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9. ABSTRACT
An investigation of the inter-relationships between the agricultural and non-agricultural sectors during economic development, with emphasis on the effects of food aid. Most of the study is devoted to a theoretical analysis of these inter-sectoral relationships. A five-sector, optimizing model of an underdeveloped, dual economy is formulated and analyzed extensively. The five sectors include subsistence or traditional agriculture, commercial agriculture, manufacturing goods production, capital goods production, and a government sector. Three products are produced: agricultural goods, which only can be consumed, manufactured goods which either can be consumed or used as non-durable factors of production, and capital goods which only can be used as durable factors of production. A summary of the study's conclusions is as follows: 1) In an economy with a given resource base, capital stock, level of technology, and wage-price configuation, the proportion of the labor force engaged in subsistence employment will increase as the size of the labor force increases. 2) If the productivity in a particular sector increases more rapidly than in other sectors, the social desirability of investing in this sector will increase if there are no adverse effects on terms of trade. 3) The effects of an increased population depend on the magnitude of the population growth rate relative to (a) the size and growth rate of the capital stock and (b) the rate of technological improvement. 4) If recipients of aid grants divert some of their income previously spent on food to non-food commodities, a drop in food price will result. With food aid sold in the market place and the revenue used to hire subsistence labor, the economy is affected in the same way as when food is distributed as wages.

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# A FIVE SECTOR MODEL OF AGRICULTURAL DEVELOPMENT, INDUSTRIALIZATION AND FOOD AID IN A DUAL ECONOMY

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# SUMMARY AND CONCLUSIONS

The over-all purpose of this study is to investigate the inter-relationships between the agricultural and nonagricultural sectors during the process of economic development, with some particular attention to the effects of food aid. The major portion of the study is devoted to a theoretical analysis of these intersectoral relationships. A five-sector, optimizing model of an underdeveloped, dual economy is formulated and extensively analyzed. The five sectors include subsistence or traditional agriculture, commercial agriculture, manufacturing goods production, capital goods production, and a government sector. Three products are produced: agricultural goods, which can only be consumed, manufacturing goods which can either be consumed or used as non-durable factors of production, and capital goods, which can only be used as durable factors of production.

The factors of production included in the model are land, labor, capital, and manufactured inputs. Production in the traditional agricultural sector requires land, labor, and manufactured inputs; production in the commercial agricultural sector requires capital goods in addition to the factors employed in the subsistence sector. Manufactured goods and capital goods production do not require land as an input and employ only labor, manufactured inputs, and capital as factors. Labor is assumed to be employed at a constant wage rate (measured in terms of manufactured goods) in the commercial agricultural sector, the manufacturing goods sector, and the capital goods sector. Any labor that cannot earn its marginal value productivity in these three sectors is employed in the subsistence sector at a lower wage rate.

Two formulations of the model are considered, a centralized and a decentralized model, with the role of the government being the principal difference between the two models. In the first formulation, the government has control over four investment alternatives. These four alternatives are investment in social overhead capital in either the subsistence or commercial agricultural sectors and investment in "private" capital in either the manufacturing or the capital goods sectors. In the second formulation, the government's role is expanded considerably to include control over the allocation of private investment funds as well as public tax revenue.

These two versions of the model are extensively analyzed in an attempt to discern the economic and physical characteristics of an economy that would tend to make it socially desirable to develop agriculture relative to industry, and vice versa. Similarly, an attempt is made to delineate the conditions under which food aid has the most positive effect on agricultural development, employment and consumer welfare. A detailed descriptive summary of the conclusions of the study follow.

1. Public investment in subsistence agriculture. In an economy with a given resource base, capital stock, level of technology, and wage-price configuration, the proportion of the labor force engaged in subsistence employment will increase as the size of the labor force increases. This is true since, for a given level of wages and prices and a fixed productive capacity, only a limited number of jobs are available in advanced sectors. Thus, as the ratio of labor to resource base increases, the proportion of the labor force in the subsistence sector also increases.

It is demonstrated later that, as the proportion of the labor force employed in subsistence agriculture increases, it becomes relatively more important to increase the productivity of this sector. There is no a priori

reason to suggest that there should not be a net inflow of savings into the subsistence sector if the proportion of the labor force employed in this sector is large enough. Conversely, there is no reason to suggest that the subsistence agricultural sector should not be used as a source of savings to finance nonagricultural development in an economy with a different resource endowment, labor force distribution, and capital structure. Whether there should be a net inflow of savings into subsistence agriculture will depend on the individual country concerned and the relevant data and parameters pertaining to that country. The following characteristics, however, may be itemized as relevant to the decision regarding investment in the subsistence sector.

The first and most obvious consideration is the physical productivity of the investment project. Ceteris paribus, the physically more productive an investment project, the greater is the likelihood that it will be a desirable undertaking. The productivity of a particular investment may crucially depend on one or more related investments. For example, an extension program extolling the virtues of a new crop variety may have an extremely low payoff if the necessary complementary fertilizer is not available. If the appropriate investment in providing fertilizer also is made, the same extension program may have a very high payoff. Considerations such as these have led to package approaches for agricultural development.

The physical productivity of an investment project is not, however, the only consideration in investment decisions. Productivity must be weighted by an appropriate value which is placed on the output. In this study, the social value of the output, reflected by the social welfare function, is used as the weighting factor (a) in the decision criteria for allocating government funds in both the centralized and decentralized models and (b) in the

allocation of private savings in the centralized model. However, prices are used to value the output in decisions regarding the allocation of private savings in the decentralized model. It is demonstrated for a closed economy with a given level of consumer income that both the social value and price of agricultural output relative to nonagricultural output will increase as the ratio of the consumption of agricultural goods to manufactured goods declines. It also is suggested that this result will not necessarily hold if the decline in the ratio of agricultural:nonagricultural goods consumption is accompanied by an increase in real income. Then the social valuations will move in favor of the agricultural sector only if the rate of decline in the consumption ratio is sufficient to offset the influence of Engel's law at higher income levels. This suggests that, as the economy achieves higher levels of output in both agricultural and nonagricultural production, investment in agriculture might become relatively less desirable than at lower levels of output. This statement does not mean that investment in agriculture is undesirable at higher income levels, nor does it mean that it is desirable to invest in agriculture at lower income levels.

It is assumed that public investment in the subsistence sector involves employing labor of this sector at a higher wage rate than it was previously earning; where this is true, the social desirability of investing in the subsistence sector tends to increase as the disparity between the government wage rate and the subsistence wage rate widens. This condition is consistent with the condition of diminishing marginal utility, together these conditions affect the social benefit derived from investments in subsistence agriculture. Whether this investment should be made depends on the size of the anticipated social benefit relative to the social opportunity cost of using resources in this manner. This criterion differs from the conventional cost-benefit anal-

ysis where anticipated actual costs are compared with anticipated returns. Actual costs of a project may differ substantially from the opportunity costs of using the resources in this manner. These conclusions are obtained from an analysis of the decentralized economy model. Similar results are derived from the centralized model.

Throughout this investigation it was assumed that investment in social overhead capital in subsistence agriculture has no productivity influences on the commercial agricultural sector or vice versa. This is a fairly realistic assumption for some forms of investment. For example, an irrigation system may be built to provide water for either subsistence producers or commercial producers. Under the assumption that there is no complementarity between sectors, investment in social overhead capital specific to the subsistence sector becomes realtively more desirable as the amount of labor employed in subsistence agriculture increases relative to that employed in commercial agriculture. Similarly, the larger the proportion of cultivated area used in subsistence agriculture, the more desirable the investment in this sector becomes relative to investment in commercial agriculture.

Investing in either commercial- or subsistence-sector social overhead capital in one period reduces the relative social desirability of investing in that sector in the subsequent periods. Increased output resulting from public investment in either of these sectors reduces the relative social value of agricultural production. Hence, investing in the subsistence sector in one period also reduces the desirability of investing in commercial agriculture in subsequent periods and vice versa.

2. Private capital accumulation. The conclusions in this section are derived from the centralized model. Two constructs of this model are possible. First, the government owns all the reproducible capital stock and rents

it to entrepreneurs, and rent collected is used to accumulate more capital. Second, the capital is privately owned and the income earned by the capital-owners is used to accumulate more capital according to guidelines determined by the central planning authorities. Regardless of the construct, savings are referred to as private savings (as compared with public savings out of taxes) and are allocated among investment alternatives in a manner consistent with maximizing welfare over the planning horizon.

The allocation of investment funds to expand capacity in capital goods as opposed to consumer-goods industries involves a difficult intertemporal comparison. Satisfactions to be derived from expanded present versus future consumption must be estimated. Capital investment in the capital goods industry requires additional periods of waiting (as compared with placing these capital goods in the agricultural or manufacturing goods sectors). Higher rates of future consumption require sacrifice of current consumption. Thus, expansion of the capital goods industry will be desirable from society's standpoint if incomes are not too low and consumers are not too impatient. In countries where pressures exist for immediate improvements in living standards, emphasis on expansion of the capital goods sector will be less. Conversely, when income is higher and more emphasis is placed on longer-run improvements in living standards, the social payoff for increasing capacity in the capital goods industry will be greater.

If the productivity in a particular sector increases more rapidly than in other sectors, the social desirability of investing in this sector will increase if there are no adverse effects on terms of trade. This condition prevails whether the productivity increases arise from investments in infrastructure or through the adoption of new techniques developed in advanced countries.

3. Population growth and economic development. The supply of labor has, to this point, been assumed to be perfectly inelastic with respect to the wage rate. Relaxing this assumption has no essential effect on the conclusions, although the magnitudes of some policies' impacts may be dampened. For example, if the labor supply is elastic, an expansion of government employment will have a smaller impact on the incomes of laborers in the subsistence sector.

The effects of an increased population depend on the magnitude of the population growth rate relative to (a) the size and growth rate of the capital stock and (b) the rate of technological improvement. If the population growth rate is too high relative to these changes, per-capita production and consumption will remain constant or decline, even though total production is increased. This underscores the importance of combining policies to control the rate of population growth with policies to promote economic development.

4. Intracountry effects of food aid. The principal commodity of U.S. foreign aid has been food. Some effects of food aid are analyzed below within a comparative static, partial equilibrium model. It can be viewed as a submodel of the centralized model. Problems associated with repayment of loans based on food aid are not considered. To investigate those types of problems requires a somewhat more comprehensive model than employed in this study. Specifically, a foreign sector must be included to incorporate foreign exchange earnings. Another study in this series deals with methods of repayment and fiscal aspects of concessional sales as they relate to economic development and economic stability.

The impact of three alternative methods of food distribution are considered: Under the first, food is given as an outright grant to consumers.

Under the second, food is used by the government as wages-in-kind for labor employed on Social Overhead Capital (SOC) projects. The third method supposes that the government sells the food in the market at prevailing prices, revenue generated by the food sales being added to the general tax budget.

The intraperiod relationships between prices and quantities of agricultural goods under the three distribution methods can be compared diagrammatically in Figure 1. (p. ix). Demand and supply curves in the absence of aid are represented by the curves $D_o$ and $S_o$, respectively. These demand and supply schedules result in a price of $P_o$ and quantity consumed of $Q_o$.

Distributing the food aid in the form of grants, A, results in the largest shift in the supply curve since employment in the subsistence sector remains unchanged. Thus, $S_g = S_o + A$, where $S_g$ represents the total supply curve. Granting food to consumers has the effect of bolstering effective aggregate consumer income. Hence, the demand schedule shifts to the right and is represented by curve $D_g$. The intersection of the resulting demand and supply curves results in a price-quantity configuration where $P_g < P_o$ and $Q_o < Q_g$. The equilibrium price with food grants must be lower than without them unless (a) the marginal propensity to consume food (out of income) is unity or (b) consumers affected are completely insulated from the market. In other words, if recipients of aid grants divert some of their income previously spent on food to nonfood commodities, a drop in food price will result.

Turning now to distribution under work projects, the income effect of this distribution system is identical to that of direct grants and $D_w = D_g$. The domestic supply curve for food shifts to the left since labor is transferred from the subsistence sector to SOC projects. The leftward shift in the domestic supply curve, however, will not be sufficient to offset the

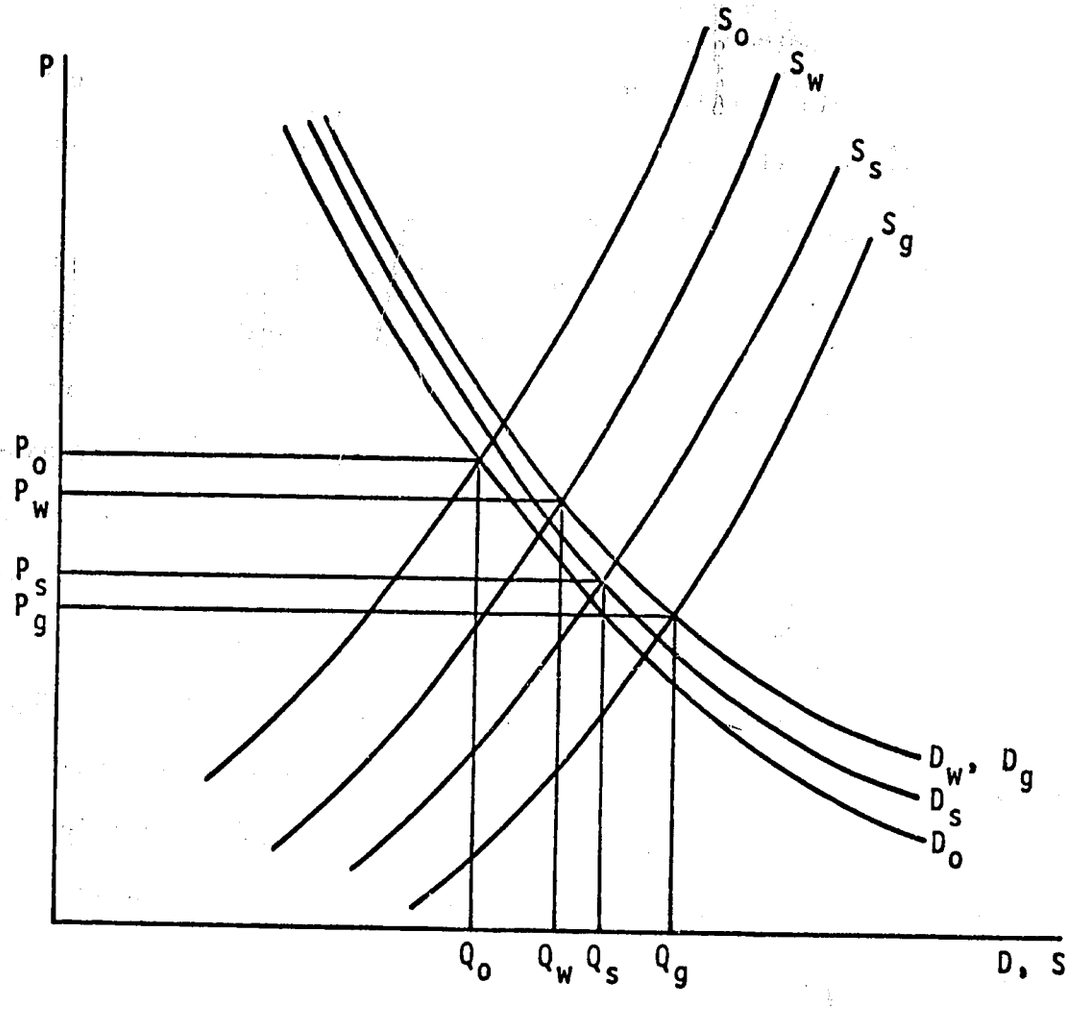


Figure 1. Prices and quantities of food consumed under alternative distribution methods

positive influence of the aid. Although the equilibrium quantity consumed is greater than in the absence of aid, the increase is less than when the food grants are given directly to consumers. This leads to equilibrium price and quantity, $P_w$ and $Q_w$, with the characteristic $P_o > P_w > P_g$ and $Q_o < Q_w < Q_g$.

With food aid sold in the market place and the revenue, used to hire subsistence labor for SOC projects, the economy, is affected the same as when food is distributed as wages in kind, (we suppose the revenue earned from sales is all paid out in wages). If, however, the revenue from government food sales is used to purchase capital goods, the domestic supply schedule for agricultural goods $S_s$, shift S to the left by a smaller amount than in the case of distribution as wages in kind. The increased demand for capital goods draws labor from the subsistence sector. The leftward shift in the demand curve, $D_s$, is less since all additional food must be purchased from income earned in employment. Income is augmented only if the increased purchase of capital goods leads to increased employment in the capital goods industry where labor return is higher than in the subsistence sector. This income effect is smaller than that experienced with food aid distributed either as grants or as wages in kind. Hence $D_s$ must lie between $D_o$ and $D_w$. For the same reason, the amount of labor removed from subsistence production is smaller if capital goods are purchased than if SOC projects are undertaken, and the new supply schedule $S_s$, must lie between $S_w$ and $S_g$. The resulting equilibrium price, $P_s$, and quantity, $Q_s$, have the properties that $P_o > P_w > P_s$ and $Q_o < Q_s < Q_g$. The equilibrium magnitude of $P_s$ relative to $P_g$ and $Q_s$ relative to $Q_w$ will depend on the extent of the shifts in the supply and demand schedules. These orderings may change if the labor hired in each of these situations does not come from the subsistence agricultural sector and is hired from an urban or rural pool of unemployed workers.

# INTRODUCTION

A central, unresolved issue in the investigation of the determinants of economic growth is the nature of the interrelationships between agricultural development and industrialization. In earlier studies of developmental priorities, industrialization typically was emphasized as the means for successful economic development. Studies of the 1940s and 1950s advocated development for underemployed and unemployed labor and to increase the demand for agricultural products. It was supposed that the industrial sector, as the leading sector, would pull the backward agricultural sector to higher levels of development. Agriculture was considered largely passive in the developmental process.

During the last decade, however, several theories of economic development and much empirical evidence have indicated that a significant role for agriculture may be appropriate in development. Increased emphasis now is being placed on developmental policies that exploit interrelationships between the industrial and agricultural sectors so as to promote mutual and simultaneous development. These studies propose that there is not a unique and best blend of agricultural development and industrialization for all countries.[1] The

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[1] Eicher and Witt [10, pp. 7-10], Meier [37, Ch. 6], Ruttan [54, pp. 1-2], Thorbecke [59, pp. 3-7], and Witt [66] express similar view. However, these views are not unanimously endorsed by either policy-makers or ecnomists. Enke goes so far as to suggest that "...most LDC (less-developed country) governments associate industrialization with development and hence favor an expansion of industrial output that exceeds the ability of a neglected agriculture to support it." [11, p. 1127]. As another example, in 1968, Higgins wrote that "Economic development in the past has consisted very largely of transferring population from low-productivity agriculture to much higher productivity industrial occupations, thus reducing population pressure on the land and permitting agricultural improvement in the form of large-scale mechanized

relative emphasis given to each should vary according to resource endowment and the phase of development of the particular country.

