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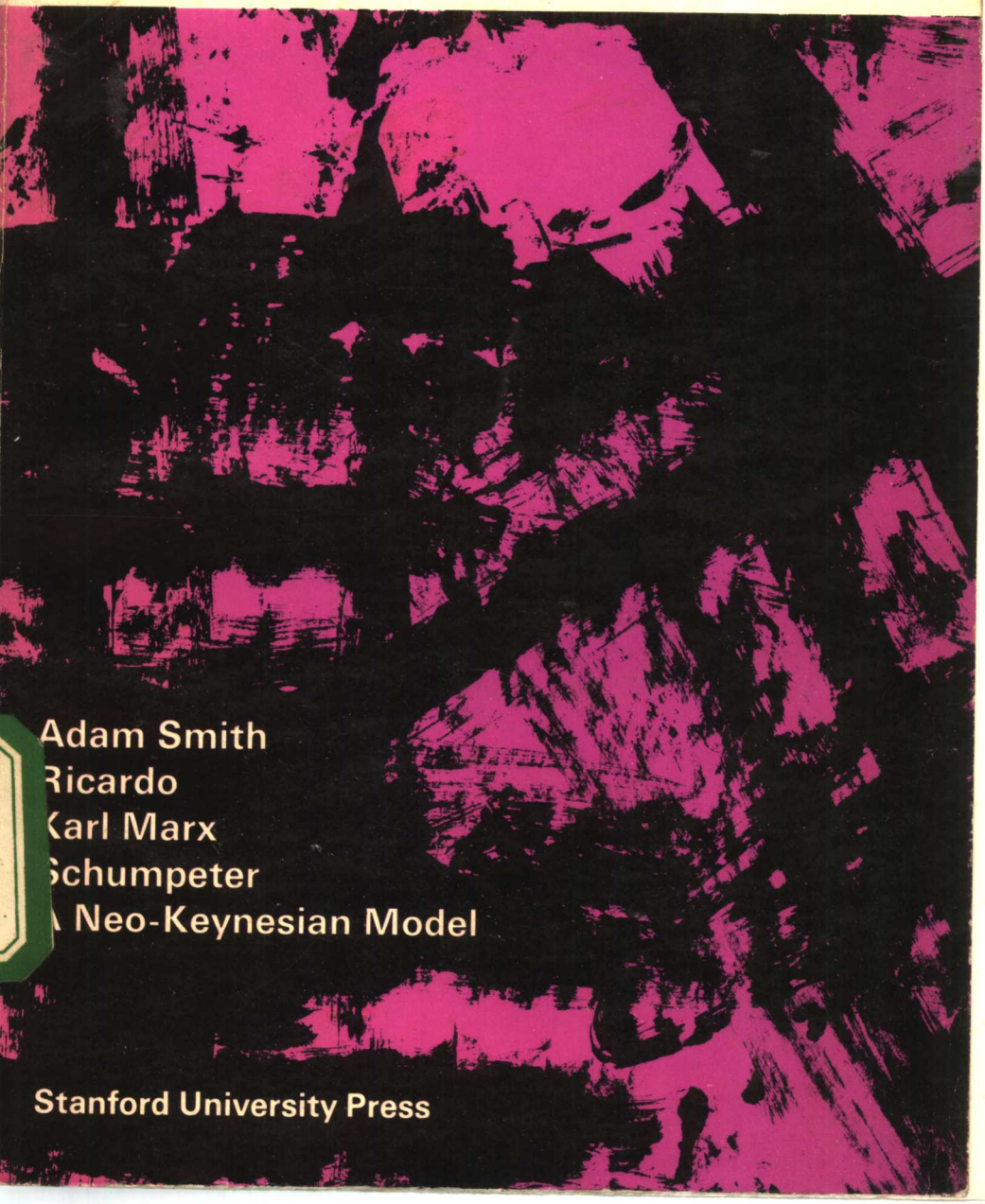
Theories of Economic Growth and Development

Irma Adelman



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IRMA ADELMAN

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PREFACE

IN THE HALF-CENTURY prior to World War II, the major concern of economists was with static, short-run, equilibrium analysis. The theories of consumer demand, of equilibrium of the firm, of income distribution, and of resource allocation were refined with the aid of these concepts. Even trade-cycle analysis and the theory of employment evolved within a largely short-run equilibrium framework.

