A QUANTITATIVE APPROACH TO THE PROBLEM OF UNDERDEVELOPMENT

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NOMENCLATURE

r_c	Correlation factor in Linear regression analysis
Y_t	Production Function
t	Time
K_t	Amount of services of the economy's capital stock at time t
N_t	Rate of use of natural resources at time t
L_t	Employment of the labor force at time t
S_t	Society's pool of applied and scientific knowledge at time t
U_t	Society's socio-cultural environment at time t
K_{jt}	j th type of capital equipment in use at time t
N_{jt}	j th kind of natural resource in use at time t
L_{jt}	j th grade of labor employed at time t
$\frac{\Delta Y}{\Delta t}$	Rate of growth of real income
$\frac{\Delta Y}{\Delta K_j}$	Marginal physical product of j th type of capital
$\frac{\Delta Y}{\Delta N_j}$	Marginal physical product of j th type of land
$\frac{\Delta Y}{\Delta L_j}$	Marginal physical product of j th type of labor
$\frac{\Delta Y}{\Delta S_j}$	Marginal physical product of j th type of technology

NOMENCLATURE (continued)

$\frac{\Delta Y}{\Delta U_j}$	Marginal physical product of j th socio-cultural factor
$\frac{\Delta K_j}{\Delta t}$	The rate of accumulation of capital with respect to time t
$\frac{\Delta N_j}{\Delta t}$	The rate of change, natural resources with respect to time t
$\frac{\Delta L_j}{\Delta t}$	The rate of increase of the labor force with respect to time t
$\frac{\Delta S_j}{\Delta t}$	The rate of introduction of innovations with respect to time t
$\frac{\Delta U_j}{\Delta t}$	The rate of change of socio-cultural environment with respect to time
a_j	Structural Parameters
P_o	Initial Population
ϕ_p	Rate of Population Increase
n	Number of Years
P_n	Population at the end of n th year
Y	Logarithm of P_n
$\bar{Y}$	Arithmetic Mean of Variable Y
$\bar{n}$	Arithmetic Mean of n values
n'	$n - \bar{n}$ values
y	$Y - \bar{Y}$ values
Q_o	Initial Aggregate Annual Agricultural Production
ϕ_o	Rate of Increase of Agricultural Production
Q_n	Aggregate Annual Agricultural Production at the end of n th year
μ_k	Per cent non-agricultural production at the end of k th year
γQ_o	Portion saved for next year's planting

$\mathfrak{Z}_o k\, Q_o$	Portion of the aggregate annual agricultural product saved for foreign trade (export), initially
$\mathfrak{Z}_n k\, Q_n$	Portion of the aggregate annual agricultural product saved for foreign trade at the end of n th year
λ_o	Initial Per Capita Consumption of Agricultural Products
λ_n	Per Capita Consumption of Agricultural Products at the end of the n th year
a_o	Initial Agricultural Production per capita farm labor
a_n	Agricultural Production per capita farm labor at the end of the n th year

CHAPTER I

INTRODUCTION

General

The most important and crucial socio-economic problem at the present time is the long delayed economical development of the so-called "underdeveloped countries", which are inhabited by approximately three-quarters of the human race. From India to Ethiopia, from Indonesia to Nigeria, from Bolivia to Thailand, billions of poverty stricken people who are persistently threatened by famines and starvation live in the most deplorable and miserable conditions. Approximately one billion human beings have a standard of living of less than one hundred dollars a year and another billion people have an annual income one-quarter to one-half the income which a typical American family spends in a single month. In Iran when famine strikes the children of the poor examine the droppings of horses to extract morsels of undigested oats. In Calcutta at least 250,000 people who have no homes live in the streets. In Cali, Colombia, the city's sewers run through the miserable shacks of the poor when the river rises.

In Turkey with a population of thirty-two million, seventy per cent of the people live in villages which have no electricity, no running water, no proper medical facilities.

On the average, the peoples of the underdeveloped countries have a life expectancy only about half that of the people of highly industrialized and developed countries. Deadly diseases such as malaria, dysentery, and tuberculosis are common in all underdeveloped countries. Measured in calories, their food supply is approximately one-third less than that of the highly developed countries. Only the richest strata can afford to purchase the "protective foods" such as milk, meat and eggs. Again a very small minority, consisting mostly of the children of the rich, can attend schools. Consequently, in underdeveloped countries only one person in four or five knows how to read and/or write.

Non-human energy utilized in agriculture, transportation, household tasks and in industry is less than one-twentieth that of the industrialized countries. The examples given can be increased ad infinitum. However, one central fact is crystal clear: At the present time a great majority of the human race is compelled to live in the most horrible and inhuman conditions. The economical misery which surrounds them begets cultural, social and spiritual degeneration and poverty as well.

From every indication of the collective behavior of the impoverished masses in the underdeveloped countries, it is evident that these peoples are not simply resigned to their fate. They seek and believe they have a natural and an inalienable right to a much better life. They demand immediate and far-reaching solutions to their problems and unequivocally claim that their centuries old economical,

social and cultural poverty can and should be eliminated. Under the impact of the modern mass media which have broken every barrier that contributed to the cultural isolation of human groups, they observe the affluency of the highly developed industrial countries, make the inevitable comparisons and assert that the existing situation is simply unbearable. This very comparison and awareness, this ever-increasing impatience, and this long delayed, yet forceful, protest are the symptoms of a highly explosive and dangerous situation that exists in all underdeveloped countries.

Under the inevitable impact of these social developments, some economists, sociologists, engineers and politicians in underdeveloped countries are attempting to analyze the situation, establish the determinants of poverty and finally discover ways and means through which the economical, social and cultural development of their countries can be accomplished. Nothwithstanding these attempts, the per capita income gap between the economically advanced nations and the underdeveloped nations is widening--- the rich have been getting richer and the poor have been getting poorer. This increasing gap intensifies the discontent of the masses of the underdeveloped countries. Consequently, it is imperative not only to understand the causes of extreme poverty, but also find concrete ways which can lead underdeveloped countries out of the vicious circles which surround them. Unless this is done immediately, the situation will be hopeless for both advanced and underdeveloped countries.

The Purpose of the Study

The purpose of this study can be categorized as follows: a) to define and describe "underdevelopment" in terms of conventionally accepted criteria and relative comparisons, b) to delineate the basic factors which determine and perpetuate the economical and social backwardness that exist in underdeveloped countries, and c) to discover the ways and means which can lead underdeveloped countires to higher living standards.

In this study a combination of qualitative and quantitative approaches, with emphasis on quantitative (in other words, Mathematical), will be used. It is the intention of the author to make extensive use of the personal and collective experience he has accumulated in his native land, Turkey, which is classified as an underdeveloped country. However, it is hoped that the general conclusions of this study can be applied to a variety of countries which are attempting to pass from an exclusively agrarian economy to a self-sufficient industrial one. The author believes that, notwithstanding all the cultural and historical differences, almost all underdeveloped countries have fundamental similarities, common problems, and common destinies. In this respect, once underdevelopment is described both qualitatively and quantitatively, these similarities will be evident. In this study an attempt will be made to integrate descriptive and mathematical approaches in order to overcome the shortcomings of these methods which arise when they are employed independently. The

author believes that capable sociologists, eminent economists and competent social scientists come up with very valuable descriptions of underdeveloped countries. However, generally speaking, their analyses are verbose, their conclusions vague, their suggestions somewhat abstract. On the other hand, the solutions offered by engineers generally suffer from one-sidedness, from excessive detailism and from limited capability for application, even though the terminology employed is concise, the methodology is clear, and the conclusions are backed with scientific data. It is hoped that through a healthy combination of these two seemingly opposite methods, a new analytical tool, free of the shortcomings of its components will be created. In Hegelian terminology, the mutual interaction of thesis and anti-thesis will give birth to synthesis.

Historical Background

Even though the economical and, consequently, cultural poverty have been constant and horrible companions of mankind, attention to the problem of underdevelopment, as such, is relatively new. In the Western World, the excesses of industrial revolution have been depicted very clearly by a great number of social scientists varying from Adam Smith, Ricardo, J. S. Mill to Keynes, C. Wright Mills and Morice Dobb. However, these investigators were mainly interested in the socio-economic problems of the Western capitalist countries. Their main attention was directed toward social conflicts and antagonisms that have erupted between the

organized working class and the capitalists, the transition from individual ownership to corporate ownership, the accumulation and concentration of financial, political and social power in industrial units, and effects of increased productivity and automation on the society in general. The problems of the underdeveloped countries began to gain importance particularly after the Second World War, which brought the division of the world into two hostile camps---the Western World under the leadership of the United States of America, and Communist countries under the leadership of the Soviet Union. In order to gain strategic victories both sides had to appeal to underdeveloped countries, most of which originally preferred and attempted to remain neutral in this global conflict. Massive American military and economical aid began to pour to all corners of the world in order to relieve social and political tensions existing in underdeveloped countries, and, consequently, to secure their alliance. Parallel to this international development, the interest in the problems of the underdeveloped countries among Western scientists began rapidly to multiply. Social conditions once again determined the particular consciousness associated with these problems and a great number of government sponsored and private studies of the underdeveloped countries have been made. Today any text book in elementary economics or sociology written would be incomplete without a concise description of the economical and social backwardness that prevail in underdeveloped countries and without briefly delineating the determining factors that act up-

on them. Underdevelopment effects the entire world's social and economic structure.

Ragnar Nurkse (1) emphasizes the lack of capital formation and underemployment as the major determinants of underdevelopment. According to his studies, predominance of agriculture is common to almost all the underdeveloped nations. Statistical data indicate that two-thirds to four-fifths of an underdeveloped nation's labor force will be engaged in agriculture. Nurkse further estimates that twenty-five to thirty per cent of this farm labor is underemployed or surplus labor which contributes almost nothing to total agricultural output. This fact leads him to the conclusion that a large fraction of an underdeveloped nation's labor force can be reallocated from agricultural to industrial occupations with little or no decline in agricultural production. Eugene Staley (2) gives an excellent description of the underdeveloped nations and concludes that unless immediate and far-reaching remedies are found, the future is indeed bleak. W. Arthur Lewis (3) points out the positive correlation between the productive investment in manufacturing, agriculture and commerce and the level of economical development that exists at a given time. He clearly shows that this type of crucial investment is very much lacking in underdeveloped countries. Peter Wiles (4) contends that there is a conflict between economical development and rational choices in the allocation of scarce resources and favors a public policy which emphasizes economic growth. Charles P. Kindleberger (5) claims that economic develop-

ment and the level of governmental participation in economic life are positively correlated. Delbert A. Snider (6) studies the effects of economic aid to the underdeveloped nations, and concludes that a reasonable rate of growth---one to two per cent annual increase in per capita incomes---will require from five to ten billion dollars of foreign capital per year over the next fifteen years. After this time, it is hoped that the underdeveloped nations would be self-sustaining. Alexander Eckstein (7) asserts that government investment financed through taxation may promote economic growth without extensive governmental ownership of enterprises, governmental controls and central planning. Daniel Lerner and Lucille Plevsner (8) emphasize the impact of the mass media (radio, television, movies, inexpensive newspapers and magazines) on the population and indicate that transformation of value systems under this impact may be extremely useful in promoting economical development in the underdeveloped countries which are tied down by archaic and fossilized traditions. Eminent sociologist, Philip Hauser, (9) also emphasizes the role of social factors in underdeveloped nations and describes five main elements hindering economic development. First, he points out that the traditional value systems emphasize spiritual rather than material values and in so many other ways conflict with material aspirations. Second, traditional societies are highly stratified into an elite and a lower class , with almost no middle class. Third, as there is great deference to age, seniority takes precedence over training and competence which

further inhibits efficient utilization of labor power. Fourth, is the existence of pre-scientific mentality. Views of the universe as controlled by non-rational and supernatural forces conflict with economic incentives. Fifth, Houser points to the loose social ties in a great number of underdeveloped countries which make it impossible for these societies to move in a concerted, integrated, social way toward common goals. Benjamin Higgins (10) shows that agricultural productivity in the underdeveloped countries is extremely low in comparison to the agricultural productivity that exists in advanced nations. He points out that the backward peasant nations which depend so desperately on their capacity to grow food cannot compete in agricultural products with the advanced countries. United States's Louisiana rice undersells Philippine rice and California oranges are both better and cheaper than Indonesian oranges. Consequently, unless agricultural productivity is increased, underdeveloped countries will never be able to advance from a totally agricultural economy to a self-sustaining mixed economy.

Eugene R. Black (11) points to the disastrous effects of the relentless proliferation of people in the fragmentation of land holdings. Under the pressure of population increase, the typical unit of agricultural production in the underdeveloped lands became far too small to allow efficient farming. The so-called "postage stamp cultivation" marks the pattern of farming throughout most of Asia, and to a considerable extent also in Africa and South America. Alvin

H. Hansen (12) shows the dependence of underdeveloped countries on advanced nations and claims that the losses sustained by the underdeveloped countries because of the 1958 recession which caused tremendous decreases in the raw material prices, by far outweighed any foreign aid given for several years. Oscar Lewis (13) points to the reactionary behavior of the social elite in the underdeveloped countries who generally oppose every measure of social progress and claims that the capacity for suffering of the poor has obvious limits, and unless ways are found to achieve a more equitable distribution of the growing national wealth and a greater equality of sacrifice during the difficult period of industrialization, social upheavals will emerge sooner or later. Irma Adelman (14) examines the growth theories of Smith, Ricardo, Marx and Schumpeter and presents a modern Neo-Keynesian model of her own. By emphasizing both qualitative and quantitative factors in economical development, she introduces a whole theory of economic growth. Walter Krause (15) points to the Soviet aid offensive and shows that as in the case of Russian foreign trade, Soviet aid is motivated by both economic and political considerations. The Soviet Union has been willing to accept certain raw materials and food stuffs as payments for its loans. It is hoped that these relationships may lead to closer economic and political ties between the Soviet Union and the underdeveloped countries. The political implications of such a development for the Western World are very clear. Franklyn D. Holzman (16) also emphasizes the economical and political

consequences of Soviet aid to the underdeveloped countries and depicts this as a very serious challenge to the Western World.

CHAPTER II

COMMON CHARACTERISTICS OF UNDERDEVELOPED COUNTRIES AND THE BASIC FACTORS DETERMINING UNDERDEVELOPMENT

Underdevelopment Defined

In this study economic development will be defined as the process by which an economy is transformed from one whose rate of growth of per capita income is small or negative to one in which a significant self-sustained rate of increase of per capita income is a permanent long-run feature. According to this definition a society will be called underdeveloped if economic development is incomplete, yet possible.

This definition distinguishes economic development from sporadic growth and development produced by external factors. Then it is evident that an underdeveloped economy cannot simply be defined by a "single criterion". On the contrary, a detailed investigation and analysis of its socio-economic relationships is absolutely necessary. Only after this task is completed can it be established whether economic development is a) possible, b) in progress, or c) basically complete. The phenomenon of underdevelopment can only be understood in the context of the totality of complex inter-relationships which determine the economic and social life of such a society. Without at least tentatively recognizing the effects

of the superstructure composed of traditions, value systems, mores, culture, and history of a society upon its substructure composed of the productive activities and relations of productions and visa versa, no satisfactory analysis of any society, developed or underdeveloped can be given.

Common Characteristics of the Underdeveloped Countries

In order to prescribe concrete and effective solutions to the problem of underdevelopment, the first task is to point to the common characteristics of the underdeveloped countries. Otherwise, the solutions will be extremely limited in scope and applicability. Furthermore, from the definition of economic development and underdevelopment, it is not difficult to see that common characteristics are implicitly assumed. Just what are these characteristics that exist in almost every underdeveloped country?