## Objectives

The purpose of this study is to investigate the nature of the relationships between the agricultural and nonagricultural sectors during the process of agricultural development. In addition, the following specific objectives are pursued:

1. To develop a rigorous, theoretical model encompassing as many agricultural-nonagricultural intersectoral relationships as consistent with operationalism.
2. To incorporate into this model as much realism or empirical relevance as is possible within a rigorous, operational framework.
3. To include the government as an integrated entity in the model.
4. To use this model to analyze the optimal allocation of private and public (government) savings between the agricultural and nonagricultural sectors.
5. To identify characteristics of economies that tend to make agricultural development socially desirable relative to industrialization and vice versa.
6. To investigate whether, and under what conditions, it is desirable to have a net inflow of savings into the agricultural sector.
7. To analyze the impact of commodity aid and, in particular, food aid on the prices and quantities produced and on the investment priorities within the economy.

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Footnote 1 continued from Page 1: agriculture at the same time" [17, p. 464-465]. Higgins uses this as a basis for advocating industrialization as the "engine for growth."

8. To investigate the implications of alternative rates of population growth on the optimal investment priorities and development plans.

## Organization of the Study

The following section is devoted to a nontechnical discussion of the agricultural development, industrialization issue. The immediately following section includes a review of some of the better-known arguments pertaining to this issue. It is followed by a brief discussion of alternative methods of analyzing the problem. We then present a heuristic description of the models developed in this study. The discussion immediately following primarily is a nontechnical exposition of the methods of analysis. We follow with the formulation of a model termed the decentralized model. It is an optimizing model and the optimizing technique is after presentation of the model. A reformulation of the model then is made within a centralized-economy framework with results very similar to those obtained for a decentralized economy. In addition, a number of highly restrictive and unrealistic assumptions are relaxed through this reformulation.

## Industrialization and Agricultural Development

Many of the arguments for either industrialization or agricultural development are doctrinaire. An argument in favor of industrialization is frequently viewed as an argument against agricultural development and vice versa. Although it is true that industry and agriculture compete for resources, an argument in favor of one need not be an argument against the other because there are certain interrelationships and complementarities between the two sectors which can and should be exploited. A brief review of some of the arguments in favor of industrialization and agricultural development, however.

may be useful.[2]

Industrialization

Some of the more common arguments in favor of industrialization in less-developed areas are briefly outlined in this section. Not all are logically defensible arguments and some are based on erroneous assumptions. Some of these arguments are more appropriately considered to be emotional or passionate appeals favoring industrialization.

Perhaps the most common argument presented in favor of industrialization is the high correlation in various countries between per capita income and the proportion of the labor force employed in nonagricultural activities. Economic history suggests that rising per capita incomes have always been accompanied by a reduction in the relative size of the agricultural labor force.[3] Similarly, the proportion of the total output originating from the agricultural sector tends to decline as per capita income increases.[4] Thus, economic development is associated with industrialization. Prebisch goes so

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[2]No attempt has been made at completeness. When this study was essentially completed, a relevant survey article by Johnston [20] appeared with fairly extensive bibliography. Interested readers may consult his bibliography for additional references.

[3]See for example, Ojala [46], or the massive works of Clark [8]. Zimmerman conducted a cross-sectional study in which he regressed the log of per capita income (y) on the percentage of the labor force (x) employed in nonprimary (secondary and tertiary) sectors for a number of economic-geographic regions and various points in time. He found the relationship $\log y = 0.0202x + 1.3235$, with a high correlation ($R=0.92$). As Zimmerman indicates, however, this does not imply causation. A country need not be poor because a large portion of the population is in the agricultural sector. See Zimmerman [67, ch. 3]. Conversely, industrialization and the accompanying structural changes are neither necessary nor sufficient conditions for increasing per capita income. Viner [62, ch. 3] is very critical of this type of argument, which Ruttan [53, p. 19] has called the structural transformation hypothesis.

[4]See for example, Kuznets [30, pp. 43-58]. Additional references can be found in Johnston [20].

far as to state that "...industrialization is an inescapable part of the process of change accompanying a gradual improvement in per capita income" [48, p. 251].

Along similar lines, Myrdal [41, p. 1151] suggests that the very rapid development of industry through government planning in the Soviet Union has had a very important influence on planning activities in many countries in South Asia. An economy centered around a comprehensive and heavy industrial structure is widely accepted by many leaders as an obvious target for attainment by an underdeveloped country. Soviet experiences in planning provide the illustration for leaders in many countries.[5]

A compelling and logical reason for industrialization in some developing countries is the prospect of foreign exchange to allow imports of manufactured goods. Bhagwati suggests that, "It is possible to argue that poor countries should continue producing primary products only if it can be established that they could always earn enough foreign exchange to import their manufactures. Where this is not so, industrialization is a rational consequence" [3, p. 165]. The implicit assumption in this argument is that industrialization will improve the balance of payments position either through import substitution or by expanding exports.[6] However, Myrdal suggests that, "Import substitution may ease the foreign exchange position in the long run, but in the short run it

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[5]This argument suffers from the same logical weakness as the structural transformation hypothesis. Success with this method in the Soviet Union does not mean repeating the same process elsewhere will produce similar results.

[6]Bhagwati uses the following example to illustrate the necessity of investing in heavy industry (such as steel plants). If a country wants to invest $250 million in plant and equipment (e.g. tractor and fertilizer plants) in a particular year, but only expects to earn $100 million in foreign exchange, the only possibility for carrying out the investment program is to produce the necessary plant and equipment [3, p. 166-168]. In this example, there is an implicit assumption that using the limited foreign exchange earnings to establish heavy industry will allow the investment program to be successfully executed.

usually aggravates it" [41, p. 1161]. This consequence arises because short-run imports of capital goods are usually required to establish import-substitution industries. The establishment of import substitution industries need not ease the balance of payments situation if raw materials must be imported to manufacture the import substitutes.

Industrialization also is cited as a means to raise the productivity of the labor force. Generally the product per worker in agriculture is below that of the economy as a whole in both developed and underdeveloped countries. The disparity in less-developed nations seems even greater.[7] Industrialization thus is suggested as a means to increase the portion of the labor force in the more productive, nonagricultural sectors. Additionally, an indirect influence may be realized and since, due to limited land area, agriculture is subject to diminishing returns. Transferring labor from agriculture reduces the labor/land ratio and should raise labor productivity. This possibility is limited when there is so much labor in the agriculture that its marginal physical productivity is zero. Labor then can be withdrawn without a concomitant reduction in agricultural production. The assumed pool of redundant labor in agriculture in the form of disguised unemployment led to great optimism for developmental possibilities during the 1950s.[8]

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[7] See, for example, the works by Bellerby [2] and Kuznets [29, pp. 415-417]. Kuznets makes the additional observation that the ratio of population to labor force in the agricultural sector is higher than for the nonagricultural sectors. Consequently, the disparity of product per capita between the sectors is even greater than the disparity of product per worker. Myrdal [41, p. 1157] points out that since the capital:labor ratio in manufacturing usually is higher than in traditional agriculture there is some question concerning the meaning of comparisons of product per worker between manufacturing and agriculture.

[8] The implications for the development of an economy with "surplus" labor: in the sense of zero marginal physical productivity of labor in the subsistence sectors was first discussed by Lewis [33]. There has been a great deal of controversy over the assumption of surplus labor. After surveying the relevant literature, Kao, Anschel, and Eicher conclude that, "To date, there is little reliable empirical evidence to support the existence of more than token -

Closely related to the productivity argument is the notion that industrialization will create new jobs and result in employment for unemployed members of the labor force. The provision of new jobs is deemed extremely important in less-developed nations where the population and labor force are expanding very rapidly. Widespread unemployment is considered to result from the failure of capital and complementary means of production to increase at the same rate as the labor supply.[9] The proposed solution is to increase the rate of capital accumulation. While employment creation is frequently used as an argument in favor of industrialization, the number of jobs created often is insufficient to absorb the natural increase in the labor force. Typically, industrial employment starts from a base which is very small relative to the total labor force.[10]

Another view holds industrialization to be crucial to development because it radiates stimuli throughout the economy. Establishment of an industry will generate a demand for inputs which are not produced domestically because of

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Footnote 8 continued from Page 6: five percent - disguised unemployment in under-developed countries as defined by a zero marginal product of labor and the condition of ceteris paribus" [26, p. 141].

[9]See, for example, Navarrete and Navarrete [42]. Under strictly neoclassical assumptions with flexible wage rates and prices, there is no reason for any labor to be unemployed even with a rapidly expanding labor force. For an excellent analysis of why unemployment may continue to persist in less-developed economies, see Eckaus [9].

[10]Myrdal cites several statements from the development plans of Burma, India, Pakistan, and Ceylon indicating the awareness of planning authorities in those countries where industrialization does not create very many new jobs. In addition to not creating many new positions, industrialization also tends to have "backwash" effects on existing industry, especially cottage industry. Myrdal concludes that, although the estimates made by the planners are crude, "...an important conclusion about the employment-creating potential of industrial expansion can be sustained by the statistical calculations of governments - namely, that industrial expansion, when beginning from a low base, cannot directly have more than a peripheral uplifting effect on (occupational) participation ratios during a very considerable early period" [41, p. 1199, 1172-1205].

insufficient demand. The additional demand resulting from the establishment of industry provides an incentive to establish an import substitution industry. This type of stimulus has become known as a backward linkage. In addition to backward linkages, forward linkages or stimuli may also be operative if industry provides products which require further processing.[11]

A second type of stimulus also has been cited as an argument in favor of industrialization: The increased incomes from new industries leads to increased demand for consumer goods. These, in turn, result in expanded markets and, hence, provide additional profitable investment opportunities. These considerations are used to argue that initiation of investment projects in a number of industries at the same time is desirable and even necessary to make investments in the individual industries more profitable. This thesis has become known as the balanced growth argument.[12]

Greater income from industrialization is proposed to have an additional positive feature. The volume of savings is expected to be larger with higher income levels. Hence, additional investments should become progressively easier if, as is often assumed, the saving rate rises with higher per capita incomes.[13]

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[11] An extensive discussion of the importance and nature of linkage can be found in Hirschman [18]. Regarding the industrialization issue, Hirschman concludes that agriculture in particular has very weak linkage effects and that "...the superiority of manufacturing in this respect is crushing. This may yet be the most important reason militating against any complete specialization of under-developed countries in primary production" [18, p. 110].

[12] Many versions of the balanced growth argument have been presented. The demand version was first discussed by Rosenstein-Rodan [50] and later popularized by Nurkse [45]. For a criticism of the balanced growth argument, see Hirschman [18, Ch. 3].

[13] The importance of this point has been emphasized by many writers. For example, Rostow [51, p. 281] regards raising the net saving rate in less-developed countries to over 10 percent of national income as a necessary (but not sufficient) condition for take-off into self-sustained growth. See also Lewis [33, p. 155].

Industrialization also is promoted for political reasons. Two reasons are frequently cited. First, in the interests of national security, a certain amount of self-sufficiency in manufactured and capital goods production may be desirable. Second, many newly independent countries have a strong desire to reverse colonial economic patterns based on export of primary products and import of consumer goods for local consumption.[14] Many countries place heavy emphasis on industrialization in their development plans to circumvent this pattern.[15]

It is sometimes argued that industrialization conditions cultural values in a manner that favors further development.[16] Industrialization supposedly modernizes the outlook of individuals and creates a more suitable environment for technological progress.

Thus, a milieu of economic, sociological, political, and historical factors may interact to make industrialization attractive as a policy. It does not, however, make industrialization imperative. There may well be certain underdeveloped countries that will find specialization in traditional and primary production to be profitable. Some of the reasons favoring agricultural development are reviewed in the following section.

## Agricultural Development

An obvious reason for emphasizing agricultural development in less-developed economies is its contribution to the growth of total and per capita

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[14] Myrdal [41, pp. 1151-1152] refers to this as the Communist doctrine of colonial exploitation.

[15] The failure of industry to develop under laissez-faire policies is one of the arguments advanced to justify development planning. See Meier [37, Ch. 8].

[16] An interesting attempt to empirically identify the relative importance of certain social and political elements on the potential for economic development has been made by Adelman and Morris [1].

product. In many less-developed economies, agriculture frequently contributes from 40 to 50 percent of the net output and employs over half the labor force.[17] If agricultural output does not increase, the rate of growth of national income will fall short of growth in nonagricultural income. With the advent of the green revolution in agriculture, the possibilities for tremendous increases in agricultural productivity and output has led to increased emphasis of agriculture as a source of growth.[18] Also, failure to increase productivity in agriculture will tend to skew the Lorenz curve even further, unless the creation of employment opportunities in nonagricultural pursuits permits sufficient migration of labor out of agriculture to offset these productivity increases.[19]

A second type of benefit cited for agricultural development is the various stimuli resulting from increased demand for manufactured goods. These increased demands from agriculture, providing an opportunity for other sectors to develop, have been designated as market contributions.[20] Market contributions are essentially of two types: The development of agriculture may

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[17]Kuznets presents data for 1958 indicating that for 12 countries with gross domestic product less than $200 per capita, 46 percent of the product originated from agriculture and related industries while employing 57.6 percent of the labor force [29, p. 402]. Myrdal presents similar data for various low income countries in Asia. For example, during the 1954-56 period, 57 percent of the income in Pakistan originated from agriculture, while employing 71 percent of the labor force. The analogous figures for South Vietnam indicate that 82 percent of the labor force was employed in the agricultural sector but that this sector only contributed 34 percent of the income [41, p. 494].

[18]Mellor [39] exhibits great enthusiasm over the developmental prospects afforded by the green revolution. A more balanced viewpoint is presented by Wharton [64].

[19]The disparity between agricultural and nonagricultural incomes is not limited to today's less-developed countries. This disparity persists in modern developed nations and has existed during the earlier phases of their development. See Bellerby [2].

[20]See, Kuznets [28, p. 63].

increase the demand for off-fram purchases such as fertilizers and insecticides. Increased demand for consumer goods by workers in the agricultural sector is expected to result from increased incomes.[21]

The process of economic development usually results in severe strains on the balance of payments. Primary exports are frequently the principal source of foreign exchange earnings in less-developed countries. In many cases, expansion of agricultural output can contribute significantly to easing of the balance of payments constraint through (a) expansion of exports if the country is in a food surplus situation or (b) through import subsitution if the country is in a food deficit situation.[22]

The development of an investable agricultural surplus also contributes to general economic development thrcugh the factors which may be provided to the nonagricultural sectors.[23] Two types of factors generally are considered: First, an agricultural surplus provides capital or, more correctly, funds for the purchase of material capital goods by the nonagricultural sectors. In a free-enterprise system, this capital can be transferred throug either taxation or in the form of private savings. Kuznets [28, p. 69]

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[21]The strength and importance of these stimuli to the industrial sectors will depend on, among other things, the size of the market created and the seriousness of the balance of payments situation. The establishment of one or more supply (or consumer goods) industries may also have second-round effects through various linkages stimulating the establishment of satellite industries.

[22]Industrialization in the absence of agricultural development will lead to increased strains on the balance of payments in the short run for at least two reasons. First, industrialization requires the import of vital capital goods, which must be financed through either capital inflows or exports. Second, as higher proportions of labor move to nonagricultural employment, increased food is required to feed the nonagricultural population and must be imported or deducted from the exportable surplus if the economy is a food exporter.

[23]Nicholls [43] discusses the concept of an agricultural surplus and its potential contributions to development.

suggests that the burden of taxation on the agricultural sector frequently exceeds the extent of the services provided to the agricultural sector by government spending. The residual benefits accrue to nonagricultural sectors either in the form of social overhead capital or a subsidy to a particular industry or industries.[24] Private savings may be used to finance the purchase of essential capital goods in nonagricultural sectors, either through lending or direct investment.[25]

The second type of factor provided to the industrial sector is labor. The release of labor from food production is possible only when a marketable surplus of food is being produced. The transfer of labor implicitly involves a transfer of capital in the form of human capital since the agricultural sector has financed the rearing and training to maturity of migrating laborers. In earlier discussions of development, the provision of labor for industrialization was considered to be one of the principal contributions of the agricultural sector in the earlier phases of development.[26]

The emphasis now seems to be shifting to providing employment for the

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[24]Mellor suggests that the central issue in agricultural developmental policy is "what level of taxes or other means of capital transfer can be placed on the agricultural sector and under what circumstances?" [40, p. 27]. Schultz thinks that Mellor goes too far in his taxation proposals [56].

[25]Owen [47] discusses another type of forced intersectoral transfer of agricultural surplus. This transfer arises from the asymmetric market structures existing in the farm sector (competitive) and the farm supply and processing sectors (monopolistic and monopsonistic). Owen argues that this market structure leads to an efficient means of intersectoral taxation since the farm supply and processing sectors manage to extract any profits arising from productivity increases in agriculture. These profits accrue to these farm supply and processing industries where they can be used for industrial capital accumulation. Owen also discusses the extraction of the agricultural surplus in the "Communist" model of development.

[26]See for example, Lewis [33] and Johnston and Mellor [22].

rapidly expanding labor force.[27]

Economic historians have compiled considerable evidence on the "necessity" for increases in agricultural productivity to sustain economic growth.[28] In this connection, Kuznets concludes that "...an agricultural revolution - a marked rise in productivity per worker in agriculture - is a precondition of the industrial revolution for any sizeable region in the world."[29] Based on a review of the historical development of a number of nations, Nicholls reached a very similar conclusion when he stated that "...until underdeveloped countries succeed in achieving and sustaining (either through domestic production or imports) a reliable food surplus, they have not fulfilled the fundamental precondition for economic development" [44, pp. 366-367]. Eicher and Witt go so far as to state that, "Economic historians generally concur that there are no cases of successful development of a major country in which a rise in agricultural productivity did not precede or accompany industrial development" [10, p. 8].

Based on the preceding summary, it is apparent that the issue of industrialization versus agricultural development has not been resolved. Agreement

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[27]Compare the change in emphasis between Johnston and Mellor [22] and Johnston and Cownie [21]. See also the recent articles by Todaro [61] which suggest that the current interest seems to be more concerned with providing employment rather than releasing additional labor from agriculture.