Since then, the problems of economic growth and development have been thrust upon the current generation of economists by a world intent on economic progress. In the last two decades, nations have become increasingly development-oriented. Economic development is now a major issue in international politics. As a result, just as in the nineteenth century, long-run economic dynamics has once more become a primary concern of the profession.

Perhaps the major function of this study is to examine, in the context of modern economic theory and with the aid of modern economic tools, the evolution of economic thought in the field of growth and development. The second chapter presents a rather general mathematical schema, which forms the basis of the remainder of the book. In the succeeding four chapters the general framework is used to clarify the basic assumptions and conclusions inherent in the theories of economic growth of Smith, Ricardo, Marx, and Schumpeter. Finally, a modern model of economic development is presented, and some conclusions are drawn concerning the nature of economic development policies in a modern underdeveloped society.

The present work is an outgrowth of my collaboration with Adamantios Pepelasis and Leon Mears on an undergraduate textbook in economic development. I am very grateful to both of them for their help and encouragement in the early stages of this book.

My greatest personal debt is to Frank L. Adelman, my severest and most exacting critic, whose dual role as patient husband and less patient inculcator of precision and logic has contributed significantly to both the quality and preparation time of this book. I must also express my deep appreciation to Robert Dorfman, whose insistence on the

scientific method and whose qualities as teacher and economist have exerted a strong and continuing influence upon my professional development.

The stimulation offered by Nicholas Kaldor, F. H. Hahn, H. B. Chenery, and the members of Professor Kaldor's seminar at Berkeley during the period in which the major portion of this book was written cannot be overestimated. Further improvements in the manuscript are due directly to the many helpful comments offered by Moses Abramovitz, K. J. Arrow, P. A. Baran, B. F. Haley, John Green, H. P. Minsky, Gustav Ranis, Henry Rosovsky, Aubrey Silberston, Stephen Sosnick, Donald Winch, Hirofumi Uzawa, and the Stanford University Press referee. In addition, the framework of Chapter Two was strongly influenced by T. Haavelmo, *A Study in the Theory of Economic Evolution*. Finally, I am very grateful to Dr. E. K. Bauer and the editorial staff of Stanford University Press for their excellent editorial assistance. Part of the preparation cost of the manuscript was borne by the Stanford Project for Quantitative Research in Economic Development, which is financed by the Ford Foundation.

I wish also to thank Harper & Brothers for their permission to quote from Schumpeter, *Capitalism, Socialism and Democracy* (New York, 1950); Harvard University Press for their permission to reprint excerpts from Joseph A. Schumpeter, *The Theory of Economic Development* (Cambridge, Mass.: Harvard University Press), Copyright 1934 by the President and Fellows of Harvard College; and McGraw-Hill for their permission to quote from Schumpeter, *Business Cycles* (New York, 1939).

I. A.

Stanford, California
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ONE

INTRODUCTION

AN ADEQUATE DEFINITION of economic development is not easy to construct. The vast disparities in natural endowments, economic structure, cultural heritage, and social and political institutions that exist between different regions of the world today are likely to invalidate any attempt to devise a single criterion for distinguishing "developed" from "underdeveloped" countries. Even definitional approaches that combine a number of indicators of economic underdevelopment have so far proved intellectually unsatisfactory because they include so many variables that they become descriptive rather than analytical in character.[1] As a result, a division of the world into "developed" and "underdeveloped" segments is more or less arbitrary and can be achieved only at the cost of great complexity or gross oversimplification.

Nevertheless, definitions are necessary to establish ground rules for discussion. In this book we shall define economic development 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. A society will be called underdeveloped if economic development is possible but incomplete.

This definition of economic development appears to be a reasonable one. It does not describe an empty set, since in the Western capitalist economies (since the Industrial Revolution) a persistent, endogenously generated rise in the rate of growth of per capita output has taken place, and this growth rate has remained significantly positive for an extended period of time. On the other hand, our definition serves to distinguish economic development from such processes as sporadic growth and growth sustained primarily by exogenous forces.

With regard to our definition of an underdeveloped economy, it should be pointed out that it is in no sense a "single criterion" definition.