1) Low Per Capita Incomes: The most descriptive common characteristic of the underdeveloped countries of the world is poverty --- low per capita incomes in comparison with the industrially advanced countries. In Table I the tremendous disparity among these incomes can easily be seen.

Table I clearly shows that the great majority of peoples of the world have pitifully low per capita annual incomes. Furthermore, as stated previously, the per capita income gap between the economically advanced nations and the underdeveloped nations has not only persisted, but also in most instances has increased. This widening obviously contributes to the social unrest and discontent that exist in the under-

developed countries.

TABLE I

PER CAPITA GROSS NATIONAL PRODUCT IN SELECTED COUNTRIES, ANNUAL AVERAGE (U. S. Dollars)

Country	Per Capita Gross National Product (U. S. Dollars)	Classification
Ethiopia	$55	Underdeveloped
Nysaland	60	"
Somalia	50	"
Afghanistan	50	"
Tanganyika	61	"
North Rhodesia	150	"
Congo	92	"
Liberia	100	"
Kenya	87	"
Nigeria	78	"
Haiti	105	"
Uganda	64	"
Sudan	60	"
Indonesia	131	"
Bolivia	99	"
Tunisia	173	"
Iran	108	"
Paraquay	114	"
Ghana	172	"
Pakistan	70	"
Peru	179	"
Iraq	156	"
Thailand	96	"
India	73	"
Egypt	142	"
Taiwan	161	"
South Korea	144	"
Mexico	202	Partially Developed
Spain	293	"
Guatemala	189	"
Dominican Republic	239	"
Equador	189	"
Turkey	220	"
Brazil	293	"
Colombia	263	"
Malaya	356	"
Jamaica	316	"
Portugal	224	"
Costa Rica	357	"
Greece	340	"
Chile	379	"
Yugoslavia	265	"

TABLE I (Continued)

Country	Per Capita Gross National Product (U. S. Dollars)	Classification
Hungary	490	Semi-advanced
Italy	516	"
Poland	475	"
Czechoslovakia	680	"
Uruguay	478	"
Venezuella	648	"
Argentina	490	"
Israel	726	"
Finland	794	"
France	943	Advanced
Netherlands	836	"
West Germany	927	"
Norway	1,130	"
Denmark	1,057	"
Sweden	1,380	"
United Kingdom	1,189	"
Belgium	1,196	
Australia	1,316	"
New Zealand	1,310	"
Canada	1,947	"
United States	2,577	"

Source: The U. S. Book of Facts, Statistics and Information, 1966, p. 614.

2) Overpopulation: Most of the underdeveloped countries have extremely large populations to support. In countries like India, because of the population explosion, per capita food consumption is pulled down to the subsistence levels. A slight change in climatic conditions reduces agricultural production, and famine strikes. The problem of overpopulation is further intensified because of the fact that any increase in consumer goods production raises the standard of living and consequently accelerates the population increase rate. Once this happens, any increase in living standards will be immediately dissipated by that increment with which popula-

tion increases. Table II compares the populations of some underdeveloped countries with that of the United States.

TABLE II

POPULATION PER SQUARE MILE OF SELECTED COUNTRIES

Country	Year	Population per Square Mile
United States	1960	60
Albania	1960	159
Burundi	1952	247
Ceylon	1963	419
Costa Rica	1963	69
Cyprus	1960	165
Dominican Republic	1960	177
El Salvador	1961	329
Greece	1961	166
Haiti	1950	415
India	1961	392
Indonesia	1961	174
Jamaica	1960	399
Republic of Korea	1960	707
Lebanon	----	548
Malaysia	1957	150
Nepal	1961	178
Nigeria	1963	156
Pakistan	1961	270
Philippines	1960	261
Portugal	1960	254
Thailand	1960	145
Trinidad and Tobago	1960	465
Turkey	1960	100
South Vietnam	1960	260

Source: The U. S. Book of Facts, Statistics and Information, 1966.

In order to relieve the pressures of the population explosion in some underdeveloped countries, many experts advocate government sponsored universal birth control measures. However, attractive as it may seem, this method has not worked well in many underdeveloped countries such as

India and Turkey. One major reason for this failure is the attitude of the impoverished masses toward the birth control measures. These poor peasants and a great majority of the industrial workers in the underdeveloped countries generally have no security, no pension plans, no retirement benefits which may help them in their old age. Consequently, a built-in natural security in the form of children is substituted for social securities which are totally lacking. It is not difficult then to see the natural hostility of these groups toward birth control measures. As long as the working people mistrust the elite government bureaucrats, the city folk, the birth control measures will not be effective.

3) Preponderence of Agriculture and Disguised Unemployment: Agriculture is predominant in almost all underdeveloped countries. Generally, from two-thirds to four-fifths of the labor force of an underdeveloped nation will be engaged in agriculture. Statistical data very clearly show that there is a definite negative correlation between the per centage of population engaged in agriculture and the national income. In all advanced countries only a small percentage varying between ten and twenty-five per cent of the population are in agriculture. The rest are engaged in industry, in services and in public activities. Table III reveals this fact.

Application of the linear regression analysis to the data given in Table III, gives a correlation factor, $r = -0.84$, between the percentage of population in agriculture and per capita gross national product. For our sample size $n = 63$,

in order to conclude that r is not zero with ninety-nine per cent confidence, r should be -0.33 which is larger than r = -0.84. Consequently, it can be stated with a confidence level above ninety-nine per cent, that in actuality between per cent population in agriculture and per capita gross national product a very strong inverse relationship exists. However, this relationship is associative rather than casual. Stated briefly, then, the smaller the per cent population in agriculture the larger the national income will be. If logarithmic values of per capita gross national product are plotted against corresponding per cent population in agriculture the result is an approximate straight line as shown in Figure 1. This Figure once again shows the inverse associative relationship. Generally, if in a given country a great majority of people can afford and find employment in the non-agricultural sectors of the economy, it would not be presumptuous to assume that the agriculture is highly mechanized, the agricultural units are of optimum size, and the use of man-made fertilizers is highly common. Unfortunately, in almost all underdeveloped countries, because of the operation of the archaic inheritance laws for centuries the agricultural units are either too small or the larger, optimal size units are under the control of landlords who are not enterprising and daring. Under these conditions mechanization is difficult and the use of man-made fertilizers is not very common. It is no wonder that the agricultural productivity in the underdeveloped countries is very low in comparison to that of advanced nations. Table

IV shows this in terms of rice production. Unfortunately, the problem of low productivity is not isolated; it exists in all spheres of agricultural production. Consequently, it is not at all unusual for an industrialized country such as the United States to sell agricultural products to India, which is predominantly agricultural.

TABLE III

THE RELATIOHSIP BETWEEN AGRICULTURAL POPULATION AND GROSS NATIONAL PRODUCT

Country	Per Cent Population in Agri-culture	Per Capita Gross National Product (U.S. Dollars)
Ethiopia	90	55
Nyasaland	90	60
Somalia	90	50
Afghanistan	85	50
Tanganyika	90	61
North Rhodesia	67	150
Congo	85	92
Liberia	80	80
Kenya	88	87
Nigeria	59	78
Haiti	83	105
Uganda	90	64
Sudan	75	60
Indonesia	75	131
Bolivia	72	99
Tunisia	68	173
Iran	80	108
Paraquay	54	114
Ghana	70	172
Pakistan	65	70
Peru	62	179
Iraq	81	156
Thailand	85	96
India	71	73
Egypt	65	142
Taiwan	63	161
South Korea	75	144
Mexico	58	262
Spain	49	293
Guatemala	71	189

TABLE III (Continued)

Country	Per Cent Population in Agriculture	Per Capita Gross National Product (U. S. Dollars)
Dominican Republic	56	239
Ecuador	53	189
Turkey	77	220
Brazil	58	293
Columbia	54	263
Malaysia	56	356
Jamaica	55	316
Portugal	48	224
Costa Rica	55	357
Greece	48	340
Chile	30	379
Yugoslavia	67	265
Hungary	53	490
Italy	31	516
Poland	57	475
Czechoslovakia	38	680
Uruguay	37	478
Venezuella	41	648
Argentina	25	490
Israel	17	726
Finland	46	794
France	26	943
Netherlands	19	836
West Germany	23	927
Norway	26	1,130
Denmark	24	1,057
Sweden	20	1,380
United Kingdom	5	1,189
Belgium	12	1,196
Australia	13	1,316
New Zealand	16	1 310
Canada	13	1,947
United States	8	2,577

Source: The U. S. Book of Facts, Statistics and Information, 1966.

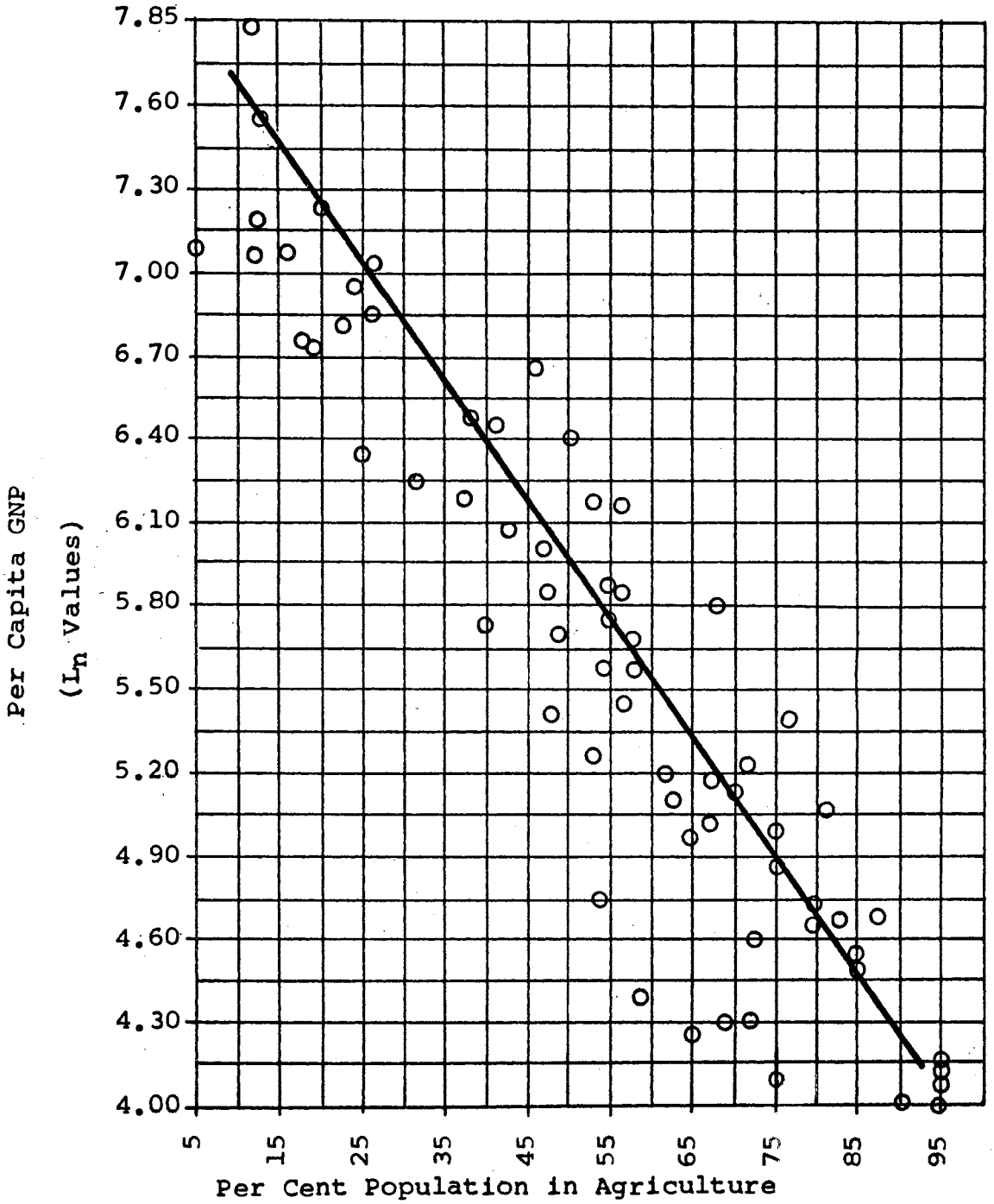

FIGURE 1. THE RELATIONSHIP BETWEEN PER CENT POPULATION IN AGRICULTURE AND PER CAPITA GNP

TABLE IV

RICE PRODUCTION

Country	Rice Production (100 kilograms per hectare)
United States	34.3
Burma	14.8
India	12.6
Indonesia	16.5
Thailand	14.3
Philippines	11.9

Another characteristic of the underdeveloped countries is the existence of underemployment which is directly connected with the preponderance of agriculture. It is estimated that on the average, twenty-five to thirty per cent of the farm labor is underemployed. This labor force which is so appropriately called "surplus labor" contributes almost nothing to total agricultural output. As a matter of fact, considering the less than optimal size of agricultural units, it is safe to assume that even the point of absolute diminishing returns may have been reached in many underdeveloped countries. Consequently, a re-allocation of this surplus labor force from agriculture to industry is not only possible, but also imperative. This rational re-allocation will result with no decline in food production. On the contrary, utilization of the surplus labor in industry will increase the total industrial output. This means that there will also be more agricultural implements and fertilizers, which will ultimately increase the agricultural production. A recognition of the interdependence of agriculture and industry is prerequisite to any development program.

4) Quality and the Re-allocation of the Human Resources

It was stated in Chapter I that in the underdeveloped nations only a small minority, mostly children of the rich, can afford to attend schools. Consequently, on the average, only one person in four or five knows how to read and/or write. In other words, in the underdeveloped countries seventy-five to eighty per cent of the population is illiterate. Certainly these illiterate people cannot be considered as an efficient labor force equipped with those qualities which are prerequisites in industrial operations. However, in this study it will be assumed that in a relatively short period of time the technical requirements of basic industrial operations can be taught to illiterate peasants. The problem is not a technological, but a social one. It has been observed in all industrial countries that the transition of the peasant from an agricultural worker to an industrial worker is time consuming, extremely difficult and frustrating. The discipline, regularity, monotony and strict hierarchical authority which exist in industry can be found only to a minimal degree in agricultural operations. Consequently, the psychological transformation of the poor peasant and the agricultural share-cropper is at times very painful both for the individuals involved and the society. The poor peasant submits himself to industrial discipline if, and only if, all other occupations are completely closed to him. In the capitalist countries this re-allocation of human resources has been accompolished through the workings of the market mechanisms and by squeezing the agricultural population out of the land

under the pressures of mechanized agricultural production. The small farmers who could not compete in the market with the big farmers simply had to sell their land and either accept working as agricultural workers or move to cities and seek employment in industry. At the present time the same phenomenon is taking place in all underdeveloped countries. However, a great number of poor peasants who leave their land and move to cities very soon realize that there are not enough jobs in industry for all. The industries of underdeveloped countries are weak, mostly stagnant and extremely inefficient. Consequently, as job opportunities are very rare, the surplus population of the villages then becomes the surplus population of the cities. Thousands of shacks mushroom around the periphery of big commercial centers and millions of people once again are condemned to poverty and horrible misery. Examples of this unfortunate development can be seen in every commercial center in the underdeveloped countries, in Istanbul, Turkey, in Rio de Janeiro, Brazil, in Calcutta, India, in Teheran, Iran, and in Mexico City, Mexico.