[28]In this connection, Gerschenkron [15a, p. 357] suggests, "There should be a fine on the use of words such as 'necessary' or 'necessity' in historical writings. As one takes a closer look at the concept of necessity as it is appended to prerequisites of industrial development, it becomes clear that, whenever the concept is not entirely destitute of meaning, it is likely to be purely definitional: industrialization is defined in terms of certain conditions, which, then...are metamorphosed into historical preconditions."

[29]Kuznets [30, pp. 59-60]. In another statement, he suggests that, "One may conclude that a substantial rise in productivity of resources in the domestic agriculture sector is a condition of the large increase in overall productivity in modern economic growth" [29, p. 120].

probably will never be unanimous regarding the "best" route to development. The general trend in the literature seems evolving toward the view that there are certain complementarities between agriculture and industry which should be exploited. Essentially, it is the purpose of this study to investigate the agriculture-industrialization issue. In the following section, several alternative methods of investigation are discussed.

## ALTERNATIVE METHODS OF INVESTIGATION

Three alternative approaches to the investigation of the industrialization-agricultural development issue are briefly discussed in this section. These are the interdisciplinary approach, the examination of economic history, and development theory.

### Interdisciplinary approach

It has been widely acknowledged by economists that cultural, social, psychological, and political factors are extremely crucial elements in the development process. Unfortunately, these factors are too frequently simply dismissed as necessary "preconditions" for economic development or given a very superficial treatment.[30] Whyte and Williams suggest that a major obstacle to conceptual integration of development research by economists and other social scientists is the difference in case size. "The economist generally focuses his analysis at the level of the nation, the economy as a whole, or some nationwide sector (the agricultural sector, for example). ....Sociologists, anthropologists, and psychologists occasionally give attention to the nation level, but their studies are more often concentrated on the behavior

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[30] See, for example, Tinbergen [60, pp. 3-4] and Rostow [51, p. 11]. Hoselitz [19, p. 53ff] suggests the preconditions that Western economists have in mind all too frequently are based on the type of socio-political organization that prevailed during the development of certain "Western success stories."

of particular individuals, groups, organizations, and communities."[31]

The issue of industrialization and agricultural development has been discussed almost exclusively at highly aggregate or national levels. Most noneconomic discussions have involved the socio-economic implications of urbanization and transformation concomitant with industrialization. Very few noneconomic discussions of the industrialization-agricultural development issue have considered micro aspects of the problem in any detail. Perhaps the most important contributions from an interdisciplinary approach to problems of development are to be made in the area of microdynamics. Several issues need further elaboration. [Brewster (5)] cites sociological and psychological factors as barriers to change. Lewis (33, p. 159) discusses the need for the emergence of a new class of people. These issues seem important to a full understanding of the process involved in transforming an underdeveloped economy.

Economic history and growth stage generalizations

Recent interest in the economic history of development has been aroused by Rostow's concept of stages of economic growth. Ruttan differentiates stage theories into three classes, which he terms industrial fundamentalism, structural transformation, and leading sectors.[32] He concludes that, "All three stage theories...treat the transition from an agricultural to the industrial society as a major problem of development policy. Rostow's system is, how-

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[31] Whyte and Williams [65]. This allegation regarding the case size for economists appears to overlook a number of microeconomic studies relating to peasant agriculture. See, for example, Sen [58] and Georgescu-Roegen [15]. It appears that the best prospects for theoretical integration are at the microeconomic level where the actions and attitudes of individuals can be studied. However, most of the studies relevant to the present investigation seem to be highly aggregated, nationwide studies.

[32] See Ruttan [53, 54].

ever, the only one which clearly specifies a role for the agricultural sector in the transition process" [53, p. 22].

In his evaluation of the contributions of the stage theories to development policy, Ruttan reaches several conclusions pertinent to the present study. These are:

> "Clearly Rostow's leading sector model and the agricultural development approaches have helped focus attention on the critical role of the agricultural sector in the development process. Although agriculture may not contribute as a leading sector, over long periods, the historical record is consistent with the proposition that failure to achieve a technically progressive agriculture can dampen the whole process of economic growth...
>
> "The leading sector concept does add a potentially useful tool to our analytical capacity...
>
> "The basic limitation of the growth stage approach when employed as a guide to development policy is that it substitutes a search for economic doctrine in the form of historical generalizations from a limited historical sample should...be based on observations drawn from the same 'population'...
>
> "...emphasis on the 'take-off' and the differentiation of 'stages' in both the general and agricultural stage approaches represents a 'blind alley'...
>
> "...a taxonomic scheme, utilizing growth stages as labels in its filing system, may represent a potential contribution to the analysis of economic development." [53, pp. 32-33]

In particular, the lack of analytical power precludes the "historical" approach in the present study.[33]

Dual-economy models

The third approach, the one adopted in this study, is through the use

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[33] For criticisms of Rostow's version of growth stages, see the papers by Kuznets, Gerschenkron, Solow and others in Rostow [52].

of specialized, general equilibrium models known as dual-economy models.[34] The term dual-economy arises from the act that economic activity in many less-developed nations can be divided into two distinct types of sectors. Various names have been given to these sectors, such as the capitalist and the subsistence sectors,[35] the advanced or modern sector and the backward or traditional sector,[36] and the industrial and agricultural sectors.[37]

The analysis of less-developed countries through the use of dual-economy models originates with the classic work of Lewis [33, 35] and has been extended by Jorgenson [23, 24, 25] and Fei and Ranis [12, 13, 14, 49].[38] The

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[34]Ruttan [54] differentiates dualism into two types: static and dynamic. Static dualism, which includes sociological dualism and enclave dualism, relates primarily to the cultural and technological characteristics prevailing in many less-developed countries. Ruttan suggests that these technological and cultural characteristics are the basis for many of the assumptions made in the dynamic dual-economy models. This section deals with the models Ruttan has classed as dynamic.

[35]Lewis [33, p. 146]. The capitalist sector is defined as "that part of the economy which uses reproducible capital and pays capitalists for the use thereof... The subsistence sector is by difference all that part of the economy which is not using reproducible capital" [33, p. 146-147]. By these definations, the subsistence sector would include the majority of services.

[36]Jorgenson [23, p. 311]. "The economic system may be divided into two sectors - the advanced or modern sector, which we will call, somewhat inaccurately, the manufacturing sector, and the backward or traditional sector, which may suggestively be denoted agriculture."

[37]Ranis and Fei use these terms as short-hand terminology for Lewis' capitalist and subsistence sectors but "...underscore the absence of any necessary one-to-one relationship between the subsistence sector and agriculture, or between the capitalist sector and industry..." [49, p. 534]. In their later work, they fail to mention this qualification [12, p. 4].

[38]Ruttan [54] considers the work by Lewis to be a bridge between static and dynamic dualism. The reason for this is unclear since Lewis' model is definitely dynamic, although not rigorously and explicitly specified as the models in the works of Jorgenson and Fei and Ranis. Also, there is some question about whether Fei and Ranis or Jorgenson contribute much besides rigor to the analysis of Lewis. With rigor, however, there are inevitably more stringent simplifying assumptions, some of which are rather difficult to accept. In the words of Lewis in commenting on the work of Fei and Ranis, "The mathematics seems impeccable; it is the assumptions that are odd... One must pay tribute to the geometrical ingenuity that makes it possible to bring

models developed by these researchers are not reviewed in any detail. The relationship between these models and the models developed in this study is indicated later.

Perhaps the most serious shortcoming of these models is the neglect of the intersectoral markets for factors. Only labor is considered in intersectoral factor trade. In the light of the recent green revolution in agriculture with its high response to agricultural inputs such as fertilizers and chemical pesticides, neglecting intersectoral factor trade seems unrealistic.[39]

A second shortcoming common to these studies is the asymmetric treatment of the investment problem. All studies arrive at the conclusion that an agricultural surplus is a necessary condition for sustained development,[40] and all emphasize the contribution made by this surplus to capital accumulation. Only Fei and Ranis, however, consider the desirability of investment in the agricultural sector. This consideration is not subjected to the same rigorous analysis as investment in the industrial sector.[41] Given the supposed

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Footnote 38 continued from Page 17: so many variables into a stagnant equilibrium. But of course, the value of a model is in direct proportion to its relationship to reality" [32, pp. 159-161].

[39]Kuznets [28] and others have indicated demand for manufactured inputs is one of agriculture's "contributions" to economic development.

[40]Jorgenson [23, p. 324] and Lewis [33, p. 173]. Fei and Ranis actually argue that "balanced" growth between agriculture and industry is desirable [14, p. 190]. Nicholls [43] also demonstrates the importance of an agricultural surplus. All these demonstrations depend crucially on the assumption of a closed economy. Only Lewis and Nicholls, however, seem to recognize the limitation of their conclusion.

[41]Their discussions of investment in agriculture take on the appearance of an afterthought. For example, in the formal model presented on pages 28 and 29 in [12] no allowance is made for investment in agriculture. Then they suggest that, "The mutually beneficial relationship between the industrial and agricultural sectors of the dualistic economy is due to the fact that, from the viewpoint of the agricultural sector 'access to the agricultural sector' stimulates agricultural productivity and from the viewpoint of the industrial sector, 'access to the agricultural sector' increases the savings fund"

importance of the development of the agricultural sector, questions to be asked are: Should there be a net inflow of savings into the agricultural sector in the earlier (or later) stages of development? Under what conditions does investment in agriculture tend to be desirable? None of the persons dealing with dual-economy models has analyzed these questions, or even posed them.[42]

The third common shortcoming of these dual-economy models is the neglect of the role of the government in the developmental process. It is now widely recognized that the government's role in less-developed countries is extremely important. Use of development planning to speed the process of development is a reflection of this importance.[43]

## THE MODELS: A HEURISTIC EXPOSITION

The models developed in this study are more elaborate than most models to analyze the development of dualistic economies. Three distinct but closely related models are discussed. For convenience, these models are referred to as the decentralized model, the centralized model, and the food aid model. In this section a heuristic description of the models is provided.

### The decentralized model

Intersectoral factor flows of labor, capital, and manufactured goods are examined in a five sector optimizing model involving three products, agricul-

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Footnote 41 continued from Page 18: [12, p. 34]. A logical question is to enquire how productivity is "stimulated" in the absence of any real resource demands.

[42] In a recent article, Dixit purports to demonstrate that, "Even a target of rapid industrial growth is shown to lead to balanced growth in the long run; and, if capital is very scarce at the beginning in agriculture, an initial phase of specialization of investment to agriculture is shown to be necessary [8a, p. 203].

[43] For a list of countries which have formulated national plans, see Waterston [63, Appendix III].

tural goods, manufactured goods, and capital goods. Agricultural goods, which are assumed to be produced in two sectors, a subsistence and a commercial sector, are used only for consumption purposes. The agricultural goods by these two sectors are perfect substitutes in consumption and consequently a common price prevails for the output from these two sectors.

Capital goods are produced in a third sector of the model. Capital goods are used only as factors of production and are assumed infinitely durable.[44] The fourth sector in the model produces the third product, manufactured goods, which may be used either for consumption or as nondurable factors of production.[45] Manufactured goods to be used either as factors of production or as consumer goods are assumed to be perfect substitutes in production. In other words, manufactured consumer goods and nondurable manufactured factors of production (manufactured inputs) are produced by the same firms using the "same" production processes. These firms are assumed to be indifferent between producing consumer goods or manufactured inputs, which leads to a common price for manufactured consumer goods and manufactured inputs.

The fifth sector included in the model is the government sector. The government has at its disposal the instruments of government expenditure. Taxes are collected on all income. This tax revenue is used to invest in social overhead capital for agriculture or in capital accumulation in the manufacturing or capital goods sectors. The government is assumed to invest in these alternatives in a manner that tends to maximize social welfare over a finite horizon, where welfare is assumed to be a function of consumption

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[44] That is, depreciation is not included in the model. This simplifying assumption is not necessary to the analysis. There is no reason to suspect that any of the conclusions of this study would be appreciably altered by relaxing this assumption.

[45] A nondurable factor of production is one completely used in production during the period of purchase.

only.

The two agricultural sectors are differentiated by both technical and institutional considerations. Production in the subsistence sector requires inputs of land, labor, and nondurable factors of production purchased from the manufacturing sector.[46] The commercial agricultural sector uses durable capital goods as a factor of production in addition to the factors used by the subsistence producers. These durable capital goods are purchased from the capital goods sector.[47]

At the institutional level, labor employed in the commercial agricultural sector receives a fixed wage rate. Employment is restricted so that the marginal value productivity of labor equals the wage rate. Labor employed in the subsistence sector, on the other hand, receives a residual income equal to the total value of subsistence production less the cost of the purchased manufactured inputs. Thus, labor in the subsistence sector receives a portion of the income actually earned by the land.[48] It is assumed that all income received by labor is consumed (including land rent in the subsistence sector), and all income earned on the capital stock is saved. The savings are used to purchase capital goods from the capital goods sector. The rent on land in the commercial agricultural sector also is saved.

For simplicity, the supply of labor is assumed to be perfectly inelastic

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[46]For example, agricultural chemicals such as fertilizers and pesticides.

[47]This does not include the substantial amounts of capital produced within the agricultural sectors, such as draft animals and livestock. These forms of capital are considered to be part of the "land" input. This assumption is valid only if these forms of capital are not increased during the period under consideration. These forms of capital may also be considered to be part of the land input in the subsistence sector.

[48]Equivalent to assuming the subsistence producers are owner-operators

throughout the period.[49] Labor employed by the government in the commercial agricultural sector, manufacturing sector, or the capital goods sector receives an exogenously fixed wage rate.[50] This wage rate is assumed to be too high to allow all labor to be employed since (a) the three advanced sectors are assumed to behave competitively and (b) all factors must earn their marginal value productivity. Any labor which is not employed in the advanced sectors finds employment in the subsistence sector where an average productivity (of the sector) is earned. The subsistence wage rate is assumed to be lower than the wage rate in the advanced sectors, which, in effect, makes the supply of labor to the advanced sectors perfectly elastic in the initial phases of development (even though the entire labor supply is assumed perfectly inelastic).[51]

The amount of land is fixed in total supply and it cannot be transferred from one sector to the other. (These two assumptions are necessary for technical reasons which are discussed later.) The former assumption may not be unrealistic. However, the latter assumption is very restrictive in the

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[49] The implications of relaxing this assumption are investigated in a later section.

[50] Various reasons for a rigid wage rate can be given. Perhaps the least objectionable and most plausible reason is that the laborers are organized in a union and restrict membership to maintain this wage rate. Other possible explanations include social legislation and unwillingness to work in other traditional employment at a lower wage rate.

[51] As explained in the following sections, the marginal physical productivity of labor in the subsistence sector is never assumed to be zero. This seems to coincide with the evidence cited by Kao, Anschel and Eicher [26]. Thus, withdrawing labor from the subsistence sector tends to reduce production in this sector, and we are following Jorgenson [23] in this respect. However, a perfectly elastic labor supply curve to the advanced sectors coincides with the assumptions of Lewis [33] and Fei and Ranis [14]. Jorgenson [24, 25] made an interesting attempt to test the appropriateness of the assumptions of zero versus positive marginal physical productivity for labor. As Marglin [36] demonstrates, however, Jorgenson's test depends crucially on the assumption of unitary elasticity of substitution between labor and capital in the industrial sector.

context of the present model and effectively precludes the possibility of transferring land between the two sectors.[52]

Production in the manufacturing and capital goods sectors requires inputs of capital, labor, and manufactured factors of production. These sectors are assumed to be organized rationally, and all variable factors are employed to the point where their marginal value productivity equals their cost.[53] The income received by labor is consumed, and all rent on capital is saved.

Time is considered in a discrete manner. The government collects taxes on all factor income. This tax revenue is used to accumulate labor intensive social overhead capital (SOC) in either of the two agricultural sectors. Alternatively, this revenue can be used to supplement the budgets of private savers who use the funds to purchase capital goods from the capital goods sector.[54] The government funds are allocated in a manner that maximizes the welfare of the country over a finite horizon.[55] This welfare is described by a quadratic function of consumption of agricultural goods (food) and manufactured goods (nonfood). This quadratic function approximates Engel's law in the sense that, as per capita consumption increases, the relative proportion of consumer income spent on food declines.

Investment expenditures on SOC involves the hiring of labor from the

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[52]The opposite possibility of "decommercializing" the commercial sector is also precluded. This, however, is of much lesser interest.

[53]Within every period, the capital stock within each of these sectors is considered a datum determined from the capital stock and investment in the preceding period.

[54]Investment in either SOC or private capital does not have any pay-off until the subsequent period.

[55]In other words, the government draws up a development plan for the next (say) 15 years.

subsistence sector at the same wage rate earned in the advanced sectors. This labor is assumed to engage in extension or similar activities that increase the productivity of the specific agricultural sector to which it is directed.[56] In other words, technical change in these two sectors is assumed to be a function of investment in SOC.[57]

Two other alternatives for government expenditures are considered in the decentralized model. These are investment in private capital in either the capital-goods-sector or the manufacturing-goods-sector. Thus, in essence, the government has a choice of investing in any one of the four sectors.

Private savings are assumed to be freely transferable among the three sectors. In other words, savings from the commercial agricultural sector can be used to accumulate capital in either the manufacturing or capital goods industries and vice versa. This is equivalent to assuming that there is only one savings fund. These savings are allocated among the three sectors in a manner that will equalize the expected marginal return in the subsequent period of the last unit spent. This allocation is made under the naive assumption that all prices and factor allocations in the subsequent period will remain unchanged. In making their investment decisions, private investors take into consideration the government investment in private capital in the manufacturing or capital-goods sectors. (This condition is equivalent to the assumption that the government announces its investment plans before private investors make their decisions.)

Relative prices are endogenously determined in this model. It is assumed that the welfare function reflects consumers' preferences with respect to the

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[56] An alternative interpretation would be to assume the labor was engaging in labor intensive capital accumulation.

[57] Technical change in the capital goods and manufacturing goods sector is assumed exogenous and productivity increases a constant percentage every year.

consumption of agricultural and manufactured commodities. With the welfare function viewed as an aggregate utility function, combining the utility function with the aggregate consumers' budget retraint (labor income) implies a pair of aggregate final demand equations for agricultural goods and manufactured goods. These aggregate, final demand equations, combined with the derived demands for capital goods (for investment) and manufactured goods (as factors of production), interact with the aggregate supply equations for each of these goods to determine the relative prices of the goods. (The price of manufactured goods is chosen as numeraire.) The aggregate supply equations are derived from the assumed aggregate production functions.

