production in the countries involved, particularly LDC2.

Improvements in life expectancies at age one were perceived in three different patterns. In higher income countries, longer human lives do not have a very substantial relationship with levels of economic welfare. In LMCs, the elasticity coefficients are in moderate sizes. The importance of longer life is more significant for them than for higher income countries. On the other hand, for LDCs, slight negative effects were observed.

The significance of the effects was not very great. It was found, however, that there was a lowest limit of life expectancy no matter the level of economic welfare of the country. Furthermore, the improvement in the life span in these groups caused by the lower mortality rate reduced the per capita GNP, since the growth rate in total GNP was lower than the rate of increase in population. This inequality in the rates for the two phenomena seemed to be reversed when GNP reached around US$400-500, which was roughly on the borderline between LMCs and LDCs. Therefore, although both infant mortality rates and life expectancies cover a similar nature of the social and human welfare dimensions, the effects of the reduction in infant mortality rates and those in life expectancies given by the estimated coefficients revealed that different structural issues existed between the groups, especially in LDCs.

The role played by the daily calorie supply per capita was hard to detect. There was no obvious difference in the magnitude of the coefficients, except in LMC2. Regardless of the difference in the amount of calories supplied in relation to the standard requirements of the people in countries, the coefficients did not show any specific indications.

Elasticity coefficients with respect to primary

enrollment ratios showed unexpected results. In the higher two income groups, DCS and UMC, the effects were significantly negative, implying that higher enrollment reduces the GNP per capita. It was hard to explain this effect though. It seems to be related to the universality in implementing primary education. In lower income countries, true effects were ambiguous. This seemed to be related to the age structure of the labor force and the demand for it.

Overall, the substantial effects by the improvements in the social welfare appeared in the middle income groups rather than DCS or LDCs. This implies the stage on which social and human conditions work as the elements to improve the level of individual economic welfare was substantially provided when the country's GNP per capita reached at least US$400-500 or higher. In DCS, the economic welfare of countries was more affected by other issues and the marginal effects by the social dimensions became less important. On the other hand, for LDCs, the linkage between economic and social dimensions was not established well enough to be detected by the approach used in this study.

## Suggestions for Future Study

This study, used four social indicators to reveal some characteristics of the behavioral differences among

country groups. This type of approach can be continued further by satisfying the following two conditions.

1) Use other social indicators that represent the levels of social welfare dimensions. This task, as stated earlier, is left to the major international organizations and their researchers. This may be the most important condition.

2) Obtain the continuously collected data. Although a time-series approach was adopted for this study, such an approach becomes more meaningful and effective if longer time-series data are available. Because of the relatively short history of the development of social indicators, the data availability is currently quite unsatisfactory.

With the use of enough data, more complicated models can be developed to establish the causal relationships. Thus, the effects given by specific dimensions can be estimated that are prescriptive for the planning of economic development.

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# APPENDIX. TESTING A HYPOTHESIS FOR POOLED TIME-SERIES DATA

In order to determine if the estimation by grouped countries is statistically meaningful (the estimated coefficients are significantly different from the estimates by pooled estimation), the following hypothesis testing is required.

A hypothesis to be tested is defined as

$$
\begin{aligned}
H_0: \ & \alpha_1 = \alpha_2 = \cdots = \alpha_6 \\
& \beta_{11} = \beta_{21} = \cdots = \beta_{61} \\
& \quad \vdots \qquad \vdots \qquad\qquad \vdots \\
& \beta_{15} = \beta_{25} = \cdots = \beta_{65}
\end{aligned}
$$

This hypothesis states that the coefficients for the same independent variables are identical for all the groups.

Using the variables selected, the model equation for a certain group is given by

$$Y_{ikt} = \alpha_i + \sum_j \beta_{ij} X_{ijkt} + \mu_{ikt}$$

where, $i = 1, \ldots, 6$ : groups
$j = 0, \ldots, 4$ : independent variables (T, M, L, C, E)
$k = 1, \ldots, K_i$ : number of countries involved in ith group
$t_k = 1, \ldots, 9$ : number of observations for kth country

Then for each group of countries, the following summations are defined.

$$SXX_{ij} = \sum_{jkt} \sum \sum (X_{ijkt} - \bar{X}_{ijk})^2$$

$$SXY_{ij} = \sum_{jkt}\sum\sum (X_{ijkt} - \bar{X}_{ijk})(Y_{ikt} - \bar{Y}_{ik})$$

$$SYY_{i} = \sum_{kt}\sum (Y_{ikt} - \bar{Y}_{ik})^2.$$

The jth coefficient for the ith group is given by

$$\beta_{ij} = SXY_{ij} / SXX_{ij}, \text{ and } \alpha_{i} = \bar{Y}_{i} - \sum\beta_{ij}\bar{X}_{ij}.$$

The sum of squares error is

$$SSE_{i} = SSY_{i} - SXY_{ij}^2 / SXX_{i}, \qquad d.f. = K_{i}t_{k} - j - 1$$

Restricting the coefficients under $H_0$, the model equation becomes

$$Y_{ikv} = \alpha + \sum_{j}\beta_{j}X_{ijkt} + \mu_{ikt}$$

In the same manner as before, the following summations are defined.

$$TXX = \sum_{ijkt}\sum\sum\sum (X_{ijkt} - \bar{X}_{j})^2$$

$$TXY = \sum_{ijkt}\sum\sum\sum (X_{ijkt} - \bar{X}_{j})(Y_{ikt} - \bar{Y}_{i})$$

$$TYY = \sum_{ikt}\sum\sum (Y_{ikt} - \bar{Y}_{i})^2.$$

The jth coefficient is given by

$$\beta_{j} = TXY / TXX, \text{ and } \alpha = \bar{Y} - \sum\beta_{j}\bar{X}_{j}$$

The sum of squares error is

$$SSE = TYY - TXY^2 / TXX, \qquad d.f. = \sum_{i}K_{i}t_{k} - j - 1$$

Without a restriction, total of $SSE_i$ for six groups is

$$SG = \sum_{i}SSE_{i}, \qquad d.f. = \sum_{i}(K_{i}t_{k} - j - 1)$$

Under the restriction,

$$ST = SSE, \qquad d.f. = \sum_i K_i t_k - j - 1$$

Then the test statistic is given by

$$F = [(ST - SG)/(6j + 6 - 6)]/[SG/\sum_i (K_i t_k - j - 1)]$$

with $6j + 6 - 6$, and

$\sum_i (K_i t_k - j - 1)$ d.f.