If by a miracle the industries of the underdeveloped countries attempt to get more vigorous, enterprising, daring and efficient, then they will soon have to give up this worthwhile venture. For, in all underdeveloped countries a great majority of those fortunate persons who attend and finish colleges prefer non-technical professions, such as law, politics, journalism and government bureaucracy. There are very few who would like to be engineers, economists, agron-

omists, chemists, et cetera, for the technical education is extremely competitive and very difficult in comparison to non-technical education. Furthermore, the prestige and monetary rewards associated with non-technical professions such as law and politics are much higher in comparison to engineering. The children of the rich who will inherit the total control of economical, cultural and political life in the underdeveloped countries generally are not at all interested in vigorous training, in scientific disciplines, and in modest, yet just renumeration for their efforts. However, it is more than obvious that without the existence and contributions of technicians, engineers, managers and scientists no development is possible. The scientific accompolishments of the Soviet Union, which was considered merely as a backward, primitive peasant society until the launching of the first Sputnik in 1957, can only be explained in terms of the tremendous emphasis which was put on technical and scientific education in the Soviet Union. If one can overcome his political inhibitions and investigate the matter objectively and thoroughly, one will see that in the years 1926 to 1952 Soviet professional manpower increased tremendously: engineers, ten times; teachers, five times; and physicians, four times.(18) A comparison of the Soviet Union and the United States as far as scientific and technical education is concerned, shows very clearly how the Soviet Union could considerably close the technological and scientific gap that exists between these two countries.

A further comparison of production of selected key commodities establishes the fact that the Soviet Union, which could definitely be classified as a underdeveloped country is now at least a semi-advanced one, due to the tremendous emphasis which is put on technical and scientific training.

Tables V and VI show once again that sociologists and economists may theoretically analyze, politicians may continuously talk, but only engineers and scientists can create and foster economical and technological development. As long as this crucial fact is not clear for underdeveloped countries, economical and social development will remain as utopia.

TABLE V

PROFESSIONAL GRADUATES WITH COMPLETED HIGHER EDUCATION IN THE SOVIET UNION AND THE UNITED STATES

Field	U.S.S.R. (1928-1959)	United States (1926-1958)	Comparison U.S.S.R. to United States Ratio
Engineering	1,117,800	620,300	1.8 : 1
Medical Doctors	420,000	181,700	2.4 : 1
Farm Specialists	389,200	166,400	2.4 : 1
Science Majors	430,000	704,400	1 : 1.6
(from universities)	(180,000)		
(from pedagogical institutes)	(250,000)		
Total: engineering, applied and theoretical sciences	2,357,000	1,672,800	1.4 : 1

Source: Joint Economic Committee, Congress of the United States, Dimensions of Soviet Economic Power, 1963.

TABLE VI

PRODUCTION OF SELECTED COMMODITIES 1950-1965

Commodity	Year	United States	Soviet Union
Pig Iron (millions metric tons)	1950	60	19
	1965	82	66
Steel (millions metric tons)	1950	88	27
	1965	121	91
Coal (millions metric tons)	1950	502	261
	1965	475	578
Oil (millions metric tons)	1950	266	38
	1965	385	243
Natural Gas (billions cubic meters)	1950	193	6
	1960	450	129
Electricity (billion kilowatt hours)	1950	389	91
	1965	1,220	507
Cement (millions metric tons)	1950	37	10
	1965	65	72

Source: Joint Economic Committee , Department of Commerce

5) Entrepreneurial Classes in the Underdeveloped Countries and the Effects of Foreign Investments: It is a well-known fact that the so-called industrial revolution "which transformed the Western World from feudal societies into capitalist ones", was carried out under the leadership of a new dynamic, enterprising and daring class --- the capitalists. It was this class which disciplined poor peasants and agricultural workers into highly efficient industrial workers, broke the barriers of archaic and fossilized traditions which strangled society, challenged the unquestionable authority of religious bodies, established the so-

called "free contract" between the employer and employee, transformed basically barter economies into money and commodity economies, accumulated capital for productive investment which increased the productivity of the labor, and, consequently, the volume of aggregate industrial and agricultural outputs. The contributions of this historically progressive class to the Western World are very clear. Yet at the present time no such class exists in any underdeveloped country and its spontaneous or induced emergence in the near future is highly unlikely. The so-called "entrepreneurial class" in any underdeveloped country generally lacks the dynamic industrialists, and mostly consists of merchants, speculators and usurers. These traditionally conservative and timid merchants and speculators accumulate capital, not to invest it productively, but to spend it conspicuously. Consequently, the first prerequisite of every industrial development, "the capital accumulation", in terms of factories, machinery, and equipment is almost nil in all underdeveloped countries. Yet, it is obvious that better-equipped labor forces can increase the productivity of the underdeveloped countries. On the average an American industrial worker uses $20,000 worth of equipment and this certainly contributes to his productivity and sets him above even the industrial workers of Western Europe. As long as merchants and speculators control the economical life of the underdeveloped countries, no significant capital accumulation will be accomplished and, consequently, as no productive investment will be made, the economical development once again will

be postponed to an indefinite future. Generally the individuals that call themselves industrialists and set themselves above the merchants in the underdeveloped countries are not genuine, domestic industrialists, but the representatives of foreign capital. An effective utilization of the foreign capital is surely beneficial to all underdeveloped countries. However, it is a well-known fact that the penetration of foreign capital also brings first subtle, then more direct infringements upon the economical, political and social life of an underdeveloped country and in a short period of time it compromises its independence and national integrity. Furthermore, foreign capital generally is invested in non-productive sectors of the economy of the underdeveloped country, such as consumer goods industry and extraction of raw materials which will be processed in the factories of the advanced countries. The industrial investment of the foreign capital is made in those countries which are already industrially advanced. For example, American capital is invested in European auto manufacturing industry, in electronics, in chemicals, in electronic computers, et cetera.

Table VII shows that in the underdeveloped sections of the world, such as Latin America, Asia and Africa, the majority of the American investment is in extractive industries. However, in industrially advanced Europe, the majority of the American investment is in manufacturing and the investment in extractive industries is minimal. The figures on petroleum represent refineries and distribution, not oil wells.

TABLE VII

PER CENT DISTRIBUTION OF DIRECT AMERICAN INVESTMENT BY AREA AND INDUSTRY, 1964

Industry	All Areas	Canada	Europe	Latin America	Africa	Asia	Oceania
Mining	8.0%	12.1%	0.4%	12.6%	21.9%	1.1%	6.3%
Petroleum	32.4	23.4	25.6	35.9	51.0	65.8	28.1
Manufacturing	44.8	54.3	24.3	24.3	13.8	17.5	54.1
Public Utilities	4.6	3.3	0.4	5.8	0.1	1.8	0.1
Trade	8.4	5.8	12.2	10.7	5.7	7.8	5.5
Other	8.6	10.6	7.1	10.7	7.5	6.0	5.9
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Survey of Current Business, September, 1965, p. 24.

Why is it that American companies generally prefer to make their investments in manufacturing in Europe and in extractive industries in the underdeveloped countries? First of all, the political regimes in Western Europe are generally more stable in comparison to those that exist in the underdeveloped countries. Secondly, the labor force in Europe is better trained, more disciplined, and, consequently, more productive. Thirdly, the danger of expropriation is nonexistent. Fourthly, a highly developed industrial base and a great number of technicians, engineers, managers, and scientists do already exist in Europe. Under these conditions, investment in manufacturing is highly profitable. On the other hand, as these necessary elements are very weak in the underdeveloped countries, foreign companies naturally prefer to consider the underdeveloped countries as sources of raw

materials, cheap labor and as non-domestic markets where their industrial goods can be sold. Consequently, foreign capital is invested in extractive industries and very soon every underdeveloped country becomes a supplier of raw materials for advanced countries. It is no wonder then, notwithstanding the transportation of billions of dollars, the underdeveloped countries still remain underdeveloped.

Another negative influence of the foreign capital is its creation of a new native class which will defend the interests of foreign capital. By virtue of its position, this new class which previously was mentioned as a pseudo-industrial class, prohibits the emergence of a national and independent industrialist class which can compete with foreign industrialists both in the domestic and non-domestic markets. For, surely it is far more convenient and easier to represent foreign capital than founding a truly national industry. Consequently, this new native class which represents foreign interests will consider the prospect of the emergence of a national industry as a genuine and deadly threat to its own existence and will do everything and anything in its power to suppress and crush any such attempt. Furthermore, as it can depend on foreign companies which control billions of dollars, its victory over a young national industrialist class is secured from the very beginning. A weak toddler has no chance in front of a giant, unless he is David and the giant is Goliath.

6) Capital Accumulation: In section 5) it was stated that the focal point of economic development is the accumu-

lation of capital in terms of factories, machinery and equipment which would increase the aggregate industrial and agricultural output. How is it possible for an underdeveloped country to accumulate capital? There is only one answer to this question --- by saving and investing. In order to accumulate capital a nation must restrict its consumption, and re-allocate resources from consumer goods production to producer's goods production. In a Keynesian sense, then, investment must catch up with the savings of the society so that the released resources in the production of capital goods can be absorbed. However, the savings potential of the underdeveloped countries is extremely low. According to statistical data, the underdeveloped countries can save, on the average, a maximum of five per cent of their national income for investment, whereas, the corresponding value for advanced nations is ten per cent. In all underdeveloped countries, the impoverished masses are not capable of making any saving. Saving is a luxury beyond the reach of these unfortunate people who have to spend their entire incomes in order to exist on the brink of starvation. And it is generally accepted that even if per capita incomes increase, this will not create significant saving, for the marginal propensities of consumption of the impoverished masses in the underdeveloped countries is very high. In other words, comparing their living standards with those of the advanced nations, these people develop new wants, new aspirations, new needs, and, consequently, they become extremely anxious to spend any increment that accrues to their incomes. However, it is also

a well established fact that in all underdeveloped countries a certain section of the population --- landlords, tribal chiefs, speculators, religious leaders, and some politicians are extremely rich and can certainly afford to make considerable amounts of savings for the society. This theoretical possibility, unfortunately, never becomes a reality. This is because the receivers of high incomes in the underdeveloped countries, as previously mentioned, generally squander their wealth on trivialities, on luxury goods, on accumulating gold and jewelry, and on the purchase of existing properties such as land or real estate in the cities. Thus, the savings of more prudent individuals find their way either to foreign banks or to the foreign companies. In other words, a certain portion of the fortunate ones who are capable of saving have no intention of saving and the rest simply prefer to channelize their savings into non-productive fields such as real estate or hoarding.

Table VIII shows that the industrially advanced nations consume less and save more of their gross national product in comparison to the underdeveloped countries. On the average, for the advanced nations, consumption of the gross national product is seventy-five per cent and the fixed capital formation is twenty-four per cent. Corresponding values for the underdeveloped countries in the same order are eighty-six and thirteen per cents. Consequently, then according to the statistical data the fixed capital formation for the advanced nations is two times that of the underdeveloped countries. If two extremes such as Japan and

Morocco are compared, it can be seen that in Japan the value for fixed capital formation is thirty-three per cent, whereas, for Morocco it is only eight per cent. Therefore, it can be concluded that capital accumulation in the underdeveloped countries is totally insufficient under the present conditions. With very meager savings, which ultimately find their way either to foreign banks or to conspicuous consumption, economic development is extremely difficult.

In conjunction with the insufficiency of fixed capital formation, the accumulation of the so-called "basic social capital" is also very unsatisfactory. Basic social capital consists of roads, adequate railways, communications, educational and public health facilities, gas and electricity production, all of which exist in meager degrees in the underdeveloped countries. The absence of social capital means that a significant amount of investment spending which does not directly result in the production of goods must preceed or at least take place simultaneously with productive investment in industrial machinery and equipment. Statistical data indicate that in the advanced nations sixty per cent of gross investment goes for public works, public utilities and housing and the remaining forty per cent goes for productive investment in agriculture, commerce and manufacturing. It is obvious that a proportionately higher amount of investment in the formation of basic social capital is needed in the underdeveloped countries. However, this policy of investment, once again deprives industry and agriculture of vital investments which are essential for increased product-

ivity. Consequently, the underdeveloped countries are confronted with another vicious circle. The significance of total investment can be seen in Table IX.

TABLE VIII

EXPENDITURE OF GROSS NATIONAL PRODUCT ON CONSUMPTION AND FIXED CAPITAL FORMATION, PER CENT DISTRIBUTION

Country	Year	Consumption (Private and Government)	Fixed Capital Formation
United States	1963	82	16
Australia	1963	74	25
Austria	1963	75	23
Belgium	1963	80	20
Canada	1963	78	22
Finland	1963	72	27
France	1963	79	20
West Germany	1963	73	25
Italy	1963	78	23
Japan	1963	63	33
Luxembourg	1961	68	25
Netherlands	1963	74	24
New Zealand	1963	75	23
Norway	1963	74	30
Sweden	1963	77	23
Brazil	1960	84	15
Burma	1963	79	17
Ceylon	1963	89	13
Taiwan	1963	81	16
Costa Rica	1962	88	75
Ecuador	1963	86	12
El Salvador	1963	89	10
Guatemala	1963	90	12
Honduras	1962	87	13
Mexico	1963	86	14
Morocco	1962	92	8
Philippines	1963	86	13
Southern Rhodesia	1963	83	15
Sudan	1962	87	13
Tanzania	1963	89	10
Turkey	1963	90	14

Source: Statistical Year Book, Statistical Office of the United Nations.

TABLE IX

THE RELATIONSHIP BETWEEN GROSS NATIONAL INVESTMENT AND THE GROSS NATIONAL PRODUCT FOR UNITED STATES

Year	Gross National Investment (billions of dollars)	Gross National Product (billions of dollars)
1950	78.0	284.6
1955	103.3	397.5
1959	114.4	482.7
1960	117.7	502.6
1961	114.5	518.7
1962	128.8	556.2
1963	136.7	583.9
1964	149.0	622.3

Sources: Federal Reserve Bulletin, Board of Governors of the Federal Reserve System, and Economic Report of the President, January, 1965, Executive Office of the President, Council of Economic Advisers.