Given the assumptions of a fixed supply of labor and the fixed wage rate in all sectors except the subsistence sector, employment in the subsistence sector is determined as a residual. The total labor supply is assumed to be large enough relative to the level of the fixed wage rate and other resources in the advanced sectors so that the resulting wage rate in the subsistence sector is below the wage rate in the advanced sectors. In other words, the labor supply is large enough so that, with the fixed wage rate in the advanced sectors, a major proportion of the labor is employed in the subsistence sector. Also, the ratio of labor to other resources in the subsistence sector is such that the marginal value productivity of labor in this sector is lower than in the other sectors.

A diagrammatic representation of the expenditure and income flows in the decentralized model is presented in Figure 2 (p. 26). The five sectors are represented as rectangles. The ovals represent the two groups of income recipients, the capital owners and the laborers. Landowners are not included as a separate class of income recipients. The rent earned on land is simply attributed to the laborers in the subsistence sector and to the capitalists

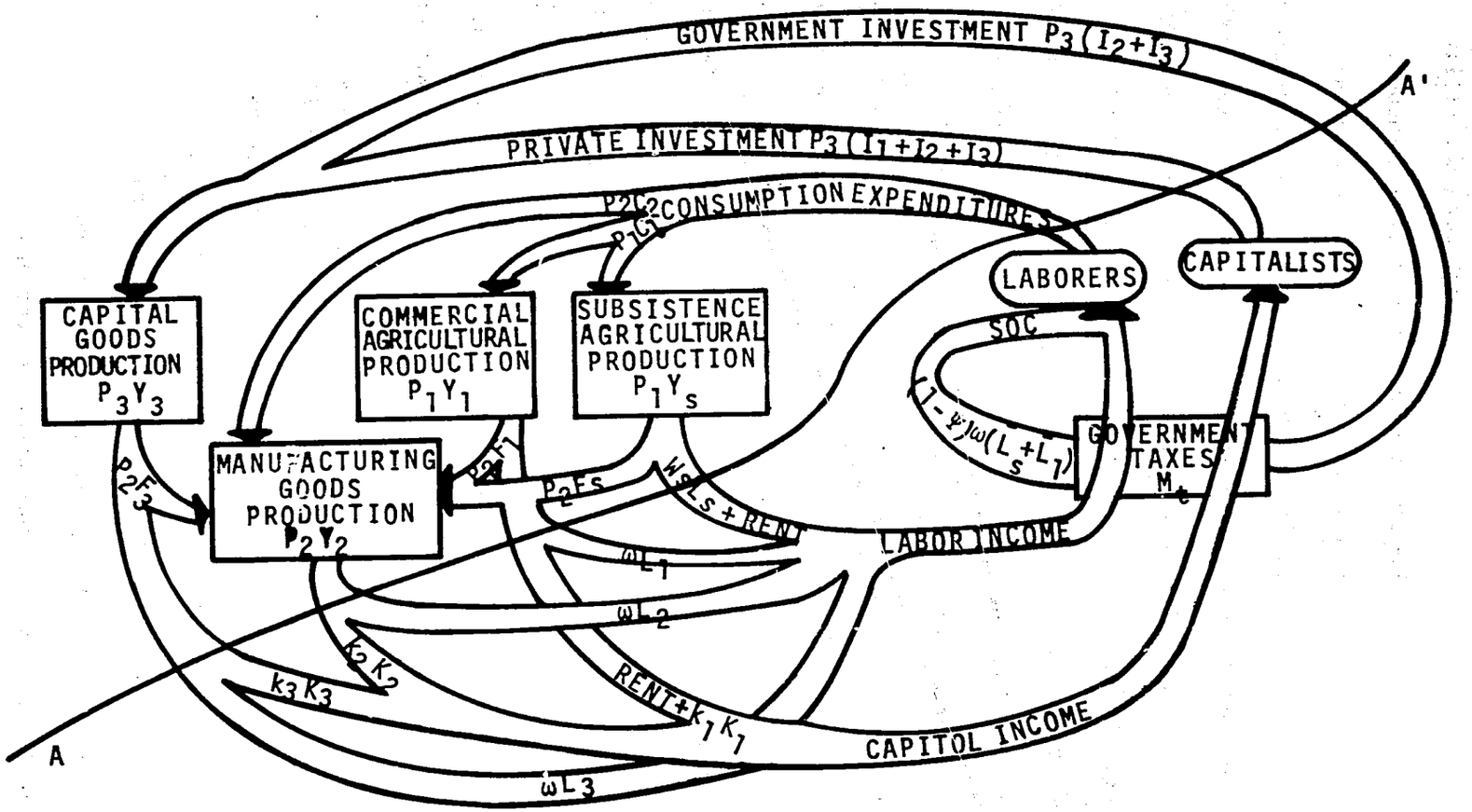


Figure 2. Income and expenditure flows

in the commercial agricutural sector. The flows above the diagonal line AA' represent expenditures and those below the line represent income receipts. Expenditure flows are discussed first.

The laborers spend all of their income on consumption goods. This consumption expenditure is divided between agricultural goods ($P_1C_1$) and manufactured goods ($P_2C_2$). The expenditures on agricultural goods are divided between the commercial and the subsistence agricultural sectors. Consumption expenditures by labor are the only source of revenue for the agricultural sectors. The manufacturing goods sector, on the other hand, sells its products to the two agricultural sectors ($P_2F_1 + P_2F_s$) and the capital goods sector ($P_2F_3$) as well as to consumers. Hence, the manufacturing goods sector receives revenue from all four other sources.

The capital goods sector sells its output ($Y_3$) to either the capitalists or to the government. The capitalists spend all their income on private investment goods $[P_3(I_1+I_2+I_3)]$. The government has two classes of expenditure alternatives. The tax revenue that the government collects may be spent on either SOC for the agricultural sectors in the form of wages net of taxes $[\omega(1-\bar{Y})\ (\bar{L}_s+\bar{L}_1)]$ or on investment goods for the capital and manufacturing goods sectors $[P_3(\bar{I}_2+\bar{I}_3)]$.[58]

Turning now to the income flows, labor receives income from all five sectors. Employment in the commercial agricultural sector ($L_1$), the manufacturing sector ($L_2$) and the capital goods sector ($L_3$) receives a fixed wage rate ($\omega$). Similarly, labor employed by the government for subsistence sector SOC ($\bar{L}_s$) and commercial agricultural sector SOC ($\bar{L}_1$) receives the same wage rate. Labor employed in the subsistence ($L_s$) sector receives a lower wage

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[58] Actually the government expenditure on SOC is both an expenditure and an income receipt since the entire expenditure net of taxes accrues directly to labor.

rate ($W_s$). Capital owners, on the other hand, do not receive any payments from the government or subsistence agricultural sectors since capital is not used in those two sectors.

Net revenue[59] in the subsistence agricultural sector accrues to labor. Part of this net revenue is rent on the land, which the laborers are presumed to own. The net revenue in the commercial agricultural sector is divided between the capitalists (who own the land in this sector) and the laborers. Since no primary factors are employed in the manufacturing and capital goods sectors, the net revenue in these sectors is divided between the laborers and capitalists as wages and rent on capital stocks.

The centralized model

The centralized model differs from the decentralized model with respect to the role of the government and in the allocation of investment funds. The essential difference is that the government exercises complete control over the allocation of both the private savings budget and the tax revenue in the centralized model. Any rent accruing to capital is invested in expansion of the capital stock in the commercial agricultural sector, capital goods sector, and manufacturing goods sector. Tax revenue can be used either to expand SOC in the agricultural sectors or to augment the private savings budget. That is, taxes can either be used to hire labor for SOC projects, or the tax revenue can be used to purchase capital goods from the capital goods sectors. The same criterion is used in the allocation of both private savings and tax revenue. Specifically, this criterion is the maximization of welfare over the

[59] Net revenue in this section is defined as total revenue less the cost of purchased manufactured inputs and taxes.

finite horizon being considered.[60]

This brief introduction to the decentralized and centralized models has been provided so that the reader has access to the principal aspects of the study without reading the more technical sections that follow.[61] The major conclusions are summarized in the following section which is followed by a separate analysis of food aid.

## THE DECENTRALIZED MODEL

We now turn to a more technical analysis of agricultural development in relation to over-all economic development. Although the decentralized model is discussed first, the notation used also applies to the analysis in sections which follow immediately. The following notation is used: Variables are denoted by upper case Latin letters. Parameters are denoted by Greek letters. Lower case Latin letters and Arabic numerals are subscripts either on variables or parameters. All parameters, indexes, and variables are nonnegative unless otherwise indicated. Subscripts on variables include s = subsistence agricultural sector, 1 = commercial agricultural sector, 2 = manufacturing sector, 3 = capital goods sector, and t = time period (discrete). The variables are as follows:

$Y_{it}$ = production of good i, (i = s, 1, 2, 3).

$F_{it}$ = use of manufactured goods (originating from sector 2) as a factor of production in sector 1, (1 = s, 1, 2, 3).

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[60] This reformulation of the model has the virtue of simplifying several very difficult technical aspects of the model, as well as relaxing one very restrictive assumption regarding investment. Specifically, the equations relating to investment in the decentralized model are so complicated that they are unmanageable unless investment is assumed to take place in every sector in every time period. It is this assumption that is relaxed in the centralized model.

[61] Some readers will prefer the more rigorous presentation in following sections.

$C_{it}$ = consumption of good i, where i = 1 denotes agricultural goods and i = 2 denotes manufactured goods.

$K_{it}$ = capital stock in sector i available for production during period t, (i = 1, 2, 3).

$L_{it}$ = labor employed in sector i, (i = s, 1, 2, 3).

$\bar{L}_{it}$ = labor employed by the government in the accumulation of social overhead capital (SOC) in sector i, (i = s, 1).

$P_{it}$ = price of good i, (i = 1, 2, 3) and $P_s = P_1$.

$I_{it}$ = private capital accumulation in sector i, (i = 1, 2, 3).

$\bar{I}_{it}$ = public or government capital accumulation in sector i, (i = 2, 3).

$G_{it}$ = level of SOC in sector i, (i = s, 1).

$E_{it}$ = government expenditure in sector i, (i = s, 1, 2, 3).

$B_i$ = amount of land in sector i, (i = s, 1).

$M_t$ = tax receipts in period t.

$Z_{it}$ = Lagrangean multiplier corresponding to the i-th constraint in period t.

The parameters are:

$\mu_1$, $\mu_2$, $\mu_{11}$, $\mu_{12}$, $\mu_{21}$, and $\mu_{22}$ are parameters of the quadratic welfare function and will be discussed in detail below.

$\sigma_i$ = "intercepts" of the Cobb-Douglas form of production function sector i, (i = s, 1, 2, 3).

$\lambda$ = "elasticity of production" of SOC in the agricultural sectors.

$\omega$ = institutionally fixed wage rate in terms of manufactured goods.

$\alpha_j$ = elasticity of production of factor j, sector s, (j = 1, 2, 4).

$\beta_j$ = elasticity of production of factor j, sector 1, (j = 1, 2, 3, 4).

$\gamma_j$ = elasticity of production of factor j, sector 2, (j = 1, 2, 3).

$\delta_j$ = elasticity of production of factor j, sector 3, (j = 1, 2, 3), where

j = 1 refers to manufactured inputs, j = 2 refers to labor inputs,

j = 3 refers to capital inputs, and j = 4 refers to land inputs.

$\tau$ = terminal period of the plan (i.e., t = 0, 1,..., $\tau$).

$\epsilon$ = exogenous rate of technological change in the manufacturing and capital sectors

$\psi$ = marginal (= average) tax rate)

$\rho$ = social discount rate on welfare.

Some modifications and additional variables are introduced for the centralized model discussed later.

## The Welfare Function

Welfare in any one period is considered a quadratic function of aggregate consumption of manufactured and agricultural goods.[62] The objective of the government is to maximize the welfare function over a finite horizon of $\tau$ periods, with welfare in future periods discounted to the present at the constant rate, or maximization of

$$V = \sum_{t=1}^{\tau} (\mu_1 C_{1t} + \mu_2 C_{2t} - \mu_{11} C_{1t}^2 + \mu_{12} C_{1t} C_{2t} - \mu_{22} C_{2t}^2)(1 + \rho)^{-t} \quad (1)$$

The welfare function is assumed to have the following characteristics. In any period t, the marginal welfare of increased consumption is positive;

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[62] Since the labor force (and population) is assumed to be constant by nature of the product and income distribution assumptions, this is equivalent to maximizing a weighted average per capita consumption, where all subsistence employees consume at one rate and all advanced sector employees consume at another (higher) rate. The weights in the average are the proportions of the labor force employed in the subsistence and advanced sectors.

$$\frac{\partial V}{\partial C_{1t}} = (\mu_1 - 2\mu_{11}C_{1t} + \mu_{12}C_{2t})(1 + \rho)^{-t} > 0, \tag{2}$$

and

$$\frac{\partial V}{\partial C_{2t}} = (\mu_2 + \mu_{12}C_{1t} - 2\mu_{22}C_{2t})(1 + \rho)^{-t} > 0. \tag{3}$$

Without loss of generality, consumption units can be chosen so that $C_{10} = C_{20} = 1$. The relative magnitudes of the various parameters of V are assumed such that $\mu_1 - 2\mu_{11} + \mu_{12} > \mu_2 + \mu_{12} - 2\mu_{22}$. That is, in the initial period, a marginal increment in food consumption will contribute more to welfare than a similar increment in nonfood consumption. It is further assumed that $\mu_1 > \mu_2$ and $2\mu_{11} > 2\mu_{22} > \mu_{12} > 0$. This implies that $\partial^2 V/\partial C_{it}^2 = -2\mu_{11} < \partial^2 V/\partial C_{2t}^2 = -2\mu_{22} < 0$. That is, the marginal welfare obtained from additional increments of food decreases at a more rapid rate than marginal welfare from additional units of nonfood consumption. The foregoing assumptions also imply that agricultural and manufactured goods are complementary in consumption and that the welfare function is negative definite.

Every negative definite quadratic form has an unconstrained maximum, which is defined by the first-order conditions. In the case of (1), the values of the variables $C_1$ and $C_2$ at the optimum are given by setting (2) and (3) equal to zero and solving. The unconstrained maximum is given by the

system

$$\begin{bmatrix} C_1 \\ C_2 \end{bmatrix} = \frac{1}{D}\begin{bmatrix} -2\mu_{22} & -\mu_{12} \\ -\mu_{12} & -2\mu_{11} \end{bmatrix}\begin{bmatrix} -\mu_1 \\ -\mu_2 \end{bmatrix} \tag{4}$$

where $D = 4\mu_{11}\mu_{22} - \mu_{12}^2 > 0$. It can readily be shown that $C_2 > C_1$, given the assumption that $\mu_1/\mu_2 < (2\mu_{11} - \mu_{12})/(2\mu_{22} - \mu_{12})$ in addition to the assumptions listed above.[63] This implies that at the "saturation point" consumers prefer relatively more manufactured goods than at the initial income levels.

Isowelfare lines corresponding to a quadratic form in which the parameters satisfy the foregoing assumptions would exhibit the general shape represented in Figure 3 (p. 34). The maximum occurs at the point denoted A. In the initial period, consumers would be consuming one unit of each good and the terms of trade (TT) implied by the isowelfare curve at that point would be

$$\frac{dC_1}{dC_2} = \frac{\mu_2 - 2\mu_{22} + \mu_{12}}{\mu_1 - 2\mu_{11} + \mu_{12}} < 1. \tag{5}$$

Moving along the ray OR tends to move the TT against the agricultural sector since $0 < \partial^2 V/\partial C_{1t}^2 < \partial^2 V/\partial C_{2t}^2$. Hence, consumers with preferences represented by this welfare function are offered an equal proportionate increment of each good, and they will (in keeping with Engel's law) bid the price of agricultural

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[63] From (4), we have $DC_1 = 2\mu_{22}\mu_1 + \mu_{12}\mu_2$ and $DC_2 = \mu_{12}\mu_1 + 2\mu_{11}\mu_2$. Differencing and collecting terms we get $(DC_1 - DC_2) = \mu_1(2\mu_{22} - \mu_{12}) - \mu_2(2\mu_{11} - \mu_{12})$ Dividing by the positive quantity $\mu_2(2\mu_{22} - \mu_{12})$ we see that $(DC_1 - DC_2)/\mu_2(2\mu_{22} - \mu_{12}) = \mu_1/\mu_2 - (2\mu_{11} - \mu_{12})/(2\mu_{22} - \mu_{12}) < 0$.

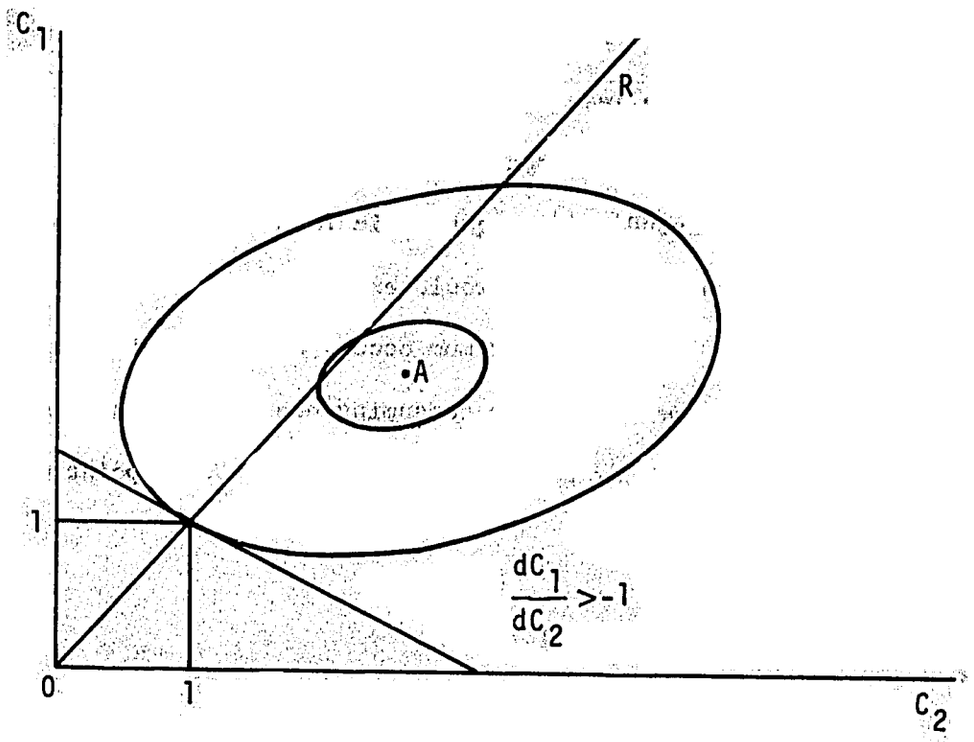


Figure 3. Iso-welfare curves and implied terms of trade

goods down relative to manufactured goods.