On the contrary, our assignment of an economy to the category of "underdeveloped" must be predicated upon a rather complete examination of its economic and socio-cultural behavioral relationships. Only on this broad basis can we determine whether economic development is (1) possible, (2) in progress, or (3) essentially complete.

Before we begin our study of the interactions governing long-run economic behavior, it may prove useful to point out some of the features of the current economic scene that lend a sense of urgency to the problem of development. Foremost among these is the tremendous difference in per capita real national income that exists between rich countries and poor. This disparity is quite evident from the Table (pp. 4 and 5). Column (1) gives the average per capita income in 52 countries for the period from 1952 to 1954, converted into 1953 U.S. dollars with the aid of exchange rates adjusted for local differences in purchasing power. The low levels of per capita income in much of the world indicate the magnitude of the economic problem ahead. Indeed, it would appear that two-thirds of the world's population lives at a bare subsistence level.[2]

Admittedly, intercountry comparisons of per capita incomes are, at best, only rough indicators of relative levels of community welfare.[3] First of all, national income statistics do not include all of the flows of goods and services in a community. They exclude barter transactions and much of the economic activity represented by home-produced, home-consumed output, and they do not take into account the domestic services of housewives, the services of consumer durables, or the services of social overhead capital. In addition, national income comparisons of this nature cannot reflect adequately any of the non-material contributions of the society to the welfare of its people.

Next, the internal inconsistency of national income estimates[4] and the distortions created by the use of exchange rates[5] (adjusted, in some sense or other, for differences in the relative costs of living) introduce a fair degree of arbitrariness into the results. And, finally, the use of per capita income figures (which constitute averages over the community) tends to conceal the large difference in the composition of output and in the distribution of income among the various members of the society.*

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* This last defect will also be present in the later chapters of this book.

In spite of these deficiencies of national income comparisons, however, the differences between nations are so big that even indicators of national welfare as crude as those derived from the currently available data on per capita incomes can serve as useful guides to the size of the required gains and as qualitative measures of economic progress.

Large as the existing national income disparities are, one can expect the development of further inequities for some years to come. Columns (2) and (3) of the Table give relevant information on estimated short-run and long-run rates of growth of per capita income. From the short-run figures it is evident that many of the poorer countries are essentially stagnant and cannot even begin to narrow the income gap without significant changes in their way of economic life.

Of course, the long-run rate of growth is the most important for our discussion, since our definitions of economic development and underdevelopment hinge upon the behavior of this quantity. Unfortunately, relatively few data exist on long-run rates of growth, but what evidence we have suggests that the more opulent societies are the ones which are growing more rapidly.

A number of other quantities often used as indicators of economic development are presented in the Table. These include such economic variables as the proportion of the labor force engaged in primary activities (column 6) and the ratio of foreign trade to the gross domestic product (column 9), both of which are negatively correlated with per capita income, and economic characteristics like the share of value added in manufacturing (column 5), the capital–labor ratio in manufacturing (column 7), and the percentage of investment (column 4), all of which are positively correlated with per capita income. In addition, several important demographic and socio-cultural features are tabulated for most of the countries listed. In the socio-cultural sphere, it is apparent that both literacy (column 10) and urbanization (column 11) increase as per capita income goes up; with regard to the demographic features, lower incomes are generally associated with higher crude birth and death rates (columns 12 and 13), larger infant mortality (column 14), and reduced life expectancy (columns 15 and 16).

Naturally, the relationships noted above are not perfect. In Chile, Venezuela, and Bolivia, for example, a high per capita income (relative to the degree of industrialization) has been reached by reliance on extractive industry, whereas New Zealand, Argentina, and Puerto Rico