The same relationship is given in Figure II. Table IX and Figure 2 show that there is a very strong positive correlation between the Gross National Investment and the Gross National Product. The higher the level of the gross national investment, the larger the gross national product is. Application of the linear regression analysis to the data given in Table IX gives a correlation factor, $r_c = +0.98$, between the gross national investment and the gross national product. This relationship has both the characteristics of an association and the cause-effect relationship. In other words, when a nation is capable of increasing its gross

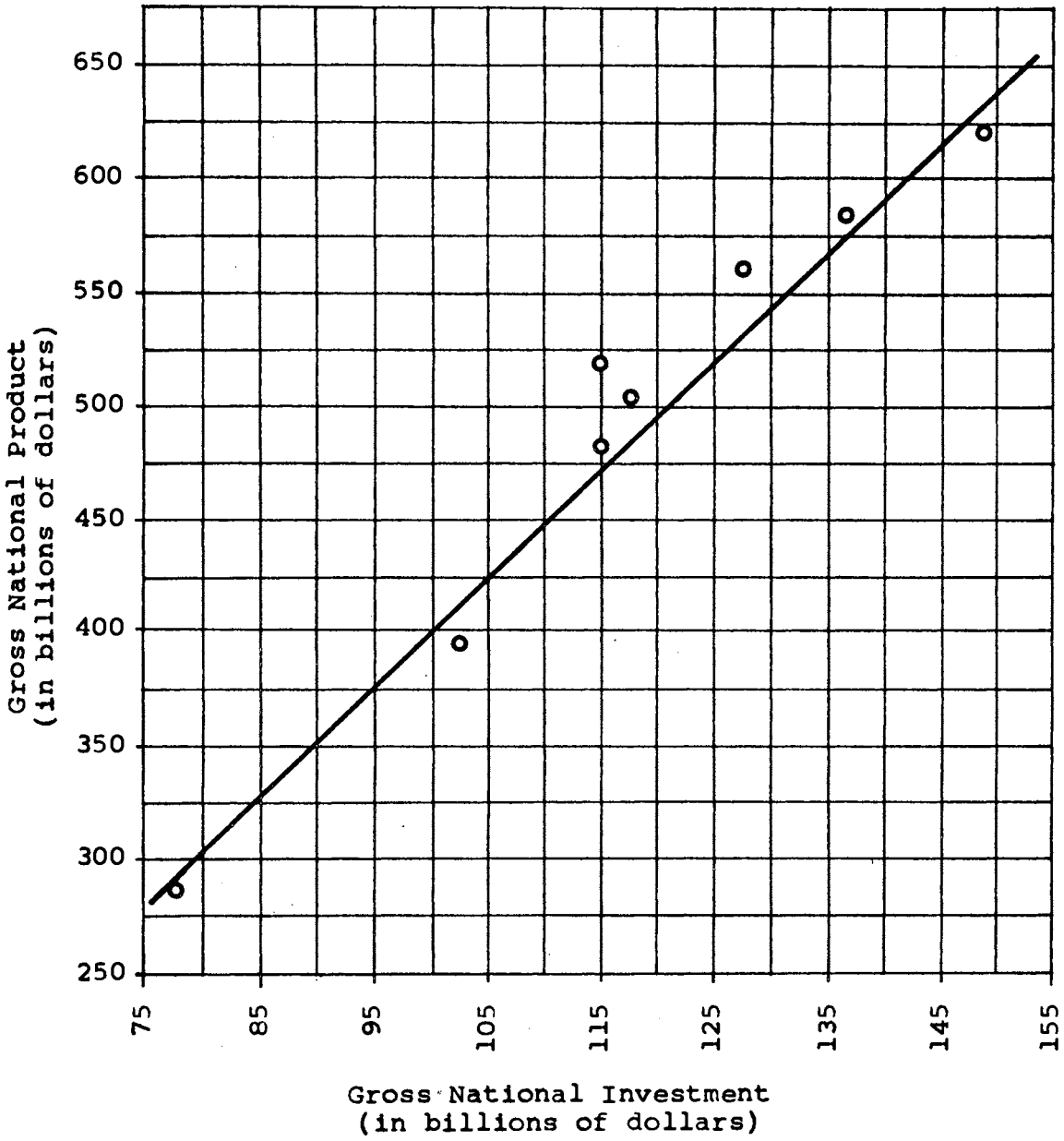

FIGURE 2. THE RELATIONSHIP BETWEEN THE GROSS NATIONAL INVESTMENT AND THE GROSS NATIONAL PRODUCT FOR THE UNITED STATES.

national investment its gross national product will increase, and, on the other hand, if the level of the gross national product is high, then the nation will be capable of making significant investments in agriculture, industry and commerce.

7) The Effects of Colonialism: A great number of the underdeveloped countries at one time or another were colonies of the Western World. India belonged to Great Britain, Indonesia to the Netherlands, Northern Africa to France,Latin American countries to Spain. The colonial policies of the Western countries caused a deformed development in the underdeveloped countries. In the eyes of colonialist Western nations, the underdeveloped countries were considered as enormous supply resources which would be exploited for the benefit of the mother countries' domestic industries. Consequently, under the impact of these policies, Malaya was transformed into a gigantic tin mine, the Arabic peninsula into an oil field, Indonesia into a vast tea and rubber plantation. It is now obvious that the colonial policies of the Western World created a lopsided, deformed economical development which most benefited the western nations, not the impoverished masses in the colonies. The expected result of these selfish policies is that almost every underdeveloped country today is unable to produce a variety of goods in order to satisfy physical and spiritual needs of its people. Consequently, these unfortunate countries enter the international market with very few commodities and, in most instances, with only one basic commodity. Table X shows

this lopsided, deformed development which took in the underdeveloped and partially developed countries of Latin America.

TABLE X

THE EFFECTS OF COLONIALISM ON LATIN AMERICAN ECONOMIES

Country	Exports (% of Gross National Product	Two most important basic commodities (% of exports)	Names of the two basic commodities
Bolivia	45.4%	67%	tin, lead
Venezuella	39.5	95	petroleum, pig iron
Cuba *	30.6	90	sugar, tobacco
Dominican Republic	25.0	65	sugar, cocoa
El Salvador	24.5	90	coffee, cotton
Costa Rica	20.6	85	coffee, bananas
Chile	19.9	77	copper, nitrates
Honduras	18.9	71	bananas, coffee
Nicaragua	18.9	77	cotton, coffee
Peru	18.5	39	cotton, sugar
Guatemela	17.6	85	coffee, bananas
Ecuador	17.1	75	coffee, bananas
Paraguay	14.5	40	timber, cotton
Uruguay	13.3	70	wool, wheat
Colombia	13.1	92	coffee, petroleum
Haiti	11.1	87	coffee, jute
Panama	10.5	76	banana, coffee
Argentina	9.5	43	meat, wheat
Mexico	8.8	36	cotton, coffee
Brazil	5.8	62	coffee, cocoa

* Cuba before the revolution

Source: The U. S. Book of Facts, Statistics and Information, 1966.

The effects of the colonialist policies of the Western World were so strong that even today Venezuella is dependent upon oil for ninety-two per cent of its exports; Colombia on coffee for seventy-seven per cent of its exports; Chile on

copper for sixty-six per cent of its foreign earnings; Honduras on bananas for fifty-one per cent of its exports, and Bolivia on tin for sixty-two per cent of its foreign earnings. To some apologists and narrow-minded economists these developments may seem as the manifestations of a vigorous, healthy international specialization of production and trade from which all sides concerned enormously benefit. However, reality has nothing to do with this rather shallow and subjective evaluation. An examination of Table X shows that a great majority of the basic products of Latin American countries are agricultural in nature, and all agricultural products have one common characteristic---the demand for agricultural products is inelastic. The reason for this inelasticity is that there are no good substitutes for agricultural products. Consequently, the price elasticity of demand for these products is extremely low. This inelastic demand for agricultural products means that buyers and consumers are relatively indifferent to changes in the prices of farm products. If prices fall, corresponding increase in sales will be very insignificant. In Figure 3 such an inelastic demand curve is given for a given agricultural product. For instance, if originally the price of this agricultural commodity is OA, people will buy an amount equal to OC, and the total income from sales will be given by the area of the rectangle, ABCD. However, if prices fall from the first level, OA, to OC the units demanded will very slightly increase from OC to OE. In this second case the total income from sales will be equal to the area of the rectangle,

EFGO. The area of rectangle EFGO is smaller than the area of the rectangle ABCO because the rectangle ABEK has a greater area than the rectangle KFGC. Consequently, then, a drop in prices will shrink the total income. In other words, if the producers could restrict their supply, then they would be better off. However, as they generally compete with each other and try to sell as much as possible, they may increase the total production and bring it up to the level OJ. Consumers in this instance, will be paying OH dollars for the agricultural products supplied and the total income for producers will further shrink to the area of the rectangle HIJO. Under the inelastic demand conditions, it is not difficult to see why tons of Brazilian coffee will be dumped in the sea, why American milk farmers will spill thousands of gallons of milk, why a bumper crop of wheat will be burned. Otherwise, prices will fall precipitously and demand will not rise proportionately. However, the basic industrial commodities that these underdeveloped countries so desperately need, yet cannot produce, have highly elastic demands. Their prices tend to be firm or to rise over the years, even if the supplies of these industrial goods significantly increase. Consequently, the result is this---an underdeveloped country gives more and more of its basic agricultural commodities for less and less machinery. For instance, when agricultural commodity prices fell considerably in 1957, the poorer nations lost more in purchasing power than the aggregate amount of all foreign aid which they received. In simple words, the underdeveloped countries subsidized the advanced countries. The

inelastic demand for agricultural products forces all underdeveloped nations to seek and establish commodity stabilization agreements which are fairly similar to the farm subsidy programs that exist in the United States.

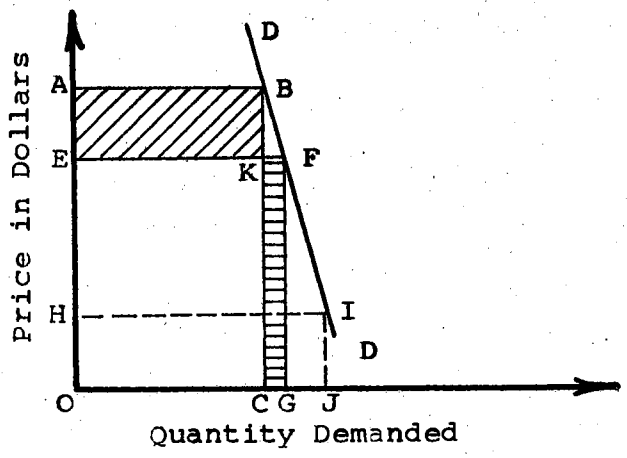

FIGURE 3. THE EFFECT OF INELASTICITY OF DEMAND ON SALES AND TOTAL INCOME

Basic Factors Determining Underdevelopment

Up to this point, the common characteristics of the underdeveloped countries have been explained in detail. Now is is time to delineate the basic determinants of underdevelopment. These factors are closely intertwined with the common characteristics, and as a matter of fact, in some instances, it is almost impossible to distinguish one from the other. A common characteristic appears as one of the determinants of the underdevelopment, and a determining factor becomes very easily a common characteristic. Consequently, instead of a detailed explaination of the determinants of the underdevelopment, a brief classification will suffice. The major virtue of such a classification is in its

virtual elimination of the danger of redundancy. The basic determining factors of the underdevelopment can be given schematically as shown in Figure 4 .

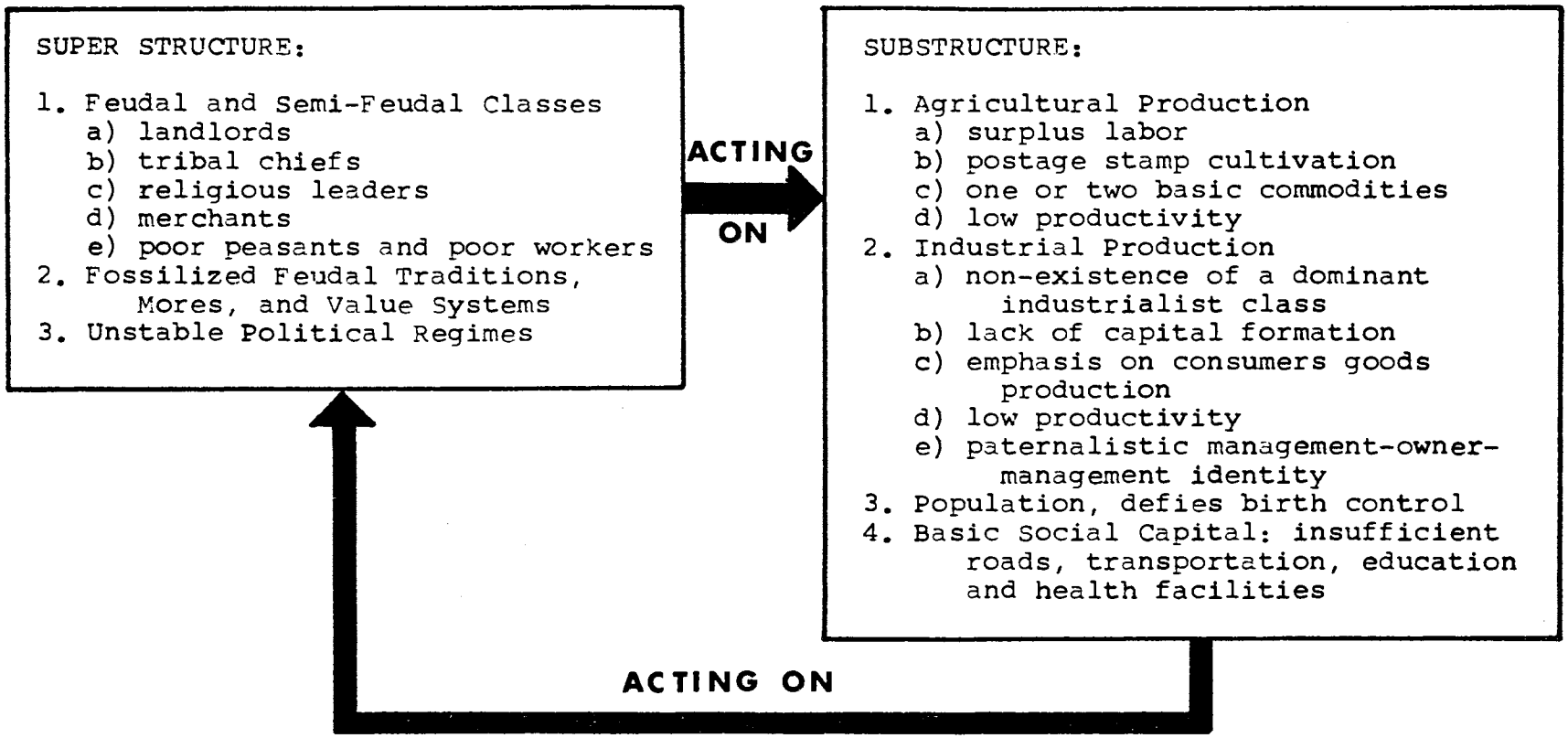

FIGURE 4. THE BASIC FACTORS OF UNDERDEVELOPMENT

CHAPTER III

DEVELOPMENT OF MATHEMATICAL MODELS AND TOOLS

In Chapter II the common characteristics of the underdeveloped countries and the factors which determine underdevelopment have been explained. Notwithstanding all the handicaps mentioned, all the social and economical shortcomings delineated, it is the author's belief that all underdeveloped countries possess the necessary ingredients and potential for social and economical development. For this to be accomplished, it is necessary only for the capital formation to increase agricultural and industrial output a little faster than the population growth. This will generate a small surplus which should be used to create capital, so that next year's output will be still higher. Consequently, a steady accumulation of capital will be created which will boost the agricultural and industrial outputs. That particular point at which an underdeveloped nation becomes capable of forming capital at a rate slightly faster than population growth is generally called the "take-off" point.

According to the estimates made by the United Nations, there are at least twenty underdeveloped countries (whose total population is more than half the population of the entire underdeveloped world), in which disciplined, vigorous, scientific and objective ten year planning can bring

economic development to the point of "take-off". Once this stage is reached, the possibility of a large-scale accumulation of capital will be at hand and the poverty that exists in the underdeveloped countries will finally be eliminated. Essentially, then, in order to grow, an underdeveloped country must build and accumulate capital. However, a theoretical solution in some cases may not be practical at all. How is it possible for an underdeveloped country in which eighty per cent of the population is struggling for a bare subsistence to build dams and roads, to construct factories, houses, health and educational facilities, to improve the transportation and communication systems, to increase agricultural and industrial productivity and aggregate output? If it is remembered that almost all underdeveloped countries have unemployed factors of production, it may be possible to devise a solution to the underdevelopment problem of these unfortunate countries. The major unemployed factor is the surplus agricultural labor which in actuality diminishes the productivity of the agriculture and the total agricultural output. It was mentioned previously that a smaller number of peasants working and tilling the same fields can raise the total agricultural output. An experiment carried out by the American College near Cairo, Egypt, proved that the existing agricultural output could be produced by about half the present rural population of Egypt. This may be an extreme case. However, it is possible to apply the conclusions of this experiment to almost all underdeveloped countries at least in a limited scope. This observation leads to the conclusion

that at least gradually the number of tillers of the soil can be reduced, a labor force can be created for industry and for building social capital in terms of dams, roads, schools, small hospitals, et cetera. Such a development will not cause a diminution of agricultural output provided that the lands are not sparsely settled. For, if the lands are sparsely populated, there will be no surplus population on the farms. In that case, a surplus farming population can be created by raising the agricultural productivity through the use of better seeds, more fertilizers, better technology and modern production methods. After this initial step, the surplus labor which is created can be channelized toward building industrial and social capital. This last method has been used very effectively in almost all advanced nations and particularly in the United States. Table XI shows the enormous significance of increased productivity in creating a surplus farm labor which in turn will be one of the major components of the expanding industry.