The maximum point, A, or the quantities of $C_1$ and $C_2$ indicated by (4), is assumed unattainable within the finite horizon. In other words, it is assumed that the economy is at such a low level of productive capacity in the initial period that, within the $\tau$ planning periods there will not be sufficient expansion in capacity.

We now turn to the constraints on the system beginning with the sectoral production functions.

## The Production Functions

The production process for each sector is a Cobb-Douglas form of production function. Output from the subsistence sector in period t is

$$Y_{st} = \bar{\sigma}_s G_{st}^{\alpha 1} F_{st}^{\alpha 2} L_{st}^{\alpha 3} B_s^{\alpha 4}, \tag{6}$$

Land input, $B_s$, is fixed throughout the period.[64] Labor $L_s$, purchased inputs, $F_s$, and social overhead capital (SOC), $G_s$, are all variable. Purchased inputs include items such as fertilizers, insecticides, and similar materials from the industrial sector. Labor, measured in man-years, is "productively" employed in the sense that withdrawing labor, other inputs remaining constant, would reduce output. The SOC variable is explained in detail below.

Production in the commercial agriculture differs from subsistence agriculture since capital is used as a factor of production, or

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[64] Since land is fixed throughout the period, notation may be simplified by defining a new intercept $\sigma_s = \bar{\sigma}_s B_s^{\alpha 4}$

$$Y_{1t} = \bar{\sigma}_1 G_{1t}^{\lambda} F_{1t}^{\beta_1} T_{1t}^{\beta_2} K_{1t}^{\beta_3} B_1^{\beta_4}. \quad (7)$$

As in subsistence, land is fixed[65] while other factors are variable.

The following specific assumptions are used for production functions: (A) $\Sigma\alpha_i = 1$; (B) $\Sigma\beta_i = 1$; (C) $\alpha_1 = \beta_1$; (D) $\alpha_2 < \beta_2$; (E) $\lambda < \beta_4$. In addition to constant scale returns under (A) and (B), assumption (C) indicates equal elasticities of production for manufactured inputs in the two sectors, and (D) indicates a lower production elasticity for labor in the subsistence sector,[66] together, the assumptions have $\alpha_4 > \beta_3 + \beta_4$, so that the production elasticity of land in the subsistence sector is greater than the combined elasticity of capital and land in the commercial sector.[67] Since land is not variable, diminishing marginal productivity of nonland resources, assumption (E) prevails as even investment is made in SOC.[68]

Production processes, in manufacturing and capital goods sectors differ from production in agricultural sectors since no primary or fixed factors are involved and technology improves at a constant exogenous rate of 100ε percent per year. The production function for manufacturing goods is

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[65] A new intercept is defined as $\sigma_1 = \bar{\sigma}_1 B_1^{\beta 4}$.

[66] Since labor is combined with capital in the commercial sector, a small change in labor input has a larger output response in sector 1 than a small change in labor input in sector s.

[67] Land is more intensively cultivated in the subsistence sector.

[68] Since $\alpha_4 > \beta_4$, this applies to sector s as well as sector 1. If $\lambda > \beta_4$ or if $\lambda > \alpha_4$, increasing returns would be permitted and lead to problems of nonconvexity. For this reason, land resources are kept fixed.

$$Y_{2t} = (1 + \epsilon)^{t} \sigma_2 F_{2t}^{\gamma_1} L_{2t}^{\gamma_2} K_{2t}^{\gamma_3} , \quad (8)$$

and for capital goods is

$$Y_{3t} = (1 + \epsilon)^{t} \sigma_3 F_{3t}^{\delta_1} L_{3t}^{\delta_2} K_{3t}^{\delta_3} . \quad (9)$$

Production in the manufacturing and capital goods sectors thus is assumed to be a function of manufactured inputs, labor, and capital inputs. Both sectors use their own output in production

The next set of constraints discussed are those of factor availabilities. Before explaining these, we discuss the role of the government sector in the decentralized model. In the section below, the various types of government expenditure are explained. A continued discussion of the constraints follows on the next section.

## Government Expenditure and SOC

In every period, the government collects taxes on all income at a constant average and marginal rate, $\psi$. Tax receipts in every period, $M_t$, are proportional to income.[69] Initially, government expenditures are assumed to equal tax receipts in each period, and no provision is made for foreign aid, deficit financing, or surplus budgets. The effect of foreign aid is analyzed with the centralized model in a later section. The government has four expenditure alternatives (denoted $E_{it}$), one relating to each sector. Thus

[69] The assumption of a constant marginal and average tax rate is not a necessary assumption. The tax rate could actually be considered as an instrumental variable.

$\sum_i E_{it} = M_t$.

Expenditure in the agricultural sectors is used to accumulate SOC, which is accomplished by hiring labor at a fixed wage rate, $\omega$. Thus, $E_{it} = \omega \bar{L}_{it}$, (i = s, l). This labor engages in various extension, general educational, and other activities that increase productivity in the agricultural sectors.[70]

Since labor employed in these activities is specific to either the commercial or the subsistence agricultural sector, the government is confronted with a choice of investing in none, one, or both sectors. SOC in these sectors is defined in terms of "accumulated manhours." That is

$$G_{st} = \bar{G}_{s1} + \sum_{i=1}^{t-1} \bar{L}_{si}, \tag{10}$$

and

$$G_{lt} = \bar{G}_{l1} + \sum_{i=1}^{t-1} \bar{L}_{li}, \tag{11}$$

where $\bar{G}_{i1}$ (i = s, l) is an index of the level of SOC available to these sectors in the initial period. Equations (10) and (11) suggest that the level of SOC is cumulative. If investment in extension activities is made in period t, the payoff is not realized initially until t + 1, but is forthcoming in all subsequent periods.

Two alternatives of a different nature are available. The government can invest in capital accumulation in either the manufacturing or the capital

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[70] An alternative interpretation is for this labor to engage in labor-intensive capital accumulation such as a road or dam. Labor-intensive capital accumulation also is assumed by Lewis [33, p. 161] in his discussion of capital accumulation by means of monetary expansion.

goods sector. In the manufacturing goods sector, the government must purchase investment goods at the market price, $P_{3t}$, and the amount spent on government investment in sector 2 is $E_{2t} = P_{3t}\bar{I}_{2t}$. These investment goods are combined with the capital stock available during period t in sector 2 and used in production in period t + 1. Government expenditure on capital accumulation in the capital goods sector is similar with $E_{3t} = P_{3t}\bar{I}_{3t}$.

These four alternatives provide the government an investment choice. In the two agricultural sectors, technological change is a function of government investment in SOC. This investment tends to offset diminishing marginal productivity from a fixed land input acting as an "additional factor." If agricultural output is expanded through public investment, the government must decide whether to invest in the commercial sector, the subsistence sector, or both. If the government is to have a legitimate choice, there must be alternative uses for funds that contibute to welfare. Government investment in manufacturing goods will have both direct and indirect effects on welfare: Output will be available for both consumption (direct effect) and for use as a factor of production in all sectors (indirect effect). Investment in the capital goods sector has its pay-off only in increased productive capacity of this section in the subsequent period. Since capital goods are not consumed, this increased capacity must be transferred to either the commercial agricultural or the manufacturing sector before any pay-off in welfare is realized. Thus, if the government invests in capacity expansion in capital goods, pay-off lags two periods. But, in all other sectors the lag is a single period. If the government chooses to invest in SOC, there is the added pay-off of job creation during the current period.

## FACTOR AVAILABILITIES

### Land

Land is assumed fixed for both agricultural sectors and there is no provision for its transfer between the subsistence and commercial sectors. The no-transfer provision effectively excludes the "commercializing" of the subsistence sector.[71]

### Labor and wage rates

Labor is mobile among the sectors and total labor, $L_o$, is employed. Thus,

$$L_o = L_{st} + L_{1t} + L_{st} + L_{1t} + L_{2t} + L_{3t}. \tag{12}$$

Wage rates, measured in terms of manufactured consumer goods, indicated by $\omega$, are assumed to be sticky in a downward direction in all sectors except subsistence agriculture. In other words, labor receives a fixed wage, $\omega$, except in subsistence agriculture. Labor in the advanced sectors is paid its marginal value productivity. Labor unable to find a job in advanced sectors at this rate is employed in the subsistence sector. It is assumed that there are not enough jobs in the advanced sector to permit all labor to earn the wage rate $\omega$. Consequently there is "surplus labor" in the economy, and the marginal value productivity of labor in the subsistence sector is less than $\omega$. (The supply of labor to the advanced sector thus is perfectly at a fixed wage rate.) This situation prevails until so much labor is withdrawn from the subsistence sector that the marginal productivity of labor in the subsistence

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[71] This very restrictive assumption precludes certain developmental possibilities and is used to present problems of nonconvexity.

sector increases sufficiently to force up the real wage rate in the advanced sectors.[72]

Manufactured Inputs

The output of the manufacturing sector may be used either for consumption or as a factor of production in other sectors:

$$Y_{2t} = F_{st} + F_{1t} + F_{2t} + F_{3t} + C_{2t}. \tag{13}$$

Capital Stocks

A given stock of capital initially is available in all three advanced sectors. This initial capital stock (denoted $K_{11}$, $\bar{K}_{21}$, and $\bar{K}_{31}$) may be augmented in subsequent periods through investment, which involves the purchase of goods from the capital goods sector. Once capital is placed in a specific sector it is not transferrable to other sectors. Capital goods placed in the manufacturing goods sector is equally productive in all lines of production.

Since depreciation is ignored, capital in period t is the sum of the initial capital stock and investments of all previous periods. Since the only source of investment funds in the commercial agricultural sector is from private savings, the capital stock in period t is

$$K_{1t} = K_{11} + \sum_{i=1}^{t-1} I_{1i}. \tag{14}$$

Two sources of investment funds, public and private savings are available for

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[72] Subsistence labor income is discussed in detail in a later section. Todaro [61] suggests that, in many less-developed countries, labor tends to migrate to urban centers even though jobs are not available.

capital accumulation in the manufacturing and, capital goods sectors. For the manufacturing sector

$$K_{2t} = \bar{K}_{21} + \sum_{i=1}^{t-1} (I_{2i} + \bar{I}_{2i}), \tag{15}$$

and for the capital goods sector,

$$K_{3t} = \bar{K}_{31} + \sum_{i=1}^{t-1} (I_{3i} + \bar{I}_{3i}). \tag{16}$$

In a closed economy, investment goods must be purchased from the capital-goods sector, which has limited capacity. The capacity constraint is

$$Y_{3t} = I_{1t} + I_{2t} + I_{3t} + \bar{I}_{2t} + \bar{I}_{3t}. \tag{17}$$

In addition, a limited supply of savings can be utilized to purchase these capital goods.

## INCOME DISTRIBUTION AND FLOWS

In this section, prices and outputs are assumed to be fixed.

Since the government collects taxes at a constant rate, $\psi$, this is equivalent to taxing government employees and all output net of payments for manufactured inputs. Thus, tax revenue is

$$M_t = \psi \{P_{1t} Y_{st} (1 - \theta_1) + P_{1t} Y_{1t} (1 - \theta_1) + P_{2t} Y_{2t} (1 - \gamma_1)$$
$$P_{3t} Y_{3t} (1 - \delta_1) + \omega (\bar{L}_{st} + \bar{L}_{1t})\} \tag{18}$$

In each of the private sectors, net income after taxes is completely distributed among the factors of production. Labor is assumed to consume all of its income after taxes, but income earned on capital is saved.[73]

Subsistence sector

The subsistence sector, like all the other private sectors, purchases manufactured inputs at the market price. These factors are employed at a level such that MVP equals cost, or

$$\alpha_1 P_{1t} Y_{st} = P_{2t} F_{st}, \tag{19}$$

The remaining income in this sector is attributed to labor, which consumes all its income after paying taxes. Thus, net labor income in the subsistence sector is denoted as

$$(1 - v)(1 - \alpha_1) P_{1t} Y_{st} = (1 - v)(\alpha_2 + \alpha_4) P_{1t} Y_{st}, \tag{20}$$

where $\alpha_2$ and $\alpha_4$ indicate the constant shares of output earned by labor and land, respectively. Assuming that the income earned by the land is consumed by the peasant operators is equivalent to assuming the peasants own the land they are farming and that these subsistence operators do not save. An alternative interpretation is that the landlord fails to collect any rent.

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[73] This is a stronger assumption than Lewis employs. Lewis allows for some leakage from income accruing to capital [33, p. 169]. Fei and Ranis, on the other hand, assume all income on capital is saved and that some additional savings are forthcoming from the agricultural sector where no capital is being used [12, pp. 29-34]. Jorgenson [23, p. 326] assumes that all wages are consumed and that all income earned on capital is saved. Only Lewis considers public savings. As mentioned above, the constant marginal and average tax rate is not a necessary assumption.

By assumption, we have

$$(\alpha_2 + \alpha_4) P_{1t} Y_{st} < L_{st}, \tag{21}$$

and it is this assumption, along with the assumption of labor mobility, which results in a perfectly elastic labor supply to the advanced sectors.

Commercial agriculture

Production in sector 1 differs from that in sector s since capital is used in the former. This capital, as for all other factors, earns its marginal value productivity in every period. Labor is hired at the constant rate $\omega$ and manufactured inputs are purchased with land in the commercial sector owned by the capitalists,[74] the income distribution relations respectively for manufactured goods, labor, and capitalists are

$$(\beta_1 + \beta_3) P_{1t} Y_{1t} = P_{2t} P_{1t}, \tag{22}$$

$$\beta_2 P_{1t} Y_{1t} = L_{1t}, \text{ and} \tag{23}$$

$$(\beta_3 + \beta_4) P_{1t} Y_{1t} = k_{1t} K_{1t} + b_{1t} B_1, \tag{24}$$

where $k_{1t}$ and $b_{1t}$ denote the rate of return on capital and land respectively.

Manufacturing and capital goods sector

Income distribution in this sector is similar to that in the capital-goods sector. Only the coefficients differ. Since manufactured goods are

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[74] The term capitalist is used as an abbreviation for "owner of capital stock." The term capitalist does not necessarily imply private ownership in the sense that individuals must own the capital. However, private ownership is perhaps the most meaningful interpretation for the decentralized model.

used as an input in their manufacture, the MPP equals one, or

$$\alpha_1 P_{2t} Y_{2t} = P_{2t} F_{2t}. \tag{25}$$

For labor

$$\alpha_2 P_{2t} Y_{2t} = \omega L_{2t} \tag{26}$$

and the capital owners receive the income earned on capital

$$\alpha_3 P_{2t} Y_{2t} = K_{2t} K_{2t} \tag{27}$$

where $K_{2t}$ represents the MVP of capital.

For manufactured inputs and labor respectively in, the capital goods sector,

$$\beta_1 P_{3t} Y_{3t} = P_{2t} F_{3t} \tag{28}$$

and

$$\beta_2 P_{3t} Y_{3t} = \omega L_{3t}. \tag{29}$$

The income accruing to capital owners is

$$\beta_3 P_{3t} Y_{3t} = K_{3t} K_{3t} \tag{30}$$

where $K_{3t}$ is the MVP of capital.

Labor income and consumption restraints

Under the assumption that all the income earned by labor is consumed on agricultural and manufactured goods, the only savings from this income source is via government as taxes collected from labor. Since capitalists save all their income, the aggregate consumers' budget restraint is

$$P_{1t}C_{1t} + P_{2t}C_{2t} = (1 - \gamma)\{(\alpha_2 + \alpha_4)Y_{st}P_{1t} + \beta_2 Y_{1t}P_{1t} + \gamma_2 Y_{2t}P_{2t} + \delta_2 Y_{3t}P_{3t} + \omega(L_{st} + L_{1t})\}. \tag{31}$$

In addition, consumption in any period of the plan cannot fall below the level attained in the preplan period, as

$$C_{1t} \geq 1 \tag{32}$$

and

$$C_{2t} \geq 1. \tag{33}$$

Finally, consumption of agricultural goods cannot exceed production.[75]

$$C_{1t} = Y_{st} + Y_{1t}. \tag{34}$$

The income earned by the capitalists is used to accumulate more capital. The allocation of these funds among alternatives is somewhat complicated and

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[75] A similar constraint applies to the consumption of manufactured goods and is given as [2.13].

and is discussed in the following section.

## PRIVATE INVESTMENT

Investment behavior has been a topic of controversy in economics. Investigation of this controversy is not the purpose of this study. Hence, some simplifying assumptions are used to specify investment decisions of the capitalists. Capitalists receive a return from their capital stock in each period. This rent is used to accumulate more capital by purchase of investment goods from the capital goods industry. Their overall budget constraint thus is

$$(1 - \nu)t(\beta_3 + \beta_4)P_{1t}Y_{1t} + \gamma_3 P_{2t}Y_{2t} + \delta_3 P_{3t}Y_{3t} = P_{3t}(I_{1t} + I_{2t} + I_{3t}), \quad (35)$$

which requires the value of private savings to equal the value of private investment.

We assume that capitalists allocate investment among the three sectors to maximize the expected return from their capital stocks in period $t + 1$ and that they expect all prices and factor allocations in subsequent periods to remain unchanged. These private investors, however, take full account of government investment in either SOC in the agricultural sectors or in "private" capital in the manufacturing or capital goods sectors. In addition, investors take into account exogenous technical changes in manufacturing and capital goods sectors.