(Date is 1953 except

Countries	(1) Per cap. income 1953 U.S. $	(2) Short-run % rate of growth per cap. income	(3) Long-run % rate of growth per cap. income	(4) Investment as a % of nat'l income	(5) Value added by mfg. as % total val. add.	(6) Agr'l labor as % of total labor force	(7) Capacity installed per person engaged (horsepower)
United States	1855.5	1.8	16.4	18.9	32.3	12.2[c]	7.53
New Zealand	1322.0	—0.9	11.8	20.4	21.4	18.4[c]	5.49
Canada	1299.2	1.4	17.0	28.4	29.1	19.1[c]	7.84
United Kingdom	1121.5	2.1	11.0	16.4	34.6	5.2[c]	4.76
Australia	1071.7	—2.8	9.5	29.3	31.0	15.6[b]	3.87
Sweden	1045.8	2.5	29.2	20.9	19.0	20.4[c]	6.95
Switzerland	1022.3	3.5	15.3	22.3	40.1	16.5[c]	4.21
Luxemburg	895.7	0.8	....	27.6	35.8	....	4.38
Denmark	795.2	1.7	16.7	22.2	27.7	25.1[c]	3.46
Belgium	734.8	2.9	....	16.6	32.1	12.5[b]	3.15
Norway	715.1	2.3	23.4	32.0	27.5	25.9[c]	6.33
France	685.6	4.0	10.4	19.6	32.2	36.5[b]	2.72
Germany, Fed. Rep.	603.2	7.1	8.3	25.2	37.6	23.2[c]	3.43
Venezuela	530.5	8.0	....	20.9	10.0	41.3[c]	3.84
Finland	490.2	3.3	....	28.1	31.9	46.0[c]	5.99
Netherlands	488.9	3.8	9.0	22.9	30.2	19.7[b]	2.94
Argentina	460.0	—0.4	....	17.0	19.7	25.2[b]	2.10
Union of S. Africa	456.4	0.6	23.8	26.1	29.0	48.3[b]	2.82
Austria	444.0	6.2	....	19.0	43.2	32.1[c]	2.82
Puerto Rico	411.9	3.6	....	20.1	19.3	37.1[c]	3.14
Ireland	403.3	1.5	16.3	18.3	27.6	39.6[c]	3.25
Chile	359.1	—0.3	....	13.3	12.8	30.1[c]	2.06
Spain	335.6	5.2	5.6	19.5	22.3	48.8[c]	....
Italy	309.8	5.2	14.2	22.1	31.9	41.2[c]	2.89
Costa Rica	268.1	2.7	....	23.5	11.2	55.0[c]	2.14
Mexico	230.1	2.8	....	13.0	24.1	58.3[c]	2.46
Brazil	230.0	2.5	....	15.7	24.5	60.6[c]	2.01
Turkey	208.6	3.6	....	13.7	10.9	85.7[c]	2.54
Fed. Rhod. & Nyas'l'd	200.2	2.7	....	32.5	18.4	....	....
Yugoslavia	196.0	8.8	....	32.0	42.4	66.8	2.60
Colombia	187.4	2.8	....	14.1	15.7	72.7[a]	2.00
Dominican Republic	186.4	3.9	....	15.5	17.1	....	2.10
Japan	181.0	6.7	21.7	31.1	31.9	48.4[c]	2.75
Portugal	172.3	3.4	....	17.9	34.7	48.4[c]	1.67
Greece	170.6	6.8	....	17.3	18.9	....	1.03
Honduras	153.0	2.2	....	17.5	8.8	83.2[c]	0.48
Peru	145.0	0.0	....	26.3	14.4	62.5[b]	2.44
Guatemala	143.6	1.2	....	9.6	15.1	....	1.58
Paraguay	140.0	1.4	....	....	19.4	55.4[c]	1.28
Ecuador	129.2	2.0	....	15.0	17.9	49.4[c]	2.38
Egypt	118.1	0.6	....	12.2	11.3	59.7[b]	1.84
Ceylon	112.1	0.4	....	11.2	5.3	52.9[b]	1.75
South Korea	104.5	4.1	....	11.5	7.2	....	1.84
Thailand	82.0	2.3	....	....	12.3	84.8[b]	1.56
Philippines	74.5	4.2	....	8.7	11.7	71.3[b]	1.84
Bolivia	68.5	—40.5	....	10.5	3.7	72.1[c]	....
Belgian Congo	62.1	3.4	....	32.0	14.2	84.9[c]	....
China-Taiwan	57.2	4.7	....	20.4	24.7	....	1.38
India	57.1	1.6	....	....	17.0	70.6[c]	1.67
Pakistan	51.4	0.3	....	....	8.8	76.5[c]	1.64
Indonesia	50.7	5.0	....	....	6.7	....	1.52
Burma	48.5	5.6	....	20.4	9.5	....	1.74

(*a*) Year or years during period 1930–39; (*b*) Year or years during period 1940–49; (*c*) Year or years during period 1950–59.