From Table XI it can be seen that the index of farm output in the United States increased $\frac{137-28}{28} \times 100 = 389$ per cent in the years between 1930 and 1964. Corresponding to this tremendous increase in agricultural productivity, farm population decreased $\frac{30.5 - 13.0}{30.5} \times 100 = 57.5$ per cent in absolute magnitude and $\frac{24.9 - 6.8}{24.9} \times 100 = 72.8$ per cent with respect to the total population. At the same time, total farm output increased $\frac{111 - 61}{61} \times 100 = 82$ per cent.

As mentioned above, this remendous change in the total structure of economy was carried out by increasing the size

of agricultural units, by using better seeds and more fertilizers and mechanized farming. Statistical data very clearly prove these points.

TABLE XI

THE EFFECT OF INCREASED PRODUCTIVITY IN AGRICULTURE UPON THE FARM LABOR FORCE IN THE UNITED STATES

Year	Farm Population (in millions)	Farm Population as % of Total Population	Index of Farm Output per Man-hour	Farm Output Index	Man-hours of Labor Required on Farms (in millions)
1930	30.5	24.9%	28	61	22,921
1940	30.5	23.2	36	70	20,472
1950	23.0	15.3	61	86	15,137
1955	19.1	11.6	80	96	12,808
1960	15.6	8.7	115	106	9,825
1961	14.8	8.1	120	107	9,473
1962	14.3	7.7	127	108	9,060
1963	13.4	7.8	135	112	8,821
1964	13.0	6.8	137	111	8,571

Source: The U. S. Book of Facts, Statistics and Information, 1966, pp. 614 and 645.

Table XII shows that the total number of farms in the United States decreased 39.4 per cent between the years 1940 and 1959. This was due to the decreased number of relatively smaller agricultural units. The number of all farm units whose sizes were below 260 acres decreased considerably. The number of farms whose sizes varied between 260 and 499 acres remained relatively stable with an insignificant increase of 2.6 per cent. Whereas, farms whose sizes varied between 500 and 999 acres and 1,000 acres and over increased twenty-two and thirty-four and eight tenths per cent, respectively. The

logical conclusion that can be derived from this statistical data is that smaller units were incorporated into larger units, farm sizes approached optimal sizes and mechanized agriculture became the major type of operation. Table XIII shows the extent of mechanization in agriculture. It can be seen in Table XIII that the value of farm implements increased 656 per cent between the years 1940 to 1964. Farmers' expenditures on motor vehicles and machinery and equipment increased 366 and 683 per cents, respectively, during the same period.

TABLE XII

FARMS---NUMBER AND ACREAGE BY SIZE OF FARM, 1940 to 1959

Size of Farm	1940	1950	1954	1959	Increase or Decrease (%)
Under 10 acres	506,402	484,914	484,291	240,733	-52.5%
10 to 49 acres	1,780,260	1,477,850	1,212,831	811,202	-54.5
50 to 99 acres	1,291,048	1,047,801	864,063	657,685	-49.0
100 to 179 acres	1,309,741	1,102,562	953,109	772,241	-41.1
180 to 259 acres	486,336	487,325	463,698	414,373	-14.8
260 to 499 acres	458,787	478,084	482,296	271,396	+ 2.6
500 to 999 acres	163,694	182,264	191,697	199,965	+22.0
1,000 acres & over	100,531	121,362	130,481	136,269	+34.8
Total	6,096,799	5,382,162	4,782,416	3,703,894	-39.4%

Source: The U. S. Book of Facts, Statistics and Information, 1966, p. 614.

An increased utilization of commercial fertilizers accompanied the increased mechanization in agriculture as shown in Table XIV. According to the statistical data given in Table XIV the quantity of commercial fertilizers consumed in American agriculture increased $\frac{29,256 - 8,556}{8,556} \times 100 = 241$

TABLE XIII

FARM MACHINERY AND EQUIPMENT---1940 TO 1964

Item	1940	1950	1955	1960	1961	1962	1963	1964	Per Cent Increase (%)
Value of Farm Implements & Machinery*(millions dollars)	3,060	12,166	18,595	22,344	21,977	22,499	23,306	24,082	656
Number on Farms, Jan. 1:									
Tractors (1,000)	1,567	3,394	4,345	4,684	4,700	4,690	4,670	4,657	198
Motor Trucks (1,000)	1,047	2,207	2,675	2,826	2,850	2,875	2,900	2,915	180
Automobiles (1,000)	4,144	4,100	4,140	3,629	NA	NA	NA	NA	---
Grain Combines (1,000)	190	714	980	1,040	1,035	1,025	1,020	1,010	431
Corn Pickers (1,000)	110	456	688	795	800	815	820	820	645
Pickup Balers (1,000)	---	196	488	680	715	735	750	775	296
Field Forage Harvesters (1,000)	---	81	202	290	305	320	330	345	326
Farms with Milking Machines	175	636	712	666	NA	NA	NA	NA	---
Farmers' Expenditures:									
Motor Vehicles** (millions dollars)	384	1,734	1,482	1,224	1,471	1,579	1,743	1,785	366
Machinery & Equipment (millions dollars)	241	1,418	1,278	1,483	1,457	1,475	1,692	1,890	683

* includes family automobiles
**excludes family automobiles

Source: The U. S. Book of Facts, Statistics and Information, 1966, p. 614

per cent. All these developments in American agriculture created a surplus of farm population which has been attracted to the non-agricultural sectors of the economy by a combination of material and non-material incentives. This trend is still in operation in the United States. In other words, the farm population is shrinking both in absolute and relative numbers, whereas, agricultural productivity and aggregate agricultural output are increasing. Consequently, at the present time one person who is engaged in agricultural production is feeding twenty-seven other persons. Unfortunately, in most of the underdeveloped countries this value is only 1 to 1.5. In other words, a peasant in an underdeveloped country can feed only himself and one additional person. Table XV shows to what extent agricultural productivity has been increased in the United States. From the investigation of the statistical data concerning American agriculture one central fact emerges. Whether the country side is overpopulated or not, a surplus population can be created by increasing the productivity in agriculture. As mentioned previously, this can be accomplished by a combination of various methods and techniques such as: a) creation of larger farms, b) use of better seeds,and c) utilization of better technology. However, even if the agricultural productivity is increased, the totality of the socio-economic problems will not be solved. As a matter of fact, a new and potentially very explosive social problem will emerge---the problem of saving part of the increased agricultural product. In other words, the problem of preventing the remaining farm

TABLE XIV

COMMERCIAL FERTILIZERS---QUANTITIES CONSUMED 1940 TO 1963

Year	Quantity (1,000 tons)
1940	8,556
1950	20,345
1955	21,404
1956	21,776
1957	21,576
1958	24,085
1959	23,499
1960	24,374
1961	25,305
1962	27,386
1963	29,256

Source: The U. S. Book of Facts, Statistics and Information, 1966, p. 629.

TABLE XV

PERSONS SUPPORTED BY PRODUCTION OF ONE FARM WORKER---SELECTED YEARS, 1820 - 1961

Year	Persons Supported per Farm Worker
1820	4
1870	5
1900	7
1910	7
1920	9
1930	10
1940	11
1950	15
1952	17
1954	19
1956	22
1957	24
1961	26

Source: Agricultural Outlook Chartbook, 1962 Department of Agriculture, November, 1961.

population from consuming the larger crop, for it is obvious that the peasant who remains on the soil will attempt to raise his living standards by increasing his consumption. However, if this natural tendency is not curbed, then there will be no possibility whatsoever of creating a surplus farm labor. For then, it will be impossible to feed the formerly unproductive peasants who are now employed in non-agricultural occupations. Therefore, the gain in agricultural output per cultivator will have to be taxed from the farm. It is somewhat utopian to expect that the hungry peasant will give up this gain in agricultural production voluntarily. It is imperative, then, for a central decision making body, in other words, central government to interfere and by taxation or exaction transfer this gain from the agricultural areas to other sectors of the economy in order to be able to feed the industrial workers, technicians, engineers, managers, et cetera. Consequently, during the early stages of an economical development plan, there will not be any significant increase in the peasant's food consumption, for the government will see to it that the newly added productivity is not consumed by the peasant, but is transferred to non-agricultural sectors in order to support industrial workers who are busy in building capital for the society. A logical conclusion of this argument is the necessity of a strong and public-minded government. In such a crucial development, market mechanisms will play a secondary role, because adjustments made by these mechanisms are time consuming and difficult to endure.

Once the existing or created surplus farm labor is channelized toward non-agricultural sectors of the economy, the industrialization process will begin. However, this increased industrial population will definitely need equipment to work with, and as mentioned previously, all underdeveloped countries possess very insignificant amounts of capital equipment. Consequently, parallel to the domestic equipment formation, additional amounts of equipment will have to be obtained from abroad. How can an underdeveloped country obtain equipment from outside? a) It can purchase this equipment from industrialized nations by foreign trade, in other words, for instance, by exchanging bananas for tractors. b) It can receive the industrial equipment by foreign investment. However, this method has obvious handicaps, for it jeopardizes the national integrity and independence of the underdeveloped countries. Futhermore, the advanced nations prefer to make their industrial investments in other industrially advanced countries, as was shown previously. c) It can buy the industrial equipment it needs by a grant or loan from an advanced nation. This method also carries most of the shortcomings of method b), and futhermore, the total foreign aid after the Second World War to the underdeveloped countries is totally inadequate. For instance, in the years 1945 to 1967, the total military and economic aid given by the United States to all advanced and underdeveloped nations totals seventy billion dollars. Approximately half of this aid is in terms of military equipment. Therefore, the total economic aid is approximately forty billion dollars.

Divided into twenty years, this gives two billion dollars of economic aid per year. If the foreign aid of other advanced nations are also added to this figure, the result is five billion a year. This figure, gigantic as it may seem, is not more than two or three per cent of the total output of the underdeveloped world. Consequently, foreign aid cannot be considered a panacea.

Then we have to conclude that the economical development of an underdeveloped country will have to basically depend upon its own efforts, upon its own discipline, vigor and enthusiasm, on its own dedication and sacrifices. Foreign aid, foreign investment and foreign trade which can be utilized effectively to a certain degree will still play secondary roles.

After this preliminary discussion, the objective assumptions which will be used in our mathematical models are listed as follows:

1. In all underdeveloped countries a surplus farm labor either exists or can be created.

2. Reallocation of this surplus labor from agricultural to non-agricultural occupations does not cause a diminution of the total agricultural output.

3. Considering the overpopulation on the farm, postage stamp cultivation, the workings of diminishing returns, it is safe to assume that the reallocation of the surplus farm labor will, as a mater of fact, cause an increase in the total agricultural output.

4. A public-minded, strong central government which has both persuasive and coercive powers in preventing the farm population from consuming the gain in agricultural production, does exist.

5. The aggregate annual agricultural production is to be shared and divided among three distinct and different categories: a) for consumption purposes, b) for next year's agricultural product, and c) for foreign trade (if the productivity level allows).

6. If birth control methods are not employed, population increases continuously at a constant annual rate.

7. Agricultural production increases as in the case of compound interest.

8. The economy's output rate at time, t, can be expressed by a production function, Y_t, which incorporates various inputs actually used in production and the major forces effecting the productivity of these inputs.

Production Function

The production function of the economy is given by the relation, $Y_t = f(K_t, N_t, L_t, S_t, U_t)$ (1) in which K_t denotes the amount of services of the economy's capital stock at time, t; N_t denotes the rate of use of natural resources; L_t stands for the employment of the labor force; S_t represents society's pool of applied knowledge; and U_t represents socio-cultural environment within which the economy operates. The last input factor, U_t, signifies the fact that the output rate of an economy is very much effected

by society's super structure composed of traditions, values, mores, history, and et cetera. At this stage one point must be emphasized: the variables K_t, N_t, L_t, S_t, and U_t are not independent of each other. As a matter of fact, their relationships to each other will be demonstrated in the further development of the productive function. It is obvious that the production function defined in terms of variables of K_t, N_t, L_t, S_t and U_t cannot be a function which incorporates all the inputs of the economy, all the quantitative and qualitative production factors. Consequently, it is a rather simple one. Futhermore, the exact determination of its variables is no easy task. Particularly in the case of the variable, U_t, which represents the society's socio-cultural environment in which the economy operates, this task is extremely difficult, if not impossible, for U_t is a qualitative factor, not a quantitative one. However, in representing the workings and interactions of the most important production factors, production function, Y_t, in its given simple form will be of great value.

In order to facilitate an understanding of the production function each input factor will be considered as a multi-component value rather than a single number. Consequently, the economy's capital stock can be defined as:

$$K_t = (K_{1t}, K_{2t}, K_{3t}, \ldots K_{jt}, \ldots K_{pt})$$

where K_{jt} represents the j th type of capital equipment in use at time, t. In the same fashion, it can be written:

$$N_t = (N_{1t}, N_{2t}, N_{3t}, \ldots N_{jt}, \ldots N_{qt})$$

and

$$L_t = (L_{1t}, L_{2t}, L_{3t}, \ldots L_{jt}, \ldots L_{rt})$$

In these expressions given above, N_{jt} and L_{jt} are the quantity of the j th kind of natural resource and the j th grade of labor employed at time, t, respectively.

Quantifying the last two input factors, S_t and U_t, is much more difficult than quantifying the first three input factors, for S_t and U_t which stand for society's pool of applied knowledge and socio-cultural environment at time, t, respectively, are of qualitative nature, as mentioned previously. The main purpose for introducing these factors is to aid the conception of totality of the production process. S_t and U_t represent factors whose effects in economic development is vital, but whose quantification is possible only in a ordinal sense. It is obvious that an inventory or classification system, as in the case of purely physical inputs, K_t, N_t and L_t cannot be used here. However, it is also obvious that the variable, S_t, which represents the society's pool of scientific, technical and organizational knowledge is a multi-dimensional value as in the case of K_t, N_t and L_t. Each component of input factor, S_t, represents a particular kind of technical, organizational or scientific knowledge and skill at time, t. By introducing input factor, S_t, into the production function, it becomes possible to analyze changes in the productivity of land, labor and capital, which are not due to quantitative variations in their rate of use, for the simple reason that with a fixed total employment of resources a redistribution, a reallocation of the physical inputs among various branches of the industry, a greater efficiency of production can be obtained.

The last variable, U_t, stands for the totality of social, cultural and institutional relationships of the society. In other words, U_t reveals whether the economy is basically competitive, monopolistic, oligopolistic, capitalistic, socialistic, communistic, et cetera. As in the case of S_t, changes in U_t may make independent contributions to the aggregate output of the economy, even if the amounts of the physical input and the state of technology are held constant. In that respect, U_t can be considered as a multi-dimensional value, whose components represent the various socio-cultural features which effect the entire economy at time, t.