Symbolically, they attempt to maximize expected or anticipated revenue

$$R = (\beta_3 + \beta_4)P_{1t}G_{1t}^{\lambda}\sigma_1 F_{1t}^{\beta_1} I_{1t}^{\beta_2}(K_{1t} + I_{1t})^{\beta_3} + \gamma_3(1+\epsilon)^{T}\sigma_2$$
$$F_{2t}^{\gamma_1}\gamma_2 I_{2t}(K_{2t} + \bar{I}_{2t} + I_{2t})^{\gamma_3} + \delta_3 P_{3t}(1+\epsilon)^{T}\sigma_3 F_{3t}^{\delta_1} L_{3t}^{\delta_2}$$
$$(K_{3t} + \bar{I}_{3t} + I_{3t})^{\delta_3}, \qquad (36)$$

where $T = t + 1$. This must be maximized subject to the budget constraint (35) without disinvestment. Formulating this as a constrained maximum through introduction of a Lagrangean multiplier, Z, and applying the Kuhn-Tucker conditions [27], the following first order conditions result:

$$\frac{\partial R}{\partial I_{1t}} = \Lambda_{1t}(K_{1t} + I_{1t})^{\beta_3 - 1} - ZP_{3t} \leq 0;$$

$$I_{1t}\frac{\partial R}{\partial I_{1t}} = 0;\ I_{1t} \geq 0; \qquad (37)$$

$$\frac{\partial R}{\partial I_{2t}} = \Lambda_{2t}(K_{2t} + \bar{I}_{2t} + I_{2t})^{\gamma_3 - 1} - ZP_{3t} \leq 0;$$

$$I_{2t}\frac{\partial R}{\partial I_{2t}} = 0;\ I_{2t} \geq 0; \qquad (38)$$

$$\frac{\partial R}{\partial I_{3t}} = \Lambda_{3t}(K_{3t} + \bar{I}_{3t} + I_{3t})^{\delta_3 - 1} - ZP_{3t} \leq 0;$$

$$I_{3t}\frac{\partial R}{\partial I_{3t}} = 0;\ I_{3t} \geq 0; \qquad (39)$$

where

$$A_{1t} = \beta_3(\beta_3 + \beta_4)P_{1t}\sigma_{1t}\sigma_1 F_{1t}^{\gamma_1}L_{1t}^{\gamma_2}, \tag{40}$$

$$A_{2t} = \gamma_3^2 P_{2t}(1+\epsilon)^T \sigma_2 F_{2t}^{\gamma_1}L_{2t}^{\gamma_2}, \tag{41}$$

and

$$A_{3t} = \delta_3^2 P_{3t}(1+\epsilon)^T \sigma_3 F_{3t}^{\delta_1}L_{3t}^{\delta_2} \tag{42}$$

Conditions (37)-(39) and the budget constraint (35) specify values of $I_{1t}$, $I_{2t}$, and $I_{3t}$ that maximize expected revenue for the capitalists. Under the additional, highly restrictive assumption that $I_{1t}$, $I_{t2}$, and $I_{3t}$ are positive in all periods, these first order conditions simplify to:

$$A_{3t}(K_{3t} + \bar{I}_{3t} + I_{3t})^{\delta_3 - 1} = A_{2t}(K_{2t} + \bar{I}_{2t} + I_{2t})^{\gamma_3 - 1} \tag{43}$$

and

$$A_{1t}(K_{1t} + I_{1t})^{\beta_3 - 1} = A_{2t}(K_{2t} + \bar{I}_{2t} + I_{2t})^{\gamma_3 - 1} \tag{44}$$

Equations (43) and (44), along with the budget constraint (35) define optimum levels of investment in the three sectors.

It is useful to digress and explain the implications of the assumption that $I_{it}$ is positive in all sectors. Under equations (43) and (44), capitalists allocate investment so that the value of expected marginal revenue is equal in all three sectors. In each period, capitalists must have sufficient investment funds to attain an equilibrium. Under the less restrictive investment criteria of (37)-(39), capitalists invest in the most profitable

industry until either the investment funds are used up or their share of expected marginal value of each expanded investment falls to the level of the second most rewarding opportunity. Then, simultaneous investment is made in the two most profitable industries until all the investment funds are used up or until returns on capital in the two most profitable lines fall to the return level expected in the third industry. Simultaneous investment then is made in all three industries to the limit of investment funds. Sufficient funds must be available to attain this state of intersector-returns equality if the economy is to afford the "luxury" of balanced growth.[76]

## WAGE, PRICE, AND OUTPUT DETERMINATION

The purpose of this section is to discuss the operation of the model aside from the influence of the government. Capital stocks in each period, $K = (K_1, K_2, K_3)$, are taken as data. The question now is how consumers, capitalists, laborers, and entrepreneurs interact within each period to determine wages, prices, and outputs. A simplified model demonstrates that there are two "degrees of freedom" in the absence of government. These "degrees of freedom" subsequently are used to choose a numeraire for prices and define the exogenous wage rate.

Consider the following simplified model where the number before the "a" on the equation number indicates the basic equation for derivation. Time subscripts are omitted since only one period is considered. In each period consumers (laborers) attempt to maximize aggregate welfare

$$W = W(C_1, C_2), \tag{1a}$$

[76] For a critique of the balanced-growth thesis and reasons that this cannot be attained, see Hirschman [18, Ch. 4]. Hirschman argues that unbalanced growth may be desirable.

subject to their budget (income) restraint

$$P_1C_1 + P_2C_2 = J(P,Y). \tag{31a}$$

where P and Y are sectors representing $(P_1, P_2, P_3)$ and $(Y_s, Y_1, Y_2, Y_3)$ respectively. Consumer theory indicates that this maximization leads to a system of demand equations that are homogeneous of degree zero in prices and incomes. Since nominal consumer income in this model (31) is homogeneous of degree zero in prices,[77] the resulting demand equations also are homogeneous of degree zero in prices. Consequently, the demand equations are sufficient to determine only relative prices. The two demand equations are denoted as

$$C_1 = C^1(P,Y) \tag{45}$$

and

$$C_2 = C^2(P,Y) \tag{46}$$

Next, consider production in the commercial agricultural sector. The production function,

$$Y_1 = H^1(F_1, L_1, K_1) \tag{7a}$$

and the first-order conditions,[77]

$$P_1H^1_{F_1} = P_2 \tag{22a}$$

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[77]The subscripts on the functions denote partial derivatives

and

$$P_1 H^1_{L_1} = \omega \tag{23a}$$

imply a short run supply equation

$$Y_1 = Y^1(P_1, P_2, \omega, K_1). \tag{47}$$

Similarly for the manufacturing sector, from

$$Y_2 = H^2(F_2, L_2, K_2); \tag{8a}$$

$$P_2 H^2_{F_2} = P_2, \tag{25a}$$

and

$$P_2 H^2_{L_2} = \omega \tag{26a}$$

we get the supply equation

$$Y_2 = Y^2(P_2, \omega, K_2) \tag{48}$$

The analogous equations relating to the capital goods sector,

$$Y_3 = H^3(F_3, L_3, K_3), \tag{9a}$$

$$P_3 H^3_{F_3} = P_2, \tag{28a}$$

and

$$P_3 H_{(3)} L_3^3 = \omega \tag{29a}$$

imply the supply equation

$$Y_3^{(1)} = Y^3(P_2, P_3, \omega, K_3). \tag{49}$$

Since employment in the subsistence sector is a residual there is no derived demand for labor for this sector. Consequently, the supply equation for the subsistence sector is of a somewhat different nature. From (22a) and (23a) for sector 1, we get an equation indicating the derived demand for labor in sector 1. This is denoted as

$$L_1 = L^1(P_1, P_2, \quad, K_1). \tag{50}$$

Similarly, for sectors 2 and 3 we get derived labor-demand equations denoted as

$$L_2 = L^2(P_2, \omega, K_2) \tag{51}$$

and

$$L_3 = L^3(P_2, P_3, \quad, K_3). \tag{52}$$

Substituting (50)-(52) into (12a), we get employment in the subsistence sector as

$$L_s = L_o - L^1 - L^2 - L^3 = L^s(P, \omega, K, L_o). \tag{53}$$

From (53), the production function

$$Y_s = H^s(F_s, L_s), \tag{6a}$$

and the first order condition

$$P_1 H^s_{Fs} = P_2, \tag{19a}$$

we get the supply equation for the subsistence sector,

$$y_s = Y^s(P, \omega, K, L_o) \tag{54}$$

From the first order conditions (19a), (22a), (23a), (25a), (26a), (28a), and (29a), we obtain derived demand equations for manufactured inputs

$$F_s = F^s(P, \omega, K, L_o), \tag{55}$$

$$F_1 = F^1(P_1, P_2, \omega, K_1), \tag{56}$$

$$F_2 = F^2(P_2, \omega, K_2), \tag{57}$$

and

$$F_3 = F^3(P_2, P_3, \omega, K_3). \tag{58}$$

Similarly, the derived demand equations for investment goods can be derived from the first order conditions (43) and (44) and the capitalists' budget constraint (35a). These investment demand equations are

$$I_1 = I^1(P, \omega, K), \tag{59}$$

$$I_2 = I^2(P, \omega, K), \tag{60}$$

and

$$I_3 = I^3(P, \omega, K). \tag{61}$$

By making the appropriate subsitutions, the following market equilibrium equations are obtained

$$Y^1(P_1, P_2, \omega, K_1) + Y^S(P, \omega, K, L_O) = C^1(P,Y) = C^1(P, \omega, K, L_O), \tag{34a}$$

for agricultural goods,

$$(P_2, \omega, K_2) = F^S(P, \omega, K, L_O) + F^1(P_1, P_2, \omega, K_1) + F^2(P_2, \omega, K_2)$$
$$+ F^3(P_2, P_3, \omega, K_3) + C^2(P, \omega, K, L_O), \tag{13a}$$

for manufactured goods,

$$^1(P_2, P_3, \omega, K) = I^1(P, \omega, K) + I^2(P, \omega, K) + I^3(P, \omega, K), \tag{17a}$$

for investment goods, and

$$L_o^d = L^s(P, \omega, K) + L^1(P_1, P_2, \omega, K_1) + L^2(P_2, \omega, K_2)$$

$$+ L^3(P_2, P_3, \omega, K_3) \qquad (12a)$$

for labor.

Four equations now determine four variables, $P_1$, $P_2$, $P_3$, and $\omega$. However, in order to determine $L_-$ in (53), the values for $L_1$, $L_2$, and $L_3$ were substituted into (12a). Thus, (12a) cannot be used as an equilibrium condition to determine a wage rate. In effect, a fifth variable, $L_-$, remains to be determined if (12a) is used as an equilibrium condition. This leaves three equations and four unknowns. By choosing a numeraire and identifying an exogenous wage rate, the system becomes determinate. Thus, two equations are added:

$$P_{2t} = 1, \qquad (62)$$

and

$$\omega = \bar{\omega}. \qquad (63)$$

In other words, manufactured output is chosen as the numeraire, and labor is paid an exogenously determined, constant amount, $\omega$, of manufactured goods per period. (These manufactured goods can, of course, be bartered or traded for agricultural goods).

A digression on supply response in agriculture

Much has been written about supply response in subsistence agriculture.[78]

[78] See, for example, the literature cited by Bhagwati and Chakravarty [4].

This section demonstrates that, in the decentralized model, subsistence output might respond inversely to a price increase. This inverse response, however, can be more than offset by the increase of the commercial agricultural sector.

A simple means of specifying supply response is to make the appropriate substitutions into the two equations.[79]

$$\frac{\partial Y_s}{\partial P_1} = H^s_{F_s} \frac{\partial F_s}{\partial P_1} + H^s_{I_s} \frac{\partial I_s}{\partial P_1} \tag{64}$$

and

$$\frac{\partial Y_1}{\partial P_1} = H^1_{F_1} \frac{\partial F_1}{\partial P_1} + H^1_{I_1} \frac{\partial I_1}{\partial P_1} \tag{65}$$

From (6) we obtain

$$H^s_{F_s} = \frac{\gamma_1 Y_s}{F_s} \tag{66}$$

and

$$H^s_{I_s} = \frac{\gamma_2 Y_s}{I_s}. \tag{67}$$

From (19) we get

$$\frac{\partial F_s}{\partial P_1} = \frac{a_1 (P_1 \gamma_1 \sigma^*_{I_s} \gamma_2)^{a_1}}{P_1} \tag{68}$$

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[79] In the derivation of (65) it has been assumed that $\frac{\partial K_1}{\partial P_1} = 0$. That is, this section deals with short-run supply responses.

and (53) together with (23) yields

$$\frac{\partial L_s}{\partial P_1} = -\frac{\partial L_1}{\partial P_1} = -\frac{b_2}{P_1}\left(\frac{P_1^{\beta_2}\sigma_1^* F_1^{\beta_1}}{w}\right)^{b_2}, \tag{69}$$

where

$$\sigma_s^* = G_s^{\lambda}\sigma_s,\ \sigma_1^* = G_1^{\lambda}\sigma_1 K_1^{\beta_3},\ a_1 = \frac{1}{1-\alpha_1},\ \text{and}\ b_2 = \frac{1}{1-\beta_2}.$$

Substituting into (64) yields

$$\frac{\partial Y_s}{\partial P_1} = \frac{Y_s}{P_1}\left[\frac{a_1\alpha_1(P_1\alpha_1\sigma_s^* L_s^{\alpha_2})^{a_1}}{F_s} - \frac{b_2\alpha_2(w^{-1}P_1\beta_2\sigma_1^* F_1^{\beta_1})^{b_2}}{L_s}\right] \tag{70}$$

This will be negative if the absolute value of the second term on the right exceeds the magnitude of the first. In other words, output from the subsistence sector will decline as the product price increases if the effect on production resulting from the exodus of labor from the subsistence sector (because of the more lucrative jobs being created in the commercial sector) more than offsets the production increase resulting from the increased use of manufactured inputs. This possibility does not exist for total supply, however, as is clearly evident by adding (70) to the analogous equation for the commercial sector. This result is

$$\frac{\partial Y_s}{\partial P_1} + \frac{\partial Y_1}{\partial P_1} = \frac{1}{P_1}\left[\frac{\alpha_1 Y_s a_1(P_1\alpha_1\sigma_s^* L_s^{\alpha_2})^{a_1}}{F_s} + \frac{\beta_1 Y_1 b_1(\beta_1 P_1\sigma_1^* L_1^{\beta_2})^{b_1}}{F_1}\right.$$

$$\left. + b_2\left(\frac{\beta_2 Y_1}{L_1} - \frac{\alpha_2 Y_s}{L_s}\right)\left(\frac{\beta_2 P_1\sigma_1^* F_1^{\beta_1}}{w}\right)^{b_2}\right] \tag{71}$$

The first and second terms to the right of the equal sign are clearly positive. Recalling the assumption implied in (21), the last term is also positive. The marginal productivity of labor in the subsistence sector is lower than in the commercial sector.

### Finite Planning Horizons and Post-plan Considerations

When only a finite horizon is considered for inter-temporal development planning, several interrelated problems arise.[80] Two of them involve the length of the planning period and the allowances made during the plan for periods after the planning period.

The choice of the planning horizon is crucial in an optimizing model. A plan that is optimal for $\tau$ periods may not be optimal for $\tau + 1$ periods. An ideal model would be one in which the optimal plan for the first periods is invariant, regardless of the horizon being considered. One theoretical solution to this problem is a horizon with an infinite future. Uncertainty regarding the future, lack of relevant data, and computational difficulties, however, invariably result in finite horizons in empirical applications.[81]

Truncating the horizon at $\tau$ periods, poses the question as to what happens in periods immediately following termination of the plan. Post-plan activities and possibilities are conditioned by the productive capacity bequeathed to the post-plan era. If no special provision is made to provide some incentive to invest or accumulate productive capacity in the latter stages of the plan, decision makers would emphasize current consumption rather than accumulate capital. One possible solution is to require a specified capital stock in period $\tau + 1$. Another possibility is to provide an additional

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[80] For a discussion of some of these problems see Chakravarty and Eckaus [7].

[81] For a discussion of some of the difficulties involved with considering infinite planning horizons, see Chakravarty [6].

incentive at the end of the plan by attaching a special value to any capital bequeathed to posterity.

In the present model, the incentives to the private investors in period t are a function of prices, returns to capital, and government investments in period t. The same considerations apply in period $\tau$. The investors are assumed to behave in the same manner in the last period of the plan as in any other period since they are not "aware" that period $\tau$ is the last period of the plan. However, the rules specifying government expenditures provide no incentive to invest in private capital accumulation or SOC in the final period since this investment does not contribute directly to welfare in period $\tau$. The only payoff realized in the plan period is through any additional employment in the placement of SOC. However, the government collects tax revenue which must be spent. The rule imposed on government expenditures in period $\tau$ is that expenditures in the final period must be allocated in the same proportions as in period $\tau - 1$. Defining $T = \tau - 1$, these rules may be specified as

$$M_\tau \bar{I}_{s\tau} = M_\tau \bar{I}_{sT} \tag{72}$$

$$M_\tau \bar{I}_{1\tau} = M_\tau \bar{I}_{1T} \tag{73}$$

$$M_\tau P_{3\tau} \bar{I}_{2\tau} = M_\tau P_{3T} \bar{I}_{2T} \tag{74}$$

and

$$M_\tau P_{3\tau} \bar{I}_{3\tau} = M_\tau P_{3T} \bar{I}_{3T} \tag{75}$$

This completes the formal presentation of the model. The model is optimized in the following section.

## OPTIMIZATION OF THE DECENTRALIZED MODEL

Solution of the optimizing problem for the decentralized, dual-economy model is through maximizing the differentiable, concave function (1) subject to a number of differentiable convex constraints. All variables must be non-negative. Application of the Kuhn-Tucker first-order conditions [27], involves formulating a Lagrangean function in the next section. The first-order conditions for the decentralized model are presented in the next section.