(1) Per capita income, 1953, U.S. dollars from *Yearbook of National Accounts Statistics*, 1958, U.N. exchange rates from "Patterns of Industrial Growth," U.N., 1960. (2) Short-run rate of growth per capita income derived from (1). (3) Long-run rate of growth per capita income from Kuznets, S., "Percent Change per Decade National Product per Capita, Constant Prices, First Half of Twentieth Century," in *Economic Development and Cultural Change*, Oct. 1956. (4) Investment as per cent of national income, from *Yearbook of National Accounts Statistics, op. cit.* (5) Value added by manufacturing as per cent total value added from *Yearbook of National Accounts Statistics, op. cit.*, and "Gross Domestic Product by Sectors of Origin, 1953," U.N., dittoed. (6) Agricultural labor as per cent of total labor force from Kuznets, S., *Econ.*

CHARACTERISTICS OF FIFTY-TWO NATIONS

where otherwise noted)

(8) Relative productivity of agriculture	(9) Exports + imports as % of nat'l income	(10) Literacy index	(11) Urbanization index	(12) Crude birth rate	(13) Crude death rate	(14) Infant mortality rates	(15) Life expectancy at birth Male	(15) Life expectancy at birth Fem.
0.59[c]	9.4	....	35.3[c]	24.6	9.6	27.8	68.6	
1.56[c]	63.2	....	41.6[c]	25.4	9.0	25.7	68.3[c]	72.4[c]
0.68[c]	47.6	....	27.5[c]	28.2	8.6	35.4	66.3[c]	70.8[c]
1.08[c]	46.4	....	59.5[c]	15.9	11.4	27.6	67.3	72.4
0.82[a]	42.4	....	48.4[a]	22.9	9.1	23.3	66.1[b]	70.6[b]
0.63[c]	55.7	....	25.4[c]	15.4	9.7	18.7	69.0[b]	71.6[b]
....	59.0	....	24.8[c]	17.0	10.2	29.8	62.7[b]	67.0[b]
....	159.4	....	21.3[b]	16.0	12.5	41.7	61.7[b]	65.8[b]
0.82[c]	66.5	....	36.7[c]	17.9	9.0	27.2	67.8[b]	70.1[b]
0.66[b]	63.0	96.9[b]	17.9[b]	16.6	12.1	41.9	62.0[b]	67.3[b]
0.58[c]	89.2	....	26.0[c]	18.7	8.5	22.0	69.3[b]	72.7[b]
0.47[b]	31.9	92.7[b]	23.1[c]	18.9	13.1	41.9	63.6[c]	69.3[c]
0.50[c]	37.9	....	32.7[c]	15.5	11.0	46.2	64.6[c]	68.5[c]
....	60.6	48.9[c]	21.8[c]	....	....	....	....	....
0.57[c]	45.8	....	14.2[c]	21.9	9.6	34.2	62.9[c]	69.1[c]
0.66[b]	104.3	....	41.3[b]	21.8	7.7	22.1	70.6[c]	72.9[c]
0.72[b]	12.2	86.7[b]	42.1[b]	24.7	8.7	....	56.9[b]	61.4[b]
0.32[b]	43.0	27.0[b]	28.2[c]	25.7	8.9	34.1	63.8[b]	68.3[b]
0.49[c]	44.3	....	35.2[c]	14.8	12.0	49.9	61.9[c]	67.0[c]
0.53[c]	129.3	74.4[c]	23.3[c]	35.1	....	....	....	....
0.82[a]	80.7	....	23.7[c]	21.2	11.7	39.4	60.5[b]	62.4[b]
0.55[c]	18.2	....	27.3[b]	34.6	12.4	112.4	49.8[c]	53.9[c]
....	13.1	....	28.3[c]	20.6	9.7	58.9	47.1[b]	53.2[b]
0.64[c]	28.5	....	28.0[c]	17.7	10.1	58.4	57.5[a]	....
....	64.1	78.8[c]	17.5[c]	....	....	....	55.7[c]	
0.32[c]	31.1	....	13.6[b]	45.0	15.9	95.2	37.9[b]	39.8[b]
0.56[c]	16.2	48.4[c]	16.3[c]	....	....	....	49.8[c]	56.0[c]
0.57[c]	17.0	34.3[c]	10.1[c]	....	....	....	....	....
....	109.6	....	0[c]	27.6	6.2	25.2	....	....
0.43[c]	15.4	74.6[b]	8.1[b]	28.4	12.4	116.3	....	....
....	33.8	....	....	....	....	....	....	....
....	44.1	43.2[c]	11.1[c]	....	....	....	....	....
0.50[c]	27.8	....	33.3[c]	21.5	8.9	48.9	61.9	65.7
0.60[c]	38.9	58.2[c]	12.7[c]	23.4	11.3	95.5	55.5[c]	60.5[c]
....	29.0	76.1[c]	16.2[c]	....	....	....	....	....
0.67[c]	50.5	33.7[b]	5.3[c]	....	11.0	87.4	....	....
0.57[b]	48.5	....	....	....	....	....	....	....
....	47.0	29.7[c]	10.2[c]	51.1	23.2	103.0	36.0[b]	37.1[b]
0.86[c]	....	68.2[c]	15.2[c]	....	....	....	....	....
0.81[c]	38.6	56.3[c]	14.6[c]	....	....	....	....	....
0.58[b]	40.4	22.1[b]	22.7[b]	....	....	....	35.7[a]	41.5[a]
1.03[b]	80.3	63.8[b]	8.8[b]	39.4	10.9	71.2	57.6[c]	55.5[c]
....	16.7	....	....	....	....	....	....	....
0.64[b]	....	53.7[b]	57.4[b]	....	....	....	48.7[b]	51.9[b]
0.57[b]	30.2	59.8[b]	17.6[b]	....	....	....	....	....
0.77[c]	72.9	31.1[c]	....	....	....	....	....	....
0.39[c]	85.7	....	....	....	....	....	37.6[c]	40.0[c]
....	28.8	....	....	45.3	9.5	33.7	41.1[a]	45.7[a]
0.71[c]	....	19.9[c]	8.7[c]	....	....	....	32.5[b]	31.7[b]
0.79[c]	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....
....	56.1	....	....	....	....	....	....	....