After introducing and briefly explaining the basic production factors, the rate of growth of real income of the society can be expressed as follows:

$$\frac{\Delta Y}{\Delta t} = \sum_{j=1}^{p} \frac{\Delta Y}{\Delta K_j} \times \frac{\Delta K_j}{\Delta t} + \sum_{j=1}^{q} \frac{\Delta Y}{\Delta N_j} \times \frac{\Delta N_j}{\Delta t} + \sum_{j=1}^{r} \frac{\Delta Y}{\Delta L_j} \times \frac{\Delta L_j}{\Delta t} + \sum_{j=1}^{v} \frac{\Delta Y}{\Delta S_j} \times \frac{\Delta S_j}{\Delta t} + \sum_{j=1}^{w} \frac{\Delta Y}{\Delta U_j} \times \frac{\Delta U_j}{\Delta t} \qquad (2)$$

In equation (2), $\frac{\Delta Y}{\Delta K_j}$, $\frac{\Delta Y}{\Delta N_j}$, $\frac{\Delta Y}{\Delta L_j}$, $\frac{\Delta Y}{\Delta S_j}$, and $\frac{\Delta Y}{\Delta U_j}$ represent the marginal physical products of the j th type of capital, land, labor, technology and institutions, at a given time, t. If $\sum_{j=1}^{w} \frac{\Delta Y}{\Delta Y_j} \times \frac{\Delta U_j}{\Delta t}$ is negative, it will be understood that the changes in the socio-cultural environment in the under-developed countries are growth-inhibiting. $\frac{\Delta K_j}{\Delta t}$, $\frac{\Delta N_j}{\Delta t}$, $\frac{\Delta L_j}{\Delta t}$, $\frac{\Delta S_j}{\Delta t}$, and $\frac{\Delta U_j}{\Delta t}$ represent, respectively, the rate of capital accumulation, the rate of change of natural resources, the rate of increase of the labor force, the rate of introduction of innovations and the rate of change of the socio-cultural

environment with respect to time.

In order to express the interdependency of input factors, the following equations can be developed:

$$\frac{\Delta K_j}{\Delta t} = k\,(Y, K, N, L, S, U, t) \quad j = 1 \ldots, p \qquad (3)$$

$$\frac{\Delta N_j}{\Delta t} = n\,(Y, K, N, L, S, U, t) \quad j = 1 \ldots, q \qquad (4)$$

$$\frac{\Delta L_j}{\Delta t} = l\,(Y, K, N, L, S, U, t) \quad j = 1 \ldots, r \qquad (5)$$

$$\frac{\Delta S_j}{\Delta t} = s\,(Y, K, N, L, S, U, t) \quad j = 1 \ldots, v \qquad (6)$$

$$\frac{\Delta U_j}{\Delta t} = u\,(Y, K, N, L, S, U, t) \quad j = 1 \ldots, w \qquad (7)$$

Equation (3) which represents the capital accumulation factor incorporates various factors, such as society's ability to save, its willingness to invest, the effect of socio-cultural environment, et cetera. Equation (4) which stands for resource change, exhibits the effects of population pressure upon new resource discoveries (through l), the influence of technological change on the resources levels (through s), the impact of the socio-cultural environment upon the utilization of the natural resources (through u), et cetera. The same type of interdependence among all basic production factors also exists in equations (5), (6) and (7).

Finally, it can be concluded that the growth and economical development of any underdeveloped country can be explained in terms of equations (1) and (3) through (7). As equation (2) is obtained by differentiating equation (1), it cannot be considered as an independent equation. If equations (1) and (3) through (7) are given, then the rate of economic development $\frac{\Delta Y}{\Delta t}$ can be determined by solving these equations simultaneously. In this case, there are $p + q + r + v + w + 1$ equations and an equal number of unknowns where solutions

will give Y and every component of the vectors K, N, L, S, and U as functions of the time. However, it is a well known fact that the solution of a large set of simultaneous equations is an extremely difficult and rather cumbersome process, if these equations cannot be reduced into relatively simpler forms. In this initial study, it will be assumed that this simplification process is possible, which will give the following explicit solution:

$$Y = Y (K_o, N_o, L_o, S_o, U_o, t, a_1 \ldots, a_j \ldots) \qquad (8)$$

In equation (8) which represents the rate of output of the economy, K_o, N_o, L_o, and S_o stand for the utilization of capital, natural resources, labor and technological knowledge and skills, respectively, at $t = 0$; and U_o represents the state of the socio-cultural environment at the beginning of the implementation of the economic development program. K_o, N_o, L_o, S_o and U_o are the initial conditions in a given underdeveloped country. The a_j coeficients represent various combinations of initial conditions and time. They can be referred to as structural parameters. If all the partial derivatives of Y with respect to independent variables (excluding time) vanish, as well as the partial derivatives of Y with respect to time, the economy will be in a stationary state. Otherwise, it is in a state of definite growth.

An advantage of equation (8) is that it clearly shows that two economies similar in initial conditions may possess entirely different structural parameters and, consequently, conform to dissimilar development patterns. On the other hand, in the case of two economies with idential structural

parameters, if the initial conditions are not the same, the whole development pattern once again will be very different. For instance, assuming that capital accumulation, technological process, et cetera are the same for two economies, yet one of them is overpopulated with poor natural resources and the other has an optimal population as well as considerable natural wealth, their development pattern will definitely diverge.

Transition from a Basically Agricultural Economy to an Industrial Economy

In the preceeding section a general, abstract production function was defined and its basic components, K, L, N, S, and U, which stand for society's capital, labor force, natural resources, its pool of technological knowledge and socio-cultural environment, respectively, were described. In this section mathematical analysis will be focused on the combination of the production factors, L and N. The labor force initially will be represented by the agricultural population and N will symbolize the agricultural resources. Furthermore, in compliance with initial assumptions which were made at the beginning of Chapter III, population increase will be represented with a continuous compounding interest formula and the increase in agricultural production will be expressed by compound interest function. The validity and the accuracy of these two last assumptions will be checked and verified by statistical data.

A Mathematical Approach in Population Estimates

If the population of an underdeveloped country before the implementation of the economic development program is represented by P_o and the population increases annually with a constant rate of ϕ_p continuously, then, n years later the population, P_n, will be

$$P_n = P_o e^{n \phi_p} \tag{9}$$

consequently, $L_n P_n = L_n P_o + \phi_p n$

if Y is substituted for $L_n P_n$ and $L_n P_o = C$, then

$$Y = C + \phi_p n \tag{10}$$

which is the equation of a straight line. Application of the method of least squares to equation (10) will give

$$C = L_n P_o = \bar{Y} - \phi_p \bar{n}$$

and, $$\phi_p = \frac{\sum n' y}{\sum (n)^2}$$

in which $n' = n - \bar{n}$ and $y = Y - \bar{Y}$. Determination of ϕ_p and $L_n P_o$ by the method of least squares will also determine the best straight line that fits the population data. In order to prove the validity of equation (9), real population data will be used. See Table XVI.

$$Y = 186.92261$$

$$(n')^2 = 110$$

$$n'y = 3.25308$$

$$\bar{Y} = \frac{Y}{11} = 16.9956$$

$$\bar{n} = \frac{55}{11} = 5.00$$

Finally, $\phi_p = \frac{n'y}{(n')^2} = \frac{3.25308}{110} = 2.95735\ \%$, which equals the annual rate of population increase.

$$L_n P_o = \bar{Y} - \phi_p \bar{n} = 16.99560 - \frac{2.95735 \times 5}{100} = 16.84773$$

Since L_nP_o equals 16.84773, therefore, P_o equals 20,774,144.

$$P_n = P_o e^{n \phi_p} \qquad (11)$$

$$P_n = (20,774,144)\ e^{n \times 0.0295735}$$

If the population is estimated by using equation (11) the values are found as shown in Table XVII.

TABLE XVI

POPULATION INCREASE IN TURKEY

n	Population P_n	$L_nP_n = Y$	$n' = n-\bar{n}$	n'^2	$y = Y-\bar{Y}$	$n'y$
0	$20,497 \times 10^3$	16.83578	-5.00	25	-0.15982	0.79910
1	$21,536 \times 10^3$	16.88058	-4.00	16	-0.11502	0.46008
2	$22,142 \times 10^3$	16.91294	-3.00	9	-0.08266	0.24798
3	$22,765 \times 10^3$	16.94073	-2.00	4	-0.05487	0.10974
4	$23,406 \times 10^3$	16.96851	-1.00	1	-0.02709	0.02709
5	$24,065 \times 10^3$	16.99561	0.00	0	0.00001	0.00000
6	$24,775 \times 10^3$	17.02534	+1.00	1	+0.02974	0.02974
7	$25,506 \times 10^3$	17.05444	+2.00	4	+0.05884	0.11768
8	$26,258 \times 10^3$	17.08348	+3.00	9	+0.08788	0.26364
9	$27,033 \times 10^3$	17.11257	+4.00	16	+0.11697	0.46788
10	$27,830 \times 10^3$	17.14163	+5.00	25	+0.14603	0.73015

TABLE XVII

COMPARISON OF ESTIMATED POPULATION

WITH ACTUAL POPULATION

n	Estimated Population	Actual Population	Per Cent Error (%)
0	20,774,144	20,497,000	-1.352
1	21,459,470	21,536,000	+0.355
2	22,028,515	22,142,000	+0.513
3	22,669,050	22,765,000	+0.421
4	23,398,545	23,406,000	+0.245
5	24,065,000	24,065,000	0.000
6	24,778,266	24,775,000	-0.013
7	25,513,769	25,506,000	-0.030
8	26,280,379	26,258,000	-0.085
9	27,069,202	27,033,000	-0.134
10	27,883,388	27,830,000	-0.192

In order to reinforce the conclusions given above, the same type of reasoning will be applied to another set of population data, as shown in Table XVIII. It is evident that the application of equation (9) to actual population data gives very accurate results.

TABLE XVIII

POPULATION ESTIMATES ABOUT SOVIET UNION

End of Year	Actual Population (in millions)	Estimated Population (in millions)	Per Cent Error (%)
1945	175.00	175.00	0.00
1950	182.30	188.00	-3.13
1955	197.00	202.00	-2.54
1960	207.10	211.00	-1.88
1965	233.70	233.70	0.00

A Mathematical Approach in Agricultural Production Estimates

If the aggregate annual agricultural production of an underdeveloped country, before the implementation of the economic development program, is represented by Q_o and according to the development program it is estimated that Q_o will increase annually with a constant rate ϕ_o, then n years later, the aggregate annual agricultural production will be

$$Q_n = Q_o (1 + \phi_o)^n \qquad (12)$$

As in the case of equation (9), the validity and the accuracy of equation (12) will be checked by statistical data.

In Table XIX it can be seen, excluding the year 1941 where a significant drop in tobacco production occured due to

unusual climatic conditions, application of equation (12) to the statistical data gives accurate results. In order to reinforce the contention about the reliability and the validity of equation (12), another attempt will be made by using the statistical data concerning the farm output in selected years in the United States. If equation (12) is applied to American farming, the results are obtained as shown in Table XX.

TABLE XIX

TOBACCO PRODUCTION IN SELECTIVE YEARS IN TURKEY

End of Year	Actual Index	Calculated Index	Per Cent Error (%)
1937	100.00	100.00	0.00
1938	104.42	104.74	-0.31
1939	107.07	109.70	-2.46
1940	116.36	114.90	+1.25
1941	108.98	120.34	-10.42
1942	131.91	126.04	+4.45
1943	132.07	132.07	0.00

TABLE XX

FARM OUTPUT IN SELECTED YEARS IN THE UNITED STATES

End of Year	Actual Farm Output Index	Calculated Farm Output Index	Per Cent Error (%)
1950	86	86	0.00
1955	96	95	+1.44
1960	106	105	+0.94
1961	107	107	0.00
1962	108	109	-0.93
1963	112	111	-0.89
1964	111	113	-1.08

$$Q_n = 111 = Q_o\ (1 + \phi_o)^n = 86\ (1 + \phi_o)^{14}$$

$$(1 + \phi_o)^{14} = \frac{111}{86} = 1.30 \therefore \phi_o = 2.00\ \%$$

Table XX also shows the validity and reliability of Equation (12) whose application to statistical data yield very insignificant errors. After the verification of equations (9) and (12), which will be used as mathematical models in this study, it can be possible to proceed to the construction of a general model about the aggregate agricultural output in an underdeveloped country.

MATHEMATICAL MODEL I

End of Years (1)	Aggregate Annual Agricultural Production (2)	Total Population (3)	Total non-Agricultural Population (4)	Total Agricultural Population (3) - (4)
0	Q_o	P_o	$\mu_o P_o$	$(1 - \mu_o)P_o$
1	$Q_o(1 + \phi_o)$	$P_o e^{\phi p}$	$\mu_1 P_o e^{\phi p}$	$(1 - \mu_1)P_o e^{\phi p}$
2	$Q_o(1 + \phi_o)^2$	$P_o e^{2\phi p}$	$\mu_2 P_o e^{2\phi p}$	$(1 - \mu_2)P_o e^{\phi p}$
⋮	⋮	⋮	⋮	⋮
k	$Q_o(1 + \phi_o)^k$	$P_o e^{k\phi p}$	$\mu_k P_o e^{k\phi p}$	$(1 - \mu_k)P_o e^{k\phi p}$
⋮	⋮	⋮	⋮	⋮
n	$Q_o(1 + \phi_o)^n$	$P_o e^{n\phi p}$	$\mu_n P_o e^{n\phi p}$	$(1 - \mu_n)P_o e^{n\phi p}$

μ_k is a factor whose multiplication with the total population at the end of the k th year gives the total non-agricultural population at the end of the same year. Aggregate annual agricultural production will be divided into three different parts for the following purposes: a) for consumption, b) for next year's planting, and c) for foreign trade (export). This division of the aggregate annual agricultural

product is in compliance with basic assumptions which were made at the beginning of Chapter III. The portion saved for the following year's planting (starting with the intital conditions) will be designated as γQ_o. Consequently, $Q_o - \gamma Q_o$ equals $Q_o(1 - \gamma)$ equals that portion of the aggregate annual agricultural production kept for consumption and foreign trade. Let $1 - \gamma = k$, then,

$$Q_o(1 - \gamma) = k\, Q_o \tag{13}$$

This amount, $k\, Q_o$, will be divided into two parts, one for consumption, the other for foreign trade. Let $\bar{3}_o k\, Q_o$ represent the amount to be exported. Then the amount for consumption will be $k Q_o - \bar{3} k Q_o = k Q_o (1 - \bar{3}_o)$. In other words, the aggregate annual agricultural product has three components:

$$Q_o = (1 - k)\, Q_o + \bar{3}_o k\, Q_o + (1 - \bar{3}_o) k\, Q_o \tag{14}$$

in which Q_o, $(1 - k)Q_o$, $\bar{3}_o k\, Q_o$, and $(1 - \bar{3}_o)k\, Q_o$ represent aggregate annual agricultural product, amount for following year's planting, amount for foreign trade, and amount for consumption, respectively.

According to the Mathematical Model I, consumption per capita of the agricultural products, for the intital conditions, is

$$\frac{(1 - \bar{3}_o)\, k\, Q_o}{P_o} = \lambda_o \tag{15}$$

n years after the implementation of the economical development program, the consumption per capita of the agricultural products is

$$\frac{(1 - \bar{3}_n)\, k\, Q_o(1 + Q_o)^n}{P_o\, e^{n\phi p}} = \lambda_n \tag{16}$$

assuming that k values are the same for both the initial and final conditions. The per capita consumption at the end of

the n th year with respect to the initial per capita consumption is

$$\frac{(1-\mathfrak{Z}_n)\ k\ Q_o\ (1+\phi_o)^n}{P_o e^{n\phi p}} \times \frac{P_o}{(1-\mathfrak{Z}_o)k\ Q_o} = \frac{(1-\mathfrak{Z}_n)(1+\phi_o)^n}{(1-\mathfrak{Z}_o)\ e^{n\phi p}} =$$

$$\frac{\lambda_n}{\lambda_o} \qquad (17)$$

Equation (17) can be used to express different conditions and different developments. These various conditions are considered in the following cases.