### The Lagrangean Function

The Lagrangean multipliers are denoted as $Z_{it}$, where the subscript i corresponds to the number of equations presented earlier. The subscript t refers to the time period. The constraints in the function are formulated to require the associated dual variables (Lagrangean multipliers) to be positive, (with the possible exceptions of $Z_{43t}$, $Z_{44t}$, $Z_{72}$, $Z_{73}$, $Z_{74}$, and $Z_{75}$, which can be either positive or negative). Letting $T = \tau - 1$, the following Lagrangean function results:

$$V = \Sigma(\mu_1 C_{1t} + \mu_2 C_{2t} - \mu_{11} C_{1t}^2 + \mu_{12} C_{1t} C_{2t} - \mu_{22} C_{2t}^2)(1+\rho)^{-t}$$

$$+ \Sigma Z_{6t}(\sigma_s G_{st}^{\lambda} F_{st}^{\gamma_1} L_{st}^{\gamma_2} - Y_{st}) + \Sigma Z_{7t}(\sigma_1 G_{1t}^{\lambda} F_{1t}^{\beta_1} L_{1t}^{\beta_2} K_{1t}^{\beta_3} - Y_{1t})$$

$$+ \Sigma Z_{8t}(\sigma_2 (1+\varepsilon)^t F_{2t}^{\gamma_1} L_{2t}^{\gamma_2} K_{2t}^{\gamma_3} - Y_{2t})$$

$$+ \Sigma Z_{9t}(\sigma_3 (1+\varepsilon)^{t/\delta_1} F_{3t}^{\delta_1} L_{3t}^{\delta_2} K_{3t}^{\delta_3} - Y_{3t})$$

$$\Sigma z_{12t}(I_{0t} - \bar{I}_{st} - \bar{I}_{1t} - I_{st} - I_{1t} - I_{2t} - I_{3t})$$

$$\Sigma z_{13t}(Y_{2t} - F_{st} - F_{1t} - F_{2t} - F_{3t} - C_{2t})$$

$$+ \Sigma z_{17t}(Y_{3t} - I_{1t} - I_{2t} - I_{3t} - \bar{I}_{2t} - \bar{I}_{3t})$$

$$+ \Sigma z_{18t}\{\psi[P_{1t}Y_{st}(1-\alpha_1) + P_{1t}Y_{1t}(1-\beta_1) + Y_{2t}(1-\gamma_1) + P_{3t}Y_{3t}(1-\delta_1)]$$

$$- \bar{w}(1-\psi)(\bar{I}_{st} + \bar{I}_{1t}) - P_{3t}(\bar{I}_{2t} + \bar{I}_{3t}$$

$$+ \Sigma z_{19t}(F_{st} - \alpha_1 P_{1t}Y_{st}) + \Sigma z_{22t}(F_{1t} - \beta_1 P_{1t}Y_{1t})$$

$$+ \Sigma z_{23t}(\beta_2 P_{1t}Y_{1t} - I_{1t}) + \Sigma z_{25t}(F_{2t} - \gamma_1 Y_{2t})$$

$$+ \Sigma z_{26t}(\gamma_2 Y_{2t} - wI_{2t}) + \Sigma z_{28t}(F_{3t} - \delta_1 P_{3t}Y_{3t})$$

$$+ \Sigma z_{29t}(\delta_2 P_{3t}Y_{3t} - wI_{3t})$$

$$+ \Sigma z_{31t}\{(1-\psi)(\alpha_2+\alpha_4)Y_{st}P_{1t} + \beta_2 Y_{1t}P_{1t} + \gamma_2 Y_{2t} + \delta_2 Y_{3t}P_{3t}$$

$$+ w(\bar{I}_{st}+\bar{I}_{1t})\} - P_{1t}C_{1t} - C_{2t}\}$$

$$+ \Sigma z_{32t}(C_{1t}-1) + \Sigma z_{33t}(C_{2t}-1)$$

$$+ \Sigma z_{34t}(Y_{st} + Y_{1t} - C_{1t})$$

$$+ \Sigma z_{35t}\{(1-\psi)[(\beta_3+\beta_4)P_{1t}Y_{1t} + \gamma_3 Y_{2t} + \delta_3 P_{3t}Y_{3t}] - P_{3t}(I_{1t}+I_{2t}+I_{3t})\}$$

$$+ \Sigma z_{43t}\{A_{2t}(K_{2t}+\bar{I}_{2t}+I_{2t})^{\gamma_3-1} - A_{3t}(K_{3t}+\bar{I}_{3t}+I_{3t})^{\delta_3-1}\}$$

$$+ \Sigma z_{44t}\{A_{2t}(K_{2t}+\bar{I}_{2t}+I_{2t})^{\gamma_3-1} - A_{1t}(K_{1t}+I_{1t})^{\beta_3-1}\}$$

$$+ \Sigma z_{72}(\bar{I}_{s\tau}M_\tau - \bar{I}_{s\tau}M_m)$$

$$+ \Sigma z_{73}(\bar{I}_{1\tau}M_\tau - \bar{I}_{1\tau}M_\tau)$$

$$+ \Sigma z_{74}(P_{3\tau}\bar{I}_{2\tau}M_\tau - P_{3\tau}\bar{I}_{2\tau}M_\tau)$$

$$+ \Sigma z_{75}(P_{3\tau}\bar{I}_{3\tau}M_\tau - P_{3\tau}\bar{I}_{3\tau}M_\tau). \qquad (76)$$

In subsequent sections (10), (11), (14), (16), (18), and (40)-(42) are treated as though they have been eliminated by substitution. However, the symbols defined by these questions are used whenever this simplifies notation. In addition, (62) and (63) are completely eliminated by substitution. All the summations in (76) refer to the subscript t and run over the range t = 1, ..., τ.

## The First-Order Conditions

The first-order conditions for an optimum resulting from the application of the Kuhn-Tucker conditions to the Lagrangean function (76) are now presented. Under the Cobb-Douglas production functions used, assuming that production is

positive in all sectors implies that factor inputs in every period are positive. The simplifying assumption was made previously that $I_{it} > 0$ for all i and t. Constraints (32) and (33) require $C_{1t}$ and $C_{2t}$ to be positive, and it is reasonable to assume $P_{1t}$ and $P_{3t}$ to be positive. This leaves only the four government expenditure variables to be subjected to the corner conditions. More specifically, the Kuhn-Tucker conditions are applied to the four variables $\bar{L}_{st}$, $\bar{L}_{1t}$, $\bar{I}_{2t}$, and $\bar{I}_{3t}$.

The first order conditions for an optimum are as follows:[82]

$$V_{C_1} = (\mu_1 - 2\mu_{11}C_1 + \mu_{12}C_2)(1+\rho)^{-t} - z_{31}P_1 + z_{32} - z_{34} = 0 \qquad (77)$$

$$V_{C_2} = (\mu_2 + \mu_{12}C_1 - 2\mu_{22}C_2)(1+\rho)^{-\tau} - z_{13} - z_{31} + z_{33} = 0 \qquad (78)$$

$$V_{Y_s} = -z_6 + z_{18}P_1\psi(1-\alpha_1) - z_{19}P_1\alpha_1 + z_{31}P_1(1-\psi)(\alpha_2+\alpha_4) + z_{34} = 0 \quad (t = 1, \ldots, \tau-2) \qquad (79)$$

$$V_{Y_1} = -z_7 + z_{18}P_1\psi(1-\beta_1) - z_{22}P_1\beta_1 + z_{23}P_1\beta_2 + z_{31}P_1(1-\psi)\beta_2 + z_{34} + z_{35}P_1(1-\psi)(\beta_3+\beta_4) = (t=1, \ldots, \tau-2) \qquad (80)$$

$$V_{Y_2} = -z_8 + z_{13} + z_{18}\psi(1-\gamma_1) - z_{25}\gamma_1 + z_{26}\gamma_2 + z_{31}(1-\psi)\gamma_2 + z_{35}(1-\psi)\gamma_3 = 0 \quad (t=1, \ldots, \tau-2) \qquad (81)$$

$$V_{Y_3} = -z_9 + z_{17} + z_{18}P_3\psi(1-\delta_1) - z_{28}P_3\delta_1 + z_{29}P_3\delta_2 + z_{31}P_3(1-\psi)\delta_2 + z_{35}P_3(1-\psi)\delta_3 = (t=1, \ldots, \tau-2) \qquad (82)$$

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[82] Subscripts on V denote partial derivatives (e.g., $V_X = \frac{\partial V}{\partial X}$). For simplicity, time subscripts are omitted whenever this will not cause any confusion. In all cases, the same first-order conditions apply to every time period (t = 1, ...τ) unless otherwise specified.

$$V_{F_s} = Z_6\alpha_1 Y_s/F_s - Z_{13} + Z_{19} = 0 \tag{83}$$

$$V_{F_1} = Z_7\beta_1 Y_1/F_1 - Z_{13}+Z_{22}-Z_{44}\beta_1 A_1(K_1+I_1)^{\beta_3-1}/F_1 = 0 \tag{84}$$

$$V_{F_2} = Z_8\gamma_1 Y_2/F_2 - Z_{13}+Z_{25}+(Z_{43}+Z_{44})\gamma_1 A_2(K_2+\bar{I}_2+I_2)^{\gamma_3-1}/F_2 = 0 \tag{85}$$

$$V_{F_3} = Z_9\delta_1 Y_3/F_3 - Z_{13}+Z_{28} - Z_{43}\delta_1 A_3(K_3+\bar{I}_3+I_3)^{\delta_3-1}/F_3 = 0 \tag{86}$$

$$V_{L_s} = Z_6\alpha_2 Y_s/L_s - Z_{12} = 0 \tag{87}$$

$$V_{L_1} = Z_7\beta_2 Y_1/L_1 - Z_{12} - Z_{23}\omega - Z_{44}\beta_2 A_1(K_1+I_1)^{\beta_3-1}/L_1 = 0 \tag{88}$$

$$V_{I_2} = Z_8\gamma_2 Y_2/L_2 - Z_{12} - Z_{26}\omega + (Z_{43}+Z_{44})\gamma_2 A_2(K_2+\bar{I}_2+I_2)^{\gamma_3-1}/L_2 = 0 \tag{89}$$

$$V_{L_3} = Z_9\delta_2 Y_3/L_3 - Z_{12} - Z_{29}\omega - Z_{43}\delta_2 A_3(K_3+\bar{I}_3+I_3)^{\delta_3-1}/L_3 = 0 \tag{90}$$

$$\begin{aligned} V_{P_1} = {} & Z_{18}\psi\{Y_s(1-\alpha_1)+Y_1(1-\beta_1)\} - Z_{19}\alpha_1 Y_s - Z_{22}\beta_1 Y_1 + Z_{23}\beta_2 Y_1 \\ & + Z_{31}[(1-\psi)\{(\alpha_2+\alpha_4)Y_s+\beta_2 Y_1\} - C_1] + Z_{35}(1-\psi)(\beta_3+\beta_4)Y_1 \\ & - Z_{44}A_1(K_1+I_1)^{\beta_3-1}/P_1 = 0 \quad (t=1, \ldots, \tau-2) \end{aligned} \tag{91}$$

$$\begin{aligned} V_{P_3} = {} & Z_{18}\{\psi(1-\delta_1)Y_3 - \bar{I}_2 - \bar{I}_3\} + \{Z_{29}\delta_2 - Z_{28}\delta_1 + Z_{31}\delta_2(1-\psi)\}Y_3 \\ & + Z_{35}\{(1-\psi)\delta_3 Y_3 - I_1 - I_2 - I_3\} - Z_{43}A_3(K_3+\bar{I}_3+I_3)^{\delta_3-1}/P_3 = 0 \\ & (t=1, \ldots, \tau-2) \end{aligned} \tag{92}$$

$$\begin{aligned} V_{I_{1t}} = {} & \beta_3 \sum_{i=t+1}^{\tau} (Z_{7i}Y_{1i}/K_{1i}) - Z_{17t} - Z_{35t}P_{3t} \\ & + (1-\beta_3) \sum_{i=t}^{\tau} Z_{44i}A_{1i}(K_{1i}+I_{1i})^{\beta_3-2} = 0 \end{aligned} \tag{93}$$

$$V_{I_{2t}} = \gamma_3 \sum_{i=t+1}^{\tau} (z_{8i}Y_{2i}/K_{2i}) - z_{17t} - z_{35t}P_{3t}$$
$$+ (\gamma_3 - 1) \sum_{i=t}^{\tau} (z_{43i}+z_{44i})A_{2i}(K_{2i}+\bar{I}_{2i}+I_{2i})^{\gamma_3-2} = 0 \quad (94)$$

$$V_{I_{3t}} = \delta_3 \sum_{i=t+1}^{\tau} (z_{9i}Y_{3i}/K_{3i}) - z_{17t} - z_{35t}P_{3t}$$
$$+ (1-\delta_3) \sum_{i=t}^{\tau} z_{43i}A_{3i}(K_{3i}+\bar{I}_{3i}+I_{3i})^{\delta_3-2} = 0 \quad (95)$$

$$V_{\bar{L}_{st}} = \lambda \sum_{i=t+1}^{\tau} (z_{6i}Y_{si}/G_{si}) - z_{12t} + \omega(1-\psi)(z_{31}-z_{18}) \leq 0;$$
$$\bar{L}_{st}V_{\bar{L}_{st}} = 0; \quad \bar{L}_{st} \geq 0 \quad (t=1, \ldots, \tau-2) \quad (96)$$

$$V_{\bar{I}_{1t}} = \lambda \sum_{i=t+1}^{\tau} (z_{7i}Y_{1i}/G_{1i}) - z_{12t} + \omega(1-\psi)(z_{31} - z_{18})$$
$$- \lambda \sum_{t=1}^{\tau} z_{44i}A_{1i}(K_{1i}+I_{1i})^{\beta_3-1}/G_{1,i+1} \leq 0;$$
$$\bar{I}_{1t}V_{\bar{I}_{1t}} = 0; \quad \bar{I}_{1t} \geq 0 \quad (t=1, \ldots, \tau-2) \quad (97)$$

$$V_{\bar{I}_{2t}} = \gamma_3 \sum_{i=t+1}^{\tau} (z_{8i}Y_{2i}/K_{2i}) - z_{17t} - z_{18t}P_{3t}$$
$$+ (\gamma_3-1) \sum_{i=t}^{\tau} (z_{43i}+z_{44i})A_{2i}(K_{2i}+\bar{I}_{2i}+I_{2i})^{\gamma_3-2} \leq 0;$$
$$\bar{I}_{2t}V_{\bar{I}_{2t}} = 0; \quad \bar{I}_{2t} \geq 0 \quad (t=1, \ldots, \tau-2) \quad (98)$$

$$V_{\bar{I}_{3t}} = \delta_3 \sum_{i=t+1}^{\tau} (z_{9i}Y_{3i}/K_{3i}) - z_{17t} - z_{18t}P_{3t}$$
$$+ (1-\delta_3) \sum_{i=t}^{\tau} z_{43i}A_{3i}(K_{3i}+\bar{I}_{3i}+I_{3i})^{\delta_3-2} \leq 0;$$
$$\bar{I}_{3t}V_{\bar{I}_{3t}} = 0; \quad \bar{I}_{3t} \geq 0; \quad (t=1, \ldots, \tau-2) \quad (99)$$

In addition, certain special first-order conditions are required to determine the values of some of the variables in the last two periods of the

plan. These special conditions, resulting from the restrictions placed on the allocation of government investment during periods $\tau - 1$ and $\tau$, can be derived directly by differentiating (1) with respect to the appropriate variables for periods $\tau - 1$ and $\tau$, and applying the Kuhn and Tucker rules. Since these conditions are not crucial to the subsequent discussion they are not presented.

The first-order conditions in (77)-(99) and the special conditions relating to the last two periods of the plan must be combined with the equations of the model to determine values for the variables that will optimize (1). The relevant equations are (6)-(9), (12), (13), (17)-(19), (22), (23), (25), (26), (28), (29), (31)-(35), (43), (44), and (72)-(75). Failure to consider all first-order conditions relating to the last two periods of the plan results in a certain amount of indeterminacy in the earlier periods of the plan as well. The subsequent discussion is not affected by this indeterminacy.

In the next section, factors influencing the feasibility and desirability of investing in SOC in the subsistence sector in one period are discussed. The subsequent section discusses the remaining investment alternatives available to the government. These alternatives are compared with private investment opportunities.

## SOC Investment in the Subsistence Sector

The government has tax revenue to allocate among the four alternatives $L_{st}$, $L_{1t}$, $I_{2t}$, and $I_{3t}$ in each period. The optimum levels of these variables must satisfy conditions (96)-(99) in each of the first $\tau$-2 periods. Thus, the government should invest in SOC in the subsistence sector in period $t$ only if $V_{L_{st}} \geq 0$ in (96). This implies that

$$\sum_{i=t+1}^{\omega} (Z_{6i} Y_{si}/G_{si}) + Z_{31t}^{\omega(1-\Psi)} = Z_{12t} + Z_{18t}^{\omega(1-\gamma)} \qquad (100$$

Where the terms on the left are social pay-offs and those on the right are social opportunity costs. An interpretation of (100) is that, if $L_{st}$ is to be greater than zero, the sum of the discounted marginal social value productivit in all subsequent plan periods of labor used in subsistence SOC accumulation in period t plus the social value of income paid to labor on the SOC project must be large enough to offset the social opportunity cost of the labor employed on the project plus the social opportunity cost of the government expenditure.[83] Thus the problem is to identify those particular characteristics of an economy that will contribute to fulfilling this requirement. From (100) a number of factors can be identified.

We first discuss the coefficient, $\lambda$. Ceteris paribus, the larger the magnitude of $\lambda$ the more productive SOC will be at all levels $G_{st}$ and consequently, the higher the optimum $G_{st}/Y_{st}$ ratio will be for any given set of social valuations of costs and pay-offs. Schultz suggests one of the crucial elements making the subsistence sector responsive to investments in SOC is the level of education of the people involved [57]. Many other social and physical characteristics of the people and the type and nature of the agricul-

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[83] The condition which must be satisfied to make it socially desirable to invest in subsistence SOC in period t depends on the amount that will be invested in subsistence SOC in period $\tau - 1$. It is this type of intertemporal or dynamic link that results in the indeterminacy in the earlier periods from not specifying all the first-order conditions for the last two periods of the plan. Thus, a certain amount of intertemporal substitution is possible. The higher the level of $L_s$, $t - 1$, the relatively less desirable it will be to invest in subsistence sector SOC in period $t < \tau - 1$. Similarly, the larger $L_{st}$, the relatively less desirable it will be to invest in subsistence SOC in period $\tau - 1$.

ture involved also have important influences on this coefficient. For example the magnitude of $\lambda$ will depend on the type of infrastructure being developed (e.g., irrigation systems, extension activities, etc.).

A higher $\lambda$ coefficient will make investment in SOC physically more productive and, ceteris paribus, more socially profitable. Similarly, the higher the social valuation of subsistence agricultural production ($Z_{6t}$) in subsequent periods, the higher the likelihood that the benefits accruing to investment in SOC in period t will offset the costs involved. The value of this variable, $Z_{6t}$, may be expected to vary inversely with the ratio of $C_{1t}/C_{2t}$. In other words, as the ratio of agricultural production to manufacturing "surplus" increases, the social valuation of agricultural production might be expected to fall. Hence, the higher the ratio $C_1/C_2$, the relatively less desirable investment in $G_{st}$ becomes.

The marginal social value of a unit of labor (consumer) income in period t is given by $Z_{31t}$. This variable varies directly with the proportion of the population employed in subsistence agriculture. That is, $Z_{31t}$ increases with the proportion of the entire labor force employed in the subsistence sector ($L_{st}/L_o$). For a given set of prices, per capita real income to labor declines as the ratio $L_{st}/L_o$ increases. Ceteris paribus, the marginal social value of an additional unit of consumer income ($Z_{31t}$) will increase as income decreases. Thus, the higher the proportion of labor in subsistence agriculture, the relatively more desirable it becomes to invest in $G_{st}$.

With the right-hand side of (25), the marginal social opportunity cost of an additional unit of labor ($Z_{12t}$) is expected to decline as the size of the labor force ($L_0$) increases. The value of $Z_{12}$ is determined largely by the social value productivity of labor in subsistence agriculture, and this value declines as $L_0$ and $L_s$ increase.