Development and Cultural Change, July 1957. (7) Capacity installed per person engaged, *Patterns of Industrial Growth, op. cit.* (8) Product per worker including family labor in current prices, Kuznets, S., July 1957, *op. cit.* (9) Foreign trade as per cent of national income from *Yearbook of National Accounts Statistics, op. cit.* (10) Literacy index from *Demographic Yearbook, 1955*, U.N., per cent population 10 years and over with ability to read and to write. (11) Urbanization index, *ibid.*, except Australia, Chile, Mexico from *World Population and Production*, Woytinsky, W. S., and E. S., Twentieth Century Fund, 1953, per cent population in places with population greater than 50,000. (12) Crude birth rates from *Statistical Yearbook, 1956*, U.N., number of live births per 1000 population. (13) Crude death rates, *ibid.*, number of deaths per 1000 population. (14) Infant mortality rates, *ibid.*, number of deaths of infants under one year age per 1000 live births. (15) Life expectancy at birth, male, *ibid.* (16) Life expectancy at birth, female, *ibid.*

have achieved a similar result with the aid of extensive commercial agriculture as a substitute for manufacturing activity. On the other hand, because of rather meager resource endowments, per capita incomes in Switzerland and Japan are lower than would be warranted by their degree of industrialization. And in Yugoslavia and Nationalist China, the full impact of the post–World War II industrialization efforts upon per capita standards of living had certainly not made itself felt by 1953.

There are a number of other exceptions to the general relationships that can be derived from the Table. Some, of course, can be explained quite easily in terms of abnormal features of the society in question. Others may require more subtle analysis to determine the reasons for departure from the general patterns. In any case, the existence of such anomalies suggests that in the absence of a sound theoretical foundation the analysis of empirical data cannot be relied upon to lead to universal conclusions about the causes and paths of economic growth. Specifically, multiple correlation studies, one of the mainstays of the empirical approach, indicate mutual association at most, and offer no intimation of cause or effect. Indeed, they occasionally lead even a sophisticated economist to spurious relationships. Observational evidence and empirical analysis, of course, often provide invaluable direction to theory, but the very abundance of variables that can affect economic development makes it difficult to determine just which of the parameters of a developing society are the significant ones. It follows, therefore, that strong theoretical guidance is a necessary prerequisite to describe sensibly the phenomena of economic development. In addition, a good theoretical model would permit valid generalizations from one specific economic situation to another, and would greatly assist in the formulation of sound economic policy.