Case A:

1. Initial conditions and following developments do not permit the underdeveloped country to exhange part of its agricultural products for industrial products between the years 0 and n. In other words, $\mathfrak{Z}_o = \mathfrak{Z}_1 = \ldots \mathfrak{Z}_n = 0$.

2. Consumption per capita at the end of the n th year is the same as in the initial year, namely, $\lambda_n = \lambda_o$ or $\frac{\lambda_n}{\lambda_o} = 1$. Under these conditions Equation (17) is reduced to the simplest form, $\frac{1-\mathfrak{Z}_n}{1-\mathfrak{Z}_o} \times \frac{(1+\phi_o)^n}{e^{n\phi p}} = \frac{\lambda_n}{\lambda_o} = 1 \therefore \frac{(1+\phi_o)^n}{e^{n\phi p}} = 1$ (17.a)

Case B:

1. At the end of the n th year, the underdeveloped country is capable of exchanging part of its agricultural products for industrial goods, whereas, initially this was impossible. In other words, $\mathfrak{Z}_o = 0$, but $\mathfrak{Z}_n \neq 0$.

2. Consumption per capita through the period stays constant, namely, $\lambda_o = \lambda_n$ or $\frac{\lambda_n}{\lambda_o} = 1$. Under these particular conditions Equation (17) is reduced to

$$\frac{1-\mathfrak{Z}_n}{1-\mathfrak{Z}_o} \times \frac{(1+\phi_o)^n}{e^{n\phi p}} = \frac{\lambda_n}{\lambda_o} = 1 \therefore (1-\mathfrak{Z}_n)\frac{(1+\phi_o)^n}{e^{n\phi p}} \qquad (17.b)$$

Case C:

1. All throughout the period, no portion of the agricultural products could be exchanged for industrial goods. In other words, again $\mathfrak{Z}_o = \mathfrak{Z}_1 = \ldots = \mathfrak{Z}_n = 0$.

2. Consumption per capita at the end of the n th year is higher than the initial one, namely, $\lambda_n > \lambda_o$ or $\frac{\lambda_n}{\lambda_o} > 1$. Under these particular conditions, Equation (17) becomes

$$\frac{1-\mathfrak{Z}_n}{1-\mathfrak{Z}_o} \times \frac{(1+\phi_o)^n}{e^{n\phi p}} = \frac{\lambda_n}{\lambda_o} \therefore \frac{(1+\phi_o)^n}{e^{n\phi p}} = \frac{\lambda_n}{\lambda_o} \qquad (17.c)$$

Case D:

1. $\mathfrak{Z} = 0, \mathfrak{Z}_n \neq 0$

2. $\lambda_n > \lambda_o$ or $\frac{\lambda_n}{\lambda_o} > 1$. Under these conditions, Equation (17) becomes:

$$\frac{(1-\mathfrak{Z}_n)}{(1-\mathfrak{Z}_o)} \times \frac{(1+\phi_o)^n}{e^{n\phi p}} = \frac{\lambda_n}{\lambda_o} \therefore (1-\mathfrak{Z}_n)\frac{(1+\phi_o)^n}{e^{n\phi p}} = \frac{\lambda_n}{\lambda_o} \qquad (17.d)$$

With the aid of Equation (17) and its special cases, Equations (17.a), (17.b), (17.c) and (17.d), different problems confronting an underdeveloped country can be solved mathematically. The application of these equations to actual problems will be made in Chapter IV.

General Mathematical Model I, which has been developed in this chapter, exhibits the general development characteristics of the agricultural sector of an underdeveloped country. An attempt will also be made to develop another model which can incorporate and express per capita productivity in agriculture.

MATHEMATICAL MODEL II

End of Year	Total Population in Agriculture	Agricultural Production per capita Farm Labor	Aggregate Annual Agricultural Production
0	$(1-\mu_0)P_0$	a_0	$(1-\mu_0)\,P_0\,a_0$
1	$(1-\mu_1)P_0e^{\phi}p$	a_1	$(1-\mu_1)P_0\,e^{\phi}p\,a_1$
2	$(1-\mu_2)P_0e^{2\phi}p$	a_2	$(1-\mu_2)P_0\,e^{2\phi}p\,a_2$
⋮	⋮	⋮	⋮
n	$(1-\mu_n)P_0e^{n\phi}p$	a_n	$(1-\mu_n)P_0\,e^{n\phi}p\,a_n$

As in the case of Model I, it will be assumed that aggregate annual agricultural production will be divided into three different parts: a) a portion for the following year's planting, b) a portion for total consumption, c) another portion for foreign trade (export). The portion kept for the following year's planting (starting with the initial conditions) will be designated as $\gamma(1-\mu_0)\,P_0a_0$. Consequently, that portion kept for total consumption and foreign trade will be

$$(1-\mu_0)\,P_0a_0 - \gamma(1-\mu_0)\,P_0a_0 =$$

$$(1-\gamma)\,(1-\mu_0)\,P_0a_0. \quad \text{Let } 1-\gamma = k,$$

then $(1-\gamma)(1-\mu_0)\,P_0a_0 = k\,(1-\mu_0)\,P_0a_0$. This amount will be divided into two parts. One for total consumption, the other for foreign trade. Let $\mathfrak{Z}_0k\,(1-\mu_0)\,P_0a_0$ represent the amount to be exported. Then the amount for total consumption will be

$$k\,(1-\mu_0)P_0a_0 - \mathfrak{Z}_0(1-\mu_0)P_0a_0 =$$

$$(1-\mu_0)(1-\mathfrak{Z}_0)\,k\,P_0a_0$$

In other words, the aggregate annual agricultural output has

three components,

$(1-\mu_o)P_oa_o = (1-k)(1-\mu_o)P_oa_o + \beta_o k(1-\mu_o)P_oa_o + k(1-\mu_o)(1-\beta_o)P_oa_o$

in which $(1-\mu_o)P_oa_o$, $k(1-\mu_o)P_oa_o$, $\beta_o k(1-\mu_o)P_oa_o$, and $k(1-\mu_o)(1-\beta_o)P_oa_o$ represent aggregate annual agricultural output, amount for following year's planting, amount for foreign trade (export), and amount for total consumption, respectively.

According to the Mathematical Model II, consumption per capita of the agricultural products, for the initial conditions, is

$$\frac{k(1-\mu_o)(1-\beta_o)P_oa_o}{P_o} = k(1-\mu_o)(1-\beta_o)a_o = \lambda_o \qquad (18)$$

n years after the implementation of the economic development program, the consumption per capita of the agricultural products is

$$\frac{k(1-\mu_n)(1-\beta_n)P_oe^{n\phi p}a_n}{P_oe^{n\phi p}} = k(1-\mu_n)(1-\beta_n)a_n = \lambda_n \qquad (19)$$

assuming that k values are the same for both the initial and final conditions. Then per capita consumption at the end of year n with respect to the initial per capita consumption is

$$\frac{k(1-\mu_n)(1-\beta_n)a_n}{k(1-\mu_o)(1-\beta_o)a_o} = \frac{(1-\mu_n)(1-\beta_n)a_n}{(1-\mu_o)(1-\beta_o)a_o} = \frac{\lambda_n}{\lambda_o} \qquad (20)$$

Equation (20) can be used to express various conditions and developments. As in the case of Equation (17), these condtions from the simplest to more complicated are given below.

Case A.

1. No exports of agricultural products throughout the period of economic development will be made. In other words,

$$\tau_o = \tau_n = \ldots, = \tau_n$$

2. Consumption per capita during the economic development is held constant, namely, $\lambda_n = \lambda_o$ or $\frac{\lambda_n}{\lambda_o} = 1$. Under these conditions Equation (20) is reduced to the simple form

$$\frac{(1-\mu_n)}{(1-\mu_o)} \times \frac{(1-\tau_n)}{(1-\tau_o)} \times \frac{a_n}{a_o} = \frac{\lambda_n}{\lambda_o} = 1 = \frac{(1-\mu_n)}{(1-\mu_o)} \times \frac{a_n}{a_o} = 1 \qquad (20.a)$$

Case B:

1. $\tau_o = 0$, $\tau_n \neq 0$.
2. $\lambda_o = \lambda_n$ or $\frac{\lambda_n}{\lambda_o} = 1$.

Under these conditons, Equation (20) gives

$$\frac{(1-\mu_n)}{(1-\mu_o)} \times \frac{(1-\tau_n)}{(1-\tau_o)} \times \frac{a_n}{a_o} = \frac{\lambda_n}{\lambda_o} = 1 = \frac{(1-\mu_n)}{(1-\mu_o)}(1-\tau_n)\frac{a_n}{a_o} = 1 \qquad (20.b)$$

Case C:

1. $\tau_o = \tau_1 = \ldots, \tau_n = 0$
2. $\lambda_n > \lambda_o$ or $\frac{\lambda_n}{\lambda_o} > 1$, in other words, consumption per capita is increasing. Under these conditions, from Equation (20), the following is obtained:

$$\frac{(1-\mu_n)}{(1-\mu_o)} \times \frac{(1-\tau_n)}{(1-\tau_o)} \times \frac{a_n}{a_o} = \frac{\lambda_n}{\lambda_o} = \frac{(1-\mu_n)}{(1-\mu_o)} \times \frac{a_n}{a_o} = \frac{\lambda_n}{\lambda_o} \qquad (20.c)$$

Case D:

1. $\tau_o = 0$, $\tau_n \neq 0$
2. $\lambda_n > \lambda_o$ or $\frac{\lambda_n}{\lambda_o} > 1$

Under these conditions Equation (20) becomes

$$\frac{(1-\mu_n)}{(1-\mu_o)} \times \frac{(1-\tau_n)}{(1-\tau_o)} \times \frac{a_n}{a_o} = \frac{\lambda_n}{\lambda_o} = \frac{(1-\mu_n)}{(1-\mu_o)}(1-\tau_n)\frac{a_n}{a_o} = \frac{\lambda_n}{\lambda_o} \qquad (20.d)$$

It will be assumed that equation (20.d) is the most realistic one for an underdeveloped country. The rearrangement of Equation (20.d) gives the certain relations by which basic

factors of the agricultural economic development of an underdeveloped country can be estimated. The practical application of Equation (20.d) to actual development problems will be given in Chapter IV.

CHAPTER IV

APPLICATION OF THE MATHEMATICAL MODELS AND TOOLS TO ACTUAL DEVELOPMENT PROBLEMS CONFRONTING UNDERDEVELOPED COUNTRIES

In Chapter III, two different mathematical models were developed and depending on these models a number of equations have been derived. In Chapter IV, the validity and practicability of these equations will be verified by applying them to various development problems which the underdeveloped countries face at the present time. Through this application, it will also be shown that these mathematical tools yield rather rational and reliable solutions which may facilitate the crucial decision-making processes in the underdeveloped countries.

Application of Mathematical Model I

Problem I:

In an underdeveloped country the population is increasing ϕ_p per cent per year continuously, and the rate of increase of the agricultural production per year is ϕ_o per cent. If according to a development program, the per capita consumption of the agricultural production will increase from λ_o to λ_n in n years, will it also be possible for this

nation to export some of the aggregate annual agricultural output at the end of the n th year, and if so, how much?

Mathematical Solution: In this problem λ_n, λ_o, n, ϕ_p and ϕ_o are given. $\zeta_o = 0$, and the only unknown is ζ_n. Therefore, Equation (17.d) will be used. Arranging Equation (17.d) the following is obtained:

$$1 - \zeta_n = \frac{\lambda_n}{\lambda_o} \times \frac{e^{n\phi_p}}{(1 + \phi_o)^n}$$

and finally, $$\zeta = 1 - \frac{\lambda_n}{\lambda_o} \times \frac{e^{n\phi_p}}{(1 + \phi_o)^n} \qquad (17.d)_I$$

Numerical Problem: Suppose for an underdeveloped country ϕ_p equals two per cent, ϕ_o equals seven per cent, n equals fifteen years, and $\frac{\lambda_n}{\lambda_o}$ equals 1.25. If $\zeta_o = 0$, Find ζ_n.

Numerical Solution: Using Equation $(17.d)_I$, the following is obtained:

$$\zeta_n = 1 - \frac{\lambda_n}{\lambda_o} \times \frac{e^{n\phi_p}}{(1 + \phi_o)^n} = 1 - 1.25 \frac{e^{15 \times 0.02}}{(1.07)^{15}}$$

$$\zeta_n = 38.84 \text{ per cent}$$

In other words, if the development program is implemented successfully for fifteen years, at the end of this period, the underdeveloped country will be able to export 38.84 per cent of its aggregate annual agricultural product (after subtracting that portion which is allocated for next year's planting).

Problem II:

An underdeveloped country plans to increase per capita consumption of the agricultural products from λ_o to λ_n in n years, and also be able to sell ζ_n per cent of its total annual agricultural output. If the population is increasing ϕ_p per cent per year, how much should agricultural prod-

uction be increased annually in order to satisfy these conditions?

Mathematical Solution: In this problem λ_o, λ_n, ϕ_p, n and ζ_n are given. If it is assumed that $\zeta_o = 0$, then the only unknown is ϕ_o. Again arranging Equation (17.d), the following is obtained:

$$(1 - \zeta_n)\frac{(1+ \phi_o)^n}{e^n \phi_p} = \frac{\lambda_n}{\lambda_o} \qquad (17.d)$$

Arrangement of Equation (17.d) gives

$$(1 + \phi_o)^n = \frac{\lambda_n}{\lambda_o} \times \frac{e^n \phi_p}{1 - \zeta_n}$$

and finally, $$\phi_o = \sqrt[n]{\frac{\lambda_n}{\lambda_o(1-\zeta_n)}}\, e^{\phi_p} - 1 \qquad (17.d)_{II}$$

Numerical Problem: Suppose for an underdeveloped country, $\frac{\lambda_n}{\lambda_o} = 1.3$, n = 10 years, $\zeta_o = 0$, $\zeta_n = 30$ per cent and $\phi_p = 3$ per cent. Determine ϕ_o.

Numerical Solution: Using Equation $(17.d)_{II}$, the following is obtained:

$$\phi_o = \sqrt[n]{\frac{\lambda_n}{\lambda_o(1-\zeta_n)}}\, e^{\phi_p} - 1 = \sqrt[10]{\frac{1.3}{1-0.3}}\, e^{0.03} - 1$$

$$\phi_o = 9.6 \text{ per cent}$$

Problem III:

In an underdeveloped country, the population and the agricultural production increase ϕ_p and ϕ_o per cent, respectively, per year. If $\zeta_o = 0$, how many years will it take for the nation to increase per capita consumption of agricultural goods from λ_o to λ_n as well as to be able to sell ζ_n per cent of its total agricultural output?

Mathematical Solution: In this problem ϕ_p, ϕ_o, λ_o, λ_n, and ζ_n are given. It is asked to determine n. Again, using

and rearranging Equation (17.d), the following is finally obtained:

$$n = \frac{L_n \frac{\lambda_n}{\lambda_o(1-\mathfrak{Z}_n)}}{L_n \frac{(1+\phi_o)}{e^{\phi_p}}} \qquad (17.d)_{III}$$

Numerical Problem: Suppose for an underdeveloped country ϕ_p = 2 per cent, ϕ_o = 6 per cent, $\mathfrak{Z}_n$ = 20 per cent, $\mathfrak{Z}_o$ = 0 and $\frac{\lambda_n}{\lambda_o}$ = 1.5. Determine the value of n.