In the next chapter we shall present a rather general theoretical framework from which we shall later attempt to adduce a common explanation for the growth patterns of various economic systems. Our task will be to present a dynamic analysis of economic development that is sufficiently broad to permit us to encompass both the phenomenon of self-sustained progress and that of economic stagnation. In short, we shall again address ourselves to the classical economic problem that is so neatly summarized in the full title of Adam Smith's treatise—*An*

Inquiry into the Nature and Causes of the Wealth of Nations. The framework of Chapter Two is intended to be a systemization of past and current economic thought about the evolution of an economy, and each economist will recognize therein many elements of his own point of view. Of necessity, we shall not be specific in this chapter; that is, we shall present neither a *theory* of growth nor a *model* of a growing economy. Rather, to analyze economic development we shall formulate a structure[6] that will be sufficiently general to permit us to treat the theories of a number of economists as particular special cases. Although this structure will not in itself permit us to draw immediate conclusions concerning the nature of the growth-promoting and growth-inhibiting forces in an economy, it will serve to channel our thinking along specific lines of inquiry into this question.

In the subsequent chapters we shall analyze in detail with the aid of the framework of Chapter Two the long-run dynamic behavior of economic systems as seen by Smith, Ricardo, Marx, Schumpeter, and the Neo-Keynesians. Then we shall see, in Chapter Eight, what common conclusions and recommendations can be derived from a reasonable synthesis of the doctrines of the authors we have discussed. Our major objectives are first to see to what extent a clearer picture of economic development can be derived, and second to suggest, if possible, reasonable policies whose implementation may speed development.

TWO

A GENERAL FRAMEWORK FOR ANALYSIS

THE ANALYSIS PRESENTED in this chapter will use, as the fundamental criterion of economic development, the total output of the economy. This implies that, for our present purposes, we are willing to accept both (1) the deficiencies associated with the use of flows of market-oriented products as indicators of comparative development, and (2) the complexities of the several welfare and index-number problems associated with the use of this concept. If some other yardsticks, such as the per capita output or the rate of growth of either per capita or total output,[1] should seem more appropriate to the reader, he may still use our analysis without modification; he need merely apply his own set of criteria at the end to draw his conclusions.

Using the economy's output level as an index of the stage of economic development suggests that the production function is the keystone of our structure. This function relates the economy's output rate at time t (Y_t)* to the quantities of various inputs actually used in production and to the major forces conditioning the productivity of production factors.† Given the state of technology and the institutional

* The subscript "t" is used to denote the value of the variable at time t.

† This definition of the production function differs from the usual one. The conventional production function is a relationship between inputs and output only. The influence of the factors that condition the productivity of the physical inputs (e.g., technology and the socio-economic environment) is usually subsumed in the shape of the production function. Hence, in the usual treatment exogenous changes in the shape of the production function are used to portray the effects of technological and environmental forces. For greater generality, we prefer to keep the shape of the production function independent of time and to provide the possibility for an endogenous treatment of technological and social factors. Note, however, that the conventional approach is merely a special case of our structure.

and socio-cultural environment of the community, the production function represents the maximum amount of output obtainable with each combination of the physical inputs. Since we assume implicitly that the institutional and economic environments determine uniquely the allocation of resources among the various firms, the usual hypothesis that each firm will operate to produce the maximum possible output with the available inputs results in our specifying, in effect, that the economy itself, at each point of the production function, is manufacturing the largest amount of goods it can produce with the given amounts and allocation of factors and the level of technology of the society.

We shall therefore take our production function to be

$$Y_t = f(K_t, N_t, L_t, S_t, U_t), \tag{2.1}$$

where K_t denotes the amount of the services of the economy's capital stock employed at time t, N_t stands for the rate of use of natural resources, and L_t represents the employment of the labor force. In order to deal more easily with factor productivity variations stemming from technological innovations and from changes in the skills of the labor force, we have introduced into our production function the symbol S_t, which represents the society's fund of applied knowledge.[2] The same thing could have been accomplished, of course, by making the shape of the production function itself time-dependent. From a mathematical point of view, however, it is simpler to define the shape of the production function f to be independent of time, as in (2.1). Similarly, in order to treat (at least in principle) the impact of social, cultural, and institutional changes upon the productivity of the economy, we also include in our production function a symbol U_t, which represents the socio-cultural milieu within which the economy operates.* Thus, we recognize explicitly that the output rate of an economy is not a purely economic phenomenon.[3]

Let us consider briefly each of the economic inputs in turn. The evaluation of the stock of capital (K_t) raises very difficult problems both in principle and in practice.[4] These problems stem primarily from the incommensurability of different types of physical products. Quan-

* Production function (2.1) does not imply that the variables K_t, N_t, L_t, S_t, and U_t are independent of each other. Indeed, in equations (2.3)–(2.7) the rates of change of each of these variables are related to all other variables in the system.

tification of capital wealth is generally achieved, therefore, by using the money values of real assets. These are derived on the basis of either the (adjusted) historical cost of the capital equipment, the (modified) replacement cost, or the (estimated) capitalized earning power of the physical assets. In an economy in which the techniques of production, the composition of output, and the characteristics of the labor force all change through time, however, estimates of the capital stock of the economy on any of these bases can be no more than a rough but educated guess. For there exists an interdependence between the evaluation of the capital stock at any point of time and the specific future time path assumed for the other economic variables of the system. In particular, the measurement of the economy's capital depends upon the nature of our postulates concerning the type and rate of technological progress.[5] (With no innovations, for example, there is no obsolescence of capital equipment, and hence the adjustment of historical costs need take account only of physical wear and tear of assets and of changes in price level.) Regardless of these difficulties of measurement, however, all economic theories of growth to date have used either the capital stock of the economy or the rate of investment as one of the crucial variables in the system.

While capital is thus often regarded as a basic determinant of economic growth, natural resources (N_t) are seldom considered to be as important.* Since, by definition, natural resources consist of non-reproducible assets, many economists consider the natural wealth of an economy to be constant through time. Others combine both the reproducible and non-reproducible forms of material wealth into a single portmanteau variable—capital.[6] In any case, the evaluation of N_t is fully as complex as that of K_t, since all the quantification difficulties mentioned in our discussion of the capital stock carry over also into the measurement of N_t, and, in addition, adequate resource surveys exist for only a very few of the more developed nations.

The labor component (L_t) of our central relationship (2.1) would appear, at first glance, to be homogeneous.[7] However, a little reflection will reveal that it too is a conglomerate of incommensurate entities. Dissimilarities in skills among the several grades of labor and varia-

* The Physiocrats are, of course, notable exceptions to this statement.

tions (both in time and in location) in the efficiency of the same grade of labor make a meaningful evaluation of the size of the work force an undertaking much more complex than a mere nose-count. Furthermore, both the quality and the composition of the labor force vary through time and are not independent of the rates of change of the other variables in the system. Specifically, changes in the skills and health of the labor force are directly dependent upon changes in the society's applied fund of technical knowledge (S_t). And, by the same token, cultural and institutional variations in the labor force cannot be divorced from differences in the socio-cultural environment (U_t).

The conceptual problems which arise from the heterogeneity and incommensurability of the production factors may be reduced somewhat if we think of each input as a multicomponent vector rather than as a single number. Therefore, we define the economy's capital stock as

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

where K_{jt} is the amount of the jth type of capital equipment in use at time t. Similarly, we write

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

and

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

In the above expressions N_{jt} and L_{jt} are the quantity of the jth kind of natural resource and the amount of the jth grade of labor employed at time t, respectively. This procedure permits us to disaggregate each input any time we feel it is desirable and practicable to do so. Of course, unless K_t, N_t, and L_t are to be minutely detailed inventory lists, the index-number problems inherent in the quantification of these concepts are merely pushed back one step further; they are not entirely eliminated.

Even more difficult than the measurement problems raised by the three production factors are those posed by an attempt to quantify our last two variables. S_t and U_t represent heuristic devices, introduced primarily for conceptual purposes. They symbolize forces whose role in development is undoubtedly vital, but whose quantification is possible, at best, only in an ordinal sense. (For our purposes this is all that is required, however.) Therefore, even in principle, these last two vari-