Numerical Solution: Using Equation $(17.d)_{III}$, the following is obtained:

$$n = \frac{L_n \frac{\lambda_n}{\lambda_o(1-\mathfrak{Z}_n)}}{L_n \frac{(1+\phi_o)}{e^{\phi_p}}} = \frac{L_n \frac{1.50}{1-0.2}}{L_n \frac{1.06}{e^{0.02}}} = 16.07 \text{ years}$$

Problem IV:

In an underdeveloped country, while agricultural production is increasing ϕ_o per cent per year, the population is also increasing ϕ_p per cent annually. The nation plans to sell $\mathfrak{Z}_n$ per cent of its aggregate annual agricultural product at the end of a "n" year planning period. If it is also planned to increase per capita consumption of agricultural products from λ_o to λ_n, will birth control measures be necessary?

Mathematical Solution: In Problem IV ϕ_o, $\phi_{p\ actual}$, n, λ_o, λ_n, and $\mathfrak{Z}_n$ are given. Assuming $\mathfrak{Z}_o$ = 0, with the given values of ϕ_o, n, λ_o, λ_n, and $\mathfrak{Z}_n$, the allowable rate of population increase can be computed. The arrangement of Equation (17.d) will give:

$$\phi_{p\ allowable} = \frac{1}{n} L_n \frac{\lambda_o(1-\mathfrak{Z}_n)}{\lambda_n} + L_n(1+\phi_o) \qquad (17.d)_{IV}$$

If $\phi_{p\ allowable}$ is smaller than or equal to $\phi_{p\ actual}$, no birth control measures are necessary. Otherwise, these

measures will have to be sponsored and implemented by the central government.

Numerical Problem: Suppose for an underdeveloped country $\phi_{p\ actual}$ equals 2.5 per cent, ϕ_o equals 10 per cent, $\mathfrak{Z}_o$ equals zero, $\mathfrak{Z}_n$ equals 15 per cent, $\frac{\lambda_n}{\lambda_o}$ equals 1.3, n equals eight years; is birth control necessary?

Numerical Solution: Equation $(17.d)_{IV}$ gives the following: $\phi_{p\ allowable} = \frac{1}{n} L_n \frac{\lambda_o}{\lambda_n} (1 - \mathfrak{Z}_n) + L_n (1 + \phi_o)$

$$= \frac{1}{8} L_n \frac{1 - 0.15}{1.3} + L_n (1.10) = 4.22\%$$

$\phi_{p\ actual} = 2.5\% < \phi_{p\ allowable} = 4.22\%$, therefore, birth control is not necessary.

Application of Mathematical Model II

Problem I:

In an underdeveloped country, initially, per capita agricultural production per year is a_o, and μ_o per cent of the population is engaged in non-agricultural occupations. According to a development plan, per capita agricultural productivity will be increased to a_n, and $\mathfrak{Z}_n$ per cent of the aggregate annual production will be exported. If it is also planned to increase per capita consumption of the agricultural goods from λ_o to λ_n, how much can the non-agricultural population be increased?

Mathematical Solution: In this problem a_o, a_n, μ_o, $\mathfrak{Z}_o$, $\mathfrak{Z}_n$, and $\frac{\lambda_n}{\lambda_o}$ are given. It is asked to determine μ_n. Arranging Equation (20.d), the following is obtained:

$$\mu_n = 1 - \frac{\lambda_n}{\lambda_o} \times \frac{a_o}{a_n} \times \frac{1 - \mu_o}{1 - \mu_n} \qquad (20.e)$$

which gives μ_n in terms of other variables.

Numerical Problem: Suppose in an underdeveloped country a_o = 60 (as an index number), $\Im_o = 0$, μ_o = 20 per cent, $\Im_n$ = 10 per cent, $a_n = a_o + 0.4\, a_o = 1.4\, a_o = 84$ (as an index number) and $\frac{\lambda_n}{\lambda_o} = 1.05$. Determine μ_n.

Numerical Solution: Equation (20.e) gives the following: $\mu_n = 1 - \frac{\lambda_n}{\lambda_o} \times \frac{a_o}{a_n} \times \frac{1 - \mu_o}{1 - \Im_n} = 1 - 1.05 \frac{60}{84} \times \frac{1 - 0.2}{1 - 0.1}$

$\mu_n = 33.5$ per cent

In other words, with respect to the total population, the non-agricultural population can be increased from twenty per cent to 33.5 per cent due to increased productivity in agriculture.

Problem II:

In an underdeveloped country, initially the agricultural production per capita farm labor as an index is a_o, and μ_o per cent of the total population is engaged in non-agricultural occupations. Through the implementation of a development program, the agricultural productivity will be increased from a_o to a_n and this increased productivity will also enable the nation to increase its non-agricultural population from μ_o to μ_n. If per capita consumption of the agricultural goods will be held constant in order to accelerate the economic development, how much of its total annual agricultural output will the nation be able to export at the end of the development program?

Mathematical Solution: In Problem II, a_o, $\Im_o$, μ_o, μ_n, and $\frac{\lambda_n}{\lambda_o}$ are given. It is asked to determine $\Im_n$. Assuming $\Im_o = 0$,

and arranging Equation (20.d), the following is obtained:

$$\mathfrak{Z}_n = 1 - \frac{\lambda_n}{\lambda_o} \times \frac{a_o}{a_n} \times \frac{1-\mu_o}{1-\mu_n} \qquad (20.f)$$

which gives $\mathfrak{Z}_n$ in terms of other variables.

Numerical Problem: For an underdeveloped country $a_o=70$, $\mathfrak{Z}_o=0$, $\mu_o=$ 25 per cent, $a_n = a_o+0.5\ a_o=1.5\ a_o = 105$, μ_n = 35 per cent, and $\frac{\lambda_n}{\lambda_o} = 1.00$. Determine $\mathfrak{Z}_n$.

Numerical Solution: Using Equation (20.f), the following is obtained:

$$\mathfrak{Z}_n = 1 - \frac{\lambda_n}{\lambda_o} \times \frac{a_o}{a_n} \times \frac{1-\mu_o}{1-\mu_n} = 1 - 1 \times \frac{70}{105} \times \frac{1-0.25}{1-0.35} = 0.23$$

$\mathfrak{Z}_n$= 23 per cent

In other words, this underdeveloped country will be able to export 23 per cent of its aggregate annual agricultural output (after substracting that portion required for the following year's planting). If the data incorporated into Equation (20.f) would give a negative value for $\mathfrak{Z}_n$, this would simply mean that under the impact of a too adventurous development program, the underdeveloped country will have to import agricultural products from other countries to feed its non-agricultural and agricultural populations. And, unfortunately, this last case is not much too uncommon for some underdeveloped countries.

Problem III.

In an underdeveloped country, through the implementation of a rational economic development program, the agricultural productivity per capita farm labor, and the non-agricultural population will be increased from a_o to a_n and from μ_o to μ_n, respectively. If the nation plans to export $\mathfrak{Z}_n$ per cent of

its aggregate annual agricultural production, will it also be able to increase per capita consumption of the agricultural products, and if so, how much?

Mathematical Solution: In problem III, a_o, μ_o, $\mathfrak{z}_o$, μ_n, and $\mathfrak{z}_n$ are given. It is asked to determine $\frac{\lambda_n}{\lambda_o}$ using Equation (20.d); we get the following, assuming that $\mathfrak{z}_o = 0$:

$$\frac{\lambda_n}{\lambda_o} = (1-\mathfrak{z}_n)\frac{1-\mu_n}{1-\mu_o} \times \frac{a_n}{a_o}$$

which gives $\frac{\lambda_n}{\lambda_o}$ in terms of all other variables.

Numerical Problem: Suppose in an underdeveloped country $a_o = 80$, $\mu_o = 30$ per cent, $a_n = a_o + 0.35\ a_o = 1.35\ a_o = 108$, $\mu_n = 40$ per cent, $\mathfrak{z}_n = 10$ per cent and $\mathfrak{z}_o = 0$. Determine $\frac{\lambda_n}{\lambda_o}$.

Numerical Solution: Equation (20.d) gives the following: $\frac{\lambda_n}{\lambda_o} = (1-\mathfrak{z}_n)\frac{1-\mu_n}{1-\mu_o} \times \frac{a_n}{a_o} = (1-0.1)\frac{1-0.4}{1-0.3} \times \frac{108}{80} = 1.04$ Under the given conditions, per capita consumption of the agricultural products can be increased slightly. In other words, at the end of the development program the people of the underdeveloped country will be able to consume 0.4 per cent more agricultural products.

If the computation would yield a value for $\frac{\lambda_n}{\lambda_o}$ less than 1.00, this would signify the fact that in order to carry out the economic development program, the people of the underdeveloped country will have to tighten their belts and reduce their consumption of agricultural products.

The applicability of the equations derived from Mathematical Models I and II, to actual development problems of the underdeveloped countries has been demonstrated in the

present chapter. Through the manipulations of Equation (17) and Equation (20) and their derivatives, some basic questions confronting the underdeveloped countries at least tentatively can be answered. The equations developed in Chapter IV are relatively simple in form and incorporation of the statistical data into these equations can hardly be considered as difficult and time consuming.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

Conclusions

The principal purposes of this study were: 1) to define and describe "underdevelopment", 2) to discover the basic factors which determine and perpetuate the economic and social backwardness that exists in the underdeveloped countries, and 3) to develop mathematical models and tools that can be employed in solving the crucial problems confronting the underdeveloped countries.

After the development of these mathematical tools and their actual application to development problems, the following conclusions can be given:

1. The underdeveloped countries are not destined to stay underdeveloped. Almost all of them have unemployed factors of production and latent and inhibited productive energies and talents.

2. The utilization and employment of all these energies, talents, skills and unemployed production factors, such as "surplus farm labor", first of all require the construction of a rational, scientific, objective and daring economic development plan.

3. The basic purposes of this plan are a) increase

agricultural and industrial productivity, and b) increase the non-agricultural population.

4. In determining the increases in the agricultural and industrial productivity and in the non-agricultural population, Mathematical Models I and II, and their derivatives, Equations (17) and (20) can be effectively employed.

5. In preparing the development program and in its implementation, the main task will have to be shouldered, not by politicans and phrase mongers, but by scientists, managers and particularly by civil, mechanical, electrical and industrial engineers who are equipped both by qualitative and quantitative tools and knowledge.

6. Once a "take-off" stage is reached, it will then be possible for the underdeveloped countries to accumulate industrial and social capital and gradually eliminate physical and spiritual poverty which have existed in all underdeveloped countries for centuries.

7. In the actual implementation of the development program all contributing external factors such as foreign economic and technical aid, loans from international banks, and assistance from the United Nations may be extremely useful. However, major emphasis will have to be put upon the creative talents and energies of the people of the underdeveloped countries. Otherwise, the development may be lopsided, deformed and the national integrity jeopardized.

8. In this respect, it would be extremely beneficial to all underdeveloped countries, if native scientists, medical doctors, managers, and particularly engineers can be attract-

ed back to their home countries by material and non-material incentives. Because, as long as these technically competent people prefer to stay in industrially advanced countries, it will not be possible to prepare and implement an economic development program for underdeveloped countries.

In the United States people who had indomitable will and courage left the comforts of the East and ventured toward the West. Such a spirit will have to be imbued to the medical doctors, engineers, scientists, and the managers of the underdeveloped countries who are being educated and trained in industrially advanced countries.

Recommendations for Future Research

The Mathematical Models I and II and the equations derived from these models are of a general nature. In other words, they may be applied to industrial processes as well as agricultural ones. In this respect, this study can be extended as follows:

1. Investigation of the effects of the increased productivity in industry upon the industrial labor force could be made. It is a well-known fact that in all industrially advanced countries, the labor force in manufacturing is decreasing in relative numbers, whereas, the population engaged in service industries and in white collar occupations is increasing. This inverse relationship can quantitatively be demonstrated by Mathematical Models I and II, after minor alterations.

2. A mathematical relationship can be developed which would express the increase in agricultural and industrial productivity as a function of time and socio-economic measures. Through the utilization of such a function, the productivity at a certain date in the future can be estimated. This would be of extreme value for engineers and planners in setting up development criteria and goals.

3. The social problems of the industrially advanced countries can be investigated, studied and explained in order to be able to prevent the emergence of these problems in the underdeveloped countries.

4. It may be possible to integrate Mathematical Models I and II into a more general and comprehensive one. The obvious advantages of such an integration would be the incorporation of productivity increases and time into a single model which can be employed in determining both aggregate output and the changes in the productivity levels.

5. The effects of paternalistic and traditional family type of ownership and management upon the productivity in the underdeveloped countries must be thoroughly studied. It is obvious that this type of management is detrimental to economic development. In that respect, the positive contributions of the corporate type of ownership and the modern scientific management intitiated by Taylor and expounded by Barnard would serve as guiding criteria.

SELECTED BIBLIOGRPAHY

1. Nurkse, Ragnar. Problems of Capital Formation in Underdeveloped Countries, New York, Oxford University Press, (1953), p. 35.

2. Staley, Eugene. The Future of Underdeveloped Countries, New York, Harper & Row, Publishers (1954), pp. 15-18.

3. Lewis, N. Arthur. The Theory of Economic Growth, Homewood, Illinois, Richard D. Irwing, Inc. (1955), p. 210.

4. Wiles, Peter. "Growth vs Choice", Economic Journal, (June 1965), pp. 244-255.

5. Kindleberger, Charles P. Economic Development, New York, McGraw-Hill Book Co., Inc. (1958), p. 139.

6. Snider, Delbert A. Introduction to International Economics, Homewood, Illinois, Richard D. Irwing, Inc. (1958), p. 453.

7. Eckstein, Alexander. "The Role of the State in Economic Growth", Economic Development and Cultural Change, (1958), pp. 81-87.

8. Lerner, Daniel and Plevsner, Lucille. The Passing of Traditional Society, The Free Press of Glencoe, Collier-McMillan, Lioniteul, London, (1958).

9. Hauser, Philip. "Cultural and Personal Obstacles to Economic Development in the Less Developed Areas", Human Organization, Vol. 18, (Summer, 1959), pp. 78-84.

10. Higgins, Benjamin. Economic Development, New York, W.W. Norton & Company, Inc., (1959) p. 16.

11. Black, Eugene R. The Diplomacy of Economic Thought, Cambridge, Massachusetts, Harvard University Press (1960) p. 9.

12. Hansen, Alvin H. Economic Issues of the 1960's, New York, McGraw-Hill Book Co., Inc. (1960) p. 136.

13. Lewis, Oscar. The Children of Sanchez, New York, Random House (1961).

14. Adelman, Irma. Theories of Economic Growth on Development, Stanford University Press, Stanford, California, (1961), pp. 9-24.

15. Krause, Walter. Economic Development, San Francisco, Wadsworth Publishing Company (1961), Chapters 23 and 24.

16. Holzman, Franklyn D. "Moscow's Motives---Profits or Politics?" Challenge (April, 1961) pp. 13-17.

17. Barnard, Chester I. The Functions of the Executive, Cambridge, Massachusetts, Harvard University Press (1962).

18. Barnard, Chester I. Organization and Management, Cambridge, Massachusetts, Harvard University Press (1962).

19. Thuesen, H. G. and Fabrycky, W. J. Engineering Economy, Prentice-Hall, Inc. (1964).

20. Taylor, F. W. Principles of Scientific Management, New York, Harpers (1947).

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