The last term on the right-hand side of the equation indicates the social opportunity cost of using government tax revenue to accumulate SOC. The magnitude of this term is related to the amount of tax revenue available and the other alternatives open to the government. In summary, for an economy with a given configuration of wages, prices, capital stocks, SOC, primary resource base, and technology, the social desirability of investing in SOC in the subsistence sector will increase as the size of the labor force ($L_o$) increases since, for a given wage-price-capital stock configuration, $L_{st}/L_o$ increases with $L_o$ ($L_{st}$ is a residual that varies directly with $L_o$). Also, $L_{st}$ increases with $Y_{st}$ and the "optimum" level of $G_{st}$ is augmented. An expanded labor supply influences the social desirability of subsistence SOC expansion through the increasing ratio $L_{st}/L_o$, the increased social pay-off to employment creation ($Z_{31}$), and the reduced social opportunity cost of labor.

Alternative Investment Opportunities

The social opportunity cost of using government tax revenue to accumulate SOC in the subsistence sector depends on the amount of tax revenue available, as well as the social desirability of investment alternatives. The alternatives available to the government in any period are expenditures on $\bar{L}_{1t}$, $\bar{I}_{2t}$, and $\bar{I}_{3t}$. If any of these alternatives are to be utilized in a particular period, the corresponding first derivative of (76) must be equal to zero in the first-order conditions (97)-(99). For example, if $\bar{I}_{3t} > 0$, then $V_{\bar{I}3t} = 0$ in (99). Suppose that $V_{\bar{I}3t} = 0$. Substracting $V_{\bar{I}3t}$ from (95), we get the result that

$$V_{I_{3t}} - V_{\bar{I}_{3t}} = Z_{35t}P_{3t} - Z_{18t}P_{3t} = 0 \qquad (101)$$

and since $P_{3t}$ is positive by assumption,

$$Z_{35t} = Z_{18t}. \tag{102a}$$

This suggests that, if it is socially desirable for the government to invest in $\bar{I}_{3t}$, then the social opportunity cost of using government tax revenue ($Z_{18t}$) for this purpose must be equal to the social opportunity cost of using private investment funds ($Z_{35t}$). Furthermore, if (102a) holds, then it follows immediately from (94) and (99) that

$$V_{I_{2t}} = V_{\bar{I}_{2t}} = 0. \tag{103}$$

In other words, if it is socially desirable for government to invest in $\bar{I}_{3t}$ at the margin, it also is desirable for it to invest in $\bar{I}_{2t}$. This result conforms with the balanced investment assumption discussed earlier. If it was socially desirable for the government to invest in either of the other two sectors, then it would also be desirable to invest in $\bar{I}_{1t}$ at the margin.

If the assumption that $V_{\bar{I}_{3t}} = 0$ is relaxed, but the requirement that $V_{\bar{I}_{3t}} \leq 0$ is retained, then it is immediately obvious from (101) that

$$Z_{18t} \geq Z_{35t} \tag{101b}$$

and the social benefit derived from an additional unit of tax revenue must always be at least as great as the social benefit to be derived from an additional unit of private savings. This result follows because of the unilateral transfer possibilities from the public budget to the private savings fund. If the marginal social benefit of private investment exceeds that of

public investment in SOC, the government simply invests in private capital in either sectors 2 or 3. The private investors allocate their investment funds in a manner taking full account of the government investments $\bar{I}_{2t}$ and $\bar{I}_{3t}$.

A model of dualistic economy is formulated in the next section. In it, the government has control over the allocation of private savings. In addition, it has the tax budget, which may be used for either investment in SOC or for additions to the private capital stock. Any income earned on the capital stock is invested in further capital accumulation. Thus, both private and public investments are controlled by the government. This model is termed the centralized dual-economy model.

## THE CENTRALIZED MODEL

The decentralized model now is reformulated to simplify the first-order conditions for the maximum. The reformulation does not appreciably alter the basic features of the original model. The simplification facilitates the analysis of the optimum conditions.

### A Reformulation of the Model

The modified decentralized model expands the role of the government planners to allocation of private investment funds to maximize the objective function. This modification simplifies the problem considerably and the restrictive assumption of balanced private investment in every period is relaxed. Investment in all three sectors during every period is not assumed.

Some features of the model remain unchanged. One modification is the nature of provisions to assure adequate post-plan productive capacity. Incentive to invest in the last plan period is induced through a modified welfare function. A positive weight is attached to post terminal productive capacity (GNP) evaluated at period $\tau$ prices. Letting $T = \tau + 1$, the new welfare

function is denoted as

$$V = \sum_{t=1}^{\tau} (\mu_1 C_{1t} + \mu_2 C_{2t} - \mu_{11} C_{1t}^2 + \mu_{12} C_{1t} C_{2t} - \mu_{22} C_{2t}^2)(1+\rho)^{-t}$$

$$+ \theta \cdot P_{1\tau} \sigma_s G_{s\tau}^{\lambda} F_{s\tau}^{\alpha_1} I_{s\tau}^{\alpha_2} + P_{1\tau} \sigma_1 G_{1\tau}^{\lambda} F_{1\tau}^{\beta_1} L_{1\tau}^{\beta_2} K_{1\tau}^{\beta_3} + (1+\varepsilon)^{\tau} \sigma_2 F_{2\tau}^{\gamma_1} I_{2\tau}^{\gamma_2} K_{2\tau}^{\gamma_3}$$

$$- F_{s\tau} - F_{1\tau} - F_{2\tau} - F_{3\tau} + P_{3\tau} (1+\varepsilon)^{\tau} \sigma_3 F_{3\tau}^{\delta_1} L_{s\tau}^{\delta_2} K_{3\tau}^{\delta_3} \}. \qquad (104)$$

Aside from the new parameter, $\theta$, indicating the weight or emphasis placed on the provision for future generations, all parameters and variables are as defined earlier. The welfare function is maximized subject to the following set of constraints in each period ($t = 1, \ldots, \tau$).

$$Y_{st} = \sigma_s G_{st}^{\lambda} F_{st}^{\alpha_1} I_{st}^{\alpha_2} \qquad (105)$$

$$Y_{1t} = \sigma_1 G_{1t}^{\lambda} F_{1t}^{\beta_1} I_{1t}^{\beta_2} K_{1t}^{\beta_3} \qquad (106)$$

$$Y_{2t} = \sigma_2 (1+\varepsilon)^{t} F_{2t}^{\gamma_1} L_{2t}^{\gamma_2} K_{2t}^{\gamma_3} \qquad (107)$$

$$Y_{3t} = \sigma_3 (1+\varepsilon)^{t} F_{3t}^{\delta_1} L_{3t}^{\delta_2} K_{3t}^{\delta_3} \qquad (108)$$

$$I_o = I_{st} + I_{1t} + L_{st} + L_{1t} + I_{2t} + I_{3t} \qquad (109)$$

$$Y_{st} + Y_{1t} = C_{1t} \qquad (110)$$

$$Y_{2t} = F_{st} + F_{1t} + F_{2t} + F_{3t} + C_{2t} \qquad (111)$$

$$Y_{3t} = I_{1t} + I_{2t} + I_{3t} \qquad (112)$$

$$\psi[P_{1t}Y_{st}(1-\alpha_1) + P_{1t}Y_{1t}(1-\beta_1) + Y_{2t}(1-\gamma_1) + P_{3t}Y_{3t}(1-\delta_1)$$

$$+ \omega(L_{st} + L_{1t})] = \omega(L_{st} + L_{1t}) + P_{3t}I_t \qquad (113)$$

$$\alpha_1 P_{1t}Y_{st} = F_{st} \qquad (114) \qquad \beta_1 P_{1t}Y_{1t} = F_{1t} \qquad (115)$$

$$\gamma_1 Y_{2t} = F_{2t} \qquad (116) \qquad \delta_1 P_{3t}Y_{3t} = F_{3t} \qquad (117)$$

$$\beta_2 P_{1t}Y_{1t} = L_{1t}\omega \qquad (118) \qquad \gamma_2 Y_{2t} = L_{2t}\omega \qquad (119)$$

$$\delta_2 P_{3t}Y_{3t} = L_{3t}\omega \qquad (120)$$

$$(1-\psi)[(\alpha_2+\alpha_4)Y_{st}P_{1t} + \beta_2 Y_{1t}P_{1t} + \gamma_2 Y_{2t} + \delta_2 Y_{3t}P_{3t}$$

$$+ \omega(I_{st} + I_{1t})] = P_{1t}C_{1t} + C_{2t} \qquad (121)$$

$$(1-\psi)[(\beta_3+\beta_4)P_{1t}Y_{1t} + \gamma_3 Y_{2t} + \delta_3 P_{3t}Y_{3t}] + P_{3t}I_t$$

$$= P_{3t}(I_{1t}+I_{2t}+I_{3t}) \qquad (122)$$

$$C_{1t} \geq 1 \qquad (123) \qquad C_{2t} \geq 1 \qquad (124)$$

In addition, the following definitions apply to variables appearing in (106)-(109):

$$G_{st} = \bar{G}_{s1} + \sum_{i=1}^{t-1} \bar{I}_{si} \qquad (125) \qquad G_{1t} = \bar{G}_{11} + \sum_{i=1}^{t-1} \bar{I}_{1i} \qquad (126)$$

$$K_{1t} = \bar{K}_{11} + \sum_{i=1}^{t-1} I_{1i} \qquad (127) \qquad K_{2t} = \bar{K}_{21} + \sum_{i=1}^{t-1} I_{2i} \qquad (128)$$

$$K_{3t} = \bar{K}_{31} + \sum_{i=1}^{t-1} I_{3i}. \qquad (129)$$

Many of these equations remain unchanged but are repeated at this point for convenience. The principal difference between this model and the decentralized model involves the role of the government in the investment sector. The government now is assumed to have control over the expenditure to be made from two budgets, the tax budget (113) and the savings budget (122). Revenue or purchasing power can be transferred from the tax budget to the savings budget to be used for the purchase of capital goods. The amount of the transfer in each period is denoted as $P_{3t}I_t$. However, private savings (income earned on capital goods) cannot be transferred to the tax budget.

In every period, the government has control over the variables $\bar{L}_{st}$, $L_{1t}$, $I_t$, $I_{1t}$, $I_{2t}$, and $I_{3t}$. The placement of capital goods is no longer subject to the allocation rules outlined for the decentralized model and expressed in (43) and (44). As a consequence, the government in the present model has much more power and, hence, control over the development of the economy.

The changes in (112) and definitions (128) and (129) relative to their counterparts in Chapter II are self explanatory. The modification of the welfare function (102) is designed to provide an incentive to invest in productive capacity for the future by imputing a social value to the productive capacity bequeathed to subsequent generations.

## The First-Order Conditions

The optimization of this model proceeds, as before, applying the Kuhn-Tucker optimality conditions to the Lagrangean function formed with (104) as the maximand and (105)-(124) as the constraints. The definitions (125)-(128) are assumed to be eliminated by substitution but the variables defined are retained for notational convenience. Consequently, these equations do not appear in the Lagrangean function. Although the Lagrangean function is not presented, we let X denote Lagrangean multipliers and define $T = \tau - 1$. The

following first-order conditions result:

$$V_{C_1} = (\mu_1 - 2\mu_{11}C_1 + \mu_{12}C_2)(1+\rho)^{-t} - X_7 - X_{18}P_1 + X_{20} = 0 \quad (130)$$

$$V_{C_2} = (\mu_2 + \mu_{12}C_1 - 2\mu_{22}C_2)(1+\rho)^{-t} - X_8 - X_{18} + X_{21} = 0 \quad (131)$$

$$V_{Y_s} = -X_2 + X_7 + X_{10}P_1(1-\alpha_1) - X_{11}P_1\alpha_1 + X_{18}P_1(1-\psi)(\alpha_2+\alpha_4) = 0 \quad (132)$$

$$V_{Y_1} = -X_3 + X_7 + P_1(X_{10}\psi(1-\beta_1) - X_{12}\beta_1 + X_{15}\beta_2 + X_{18}\beta_2(1-\psi) + X_{19}(1-\psi)(\beta_3+\beta_4) = 0 \quad (133)$$

$$V_{Y_2} = -X_4 + X_8 + X_{10}\psi(1-\gamma_1) - X_{13}\gamma_1 + X_{16}\gamma_2 + X_{18}(1-\psi)\gamma_2 + X_{19}(1-\psi)\gamma_3 = 0 \quad (134)$$

$$V_{Y_3} = -X_5 + X_9 + P_3(X_{10}\psi(1-\delta_1) - X_{14}\delta_1 + X_{17}\delta_2 + X_{18}(1-\psi)\delta_2 + X_{19}(1-\psi)\delta_3) = 0 \quad (135)$$

$$V_{F_s} = X_2\alpha_1 Y_s/F_s - X_8 + X_{11} = 0 \quad (t=1, \ldots, T-1) \quad (136)$$

$$V_{F_1} = X_3\beta_1 Y_1/F_1 - X_8 + X_{12} = 0 \quad (t=1, \ldots, T-1) \quad (137)$$

$$V_{F_2} = X_4\gamma_1 Y_2/F_2 - X_8 + X_{13} = 0 \quad (t=1, \ldots, T-1) \quad (138)$$

$$V_{F_3} = X_5\delta_1 Y_3/F_3 - X_8 + X_{14} = 0 \quad (t=1, \ldots, T-1) \quad (139)$$

$$V_{I_s} = X_2\alpha_2 Y_s/I_s - X_6 = 0 \quad (t=1, \ldots, T-1) \quad (140)$$

$$V_{I_1} = X_3\beta_2 Y_1/I_1 - X_6 - X_{15}\psi = 0 \quad (t=1, \ldots, T-1) \quad (141)$$

$$V_{I_2} = X_4\gamma_2 Y_2/I_2 - X_6 - X_{16}\psi = 0 \quad (t=1, \ldots, T-1) \quad (142)$$

$$V_{I_3} = X_5\delta_2 Y_3/I_3 - X_6 - X_{17}\omega = 0 \quad (t=1, \ldots, \tau-1) \tag{143}$$

$$V_{P_1} = X_{10}\psi_1 Y_s(1-\alpha_1) + Y_1(1-\beta_1) - X_{11}\alpha_1 Y_s - X_{12}\beta_1 Y_1$$
$$+ X_{15}\beta_2 Y_1 + X_{18}[(1-\psi)_1((\alpha_2+\alpha_4)Y_s + \beta_2 Y_1) - C_1] \tag{144}$$
$$+ X_{19}(1-\psi)(\beta_3+\beta_4)Y_1 = 0 \quad (t=1, \ldots, \tau-1)$$

$$V_{P_3} = X_{10}[\psi(1-\delta_1)Y_3 - I - X_{14}\delta_1 Y_3 + X_{17}\delta_2 Y_3 + X_{18}(1-\psi)\delta_2 Y_3$$
$$+ X_{19}[(1-\psi)\delta_3 Y_3 + I - I_1 - I_2 - I_3] = 0 \quad (t=1, \ldots, \tau-1) \tag{145}$$

$$V_I = P_3(X_{19} - X_{10}) \leq 0; \; IV_I = 0; \; I \geq 0 \tag{146}$$

$$V_{\bar{I}_{st}} = \lambda^a P_{1\tau}\sigma_s G_{s\tau}^{\lambda-1} F_{s\tau}^{\alpha_1} I_{s\tau}^{\alpha_2} + \lambda \sum_{i=t+1}^{\tau} (X_{2i}Y_{si}/G_{si}) - X_{6t}$$
$$+ \omega(1-\psi)(X_{18t} - X_{10t}) \leq 0; \; \bar{I}_{st} V_{\bar{I}_{st}} = 0; \; \bar{I}_{st} \geq 0 \tag{147}$$

$$V_{\bar{I}_{1t}} = \lambda^a P_{1\tau}\sigma_1 G_{1\tau}^{\lambda-1} F_{1\tau}^{\beta_1} I_{1\tau}^{\beta_2} K_{1\tau}^{\beta_3} + \lambda \sum_{i=t+1}^{\tau} (X_{3i}Y_{1i}/C_{1i}) - X_{6t}$$
$$+ \omega(1-\psi)(X_{18t} - X_{10t}) \leq 0; \; \bar{I}_{1t} V_{\bar{I}_{1t}} = 0; \; \bar{I}_{1t} \geq 0 \tag{148}$$

$$V_{I_{1t}} = \beta_3 {}^a P_{1\tau}\sigma_1 G_{1\tau}^{\lambda} F_{1\tau}^{\beta_1} I_{1\tau}^{\beta_2} K_{1\tau}^{\beta_3-1} + \beta_3 \sum_{i=t+1}^{\tau} (X_{3i}Y_{1i}/K_{1i}) - X_{9t}$$
$$- X_{19t}P_{3t} \leq 0; \; I_{1t} V_{I_{1t}} = 0; \; I_{1t} \geq 0 \tag{149}$$

$$V_{I_{2t}} = \gamma_3 {}^a(1+\varepsilon)^{\tau} \sigma_2 P_{2\tau}^{\gamma_1} I_{2t}^{\gamma_2} K_{2\tau}^{\gamma_3-1} + \gamma_3 \sum_{i=t+1}^{\tau} (X_{4i}Y_{2i}/K_{2i}) - X_{9t}$$
$$- X_{19t}P_{3t} \leq 0; \; I_{2t} V_{I_{2t}} = 0; \; I_{2t} \geq 0 \tag{150}$$

$$V_{I_{3t}} = \delta_3 {}^{a}P_{3\tau}(1+\varepsilon)^{T}\sigma_3 F_{3\tau}^{\delta 1} L_{3\tau}^{\delta 2} K_{3\tau}^{\delta 3 - 1} + \delta_3 \sum_{i=t+1}^{} (X_{5i} Y_{3i}/K_{3i}) - X_{9t}$$

$$- X_{19} P_{3t} \leq 0; \; I_{3t} V_{I_{3t}} = 0; \; I_{3t} \geq 0 \qquad (151)$$

The following special conditions apply to the final period of the plan.

$$V_{F_{s\tau}} = {}^{a}P_{1\tau}\alpha_1\sigma_s G_{s\tau}^{\lambda} F_{s\tau}^{\alpha_1 - 1} I_{s\tau}^{\alpha_2} - a + X_{2\tau}\alpha_1 Y_{s\tau}/F_{s\tau} - X_{8\tau} + X_{11\tau} = 0 \qquad (136a)$$

$$V_{F_{1\tau}} = {}^{a}P_{1\tau}\beta_1\sigma_1 G_{1\tau}^{\lambda} F_{1\tau}^{\beta_1 - 1} L_{1\tau}^{\beta_2} K_{1\tau}^{\beta_3} - a + X_{3\tau}\beta_1 Y_{1\tau}/F_{1\tau}$$

$$-X_{8\tau} + X_{12\tau} = 0 \qquad (137a)$$

$$V_{F_{2\tau}} = {}^{a}\gamma_1(1+\varepsilon)^{T}\sigma_2 F_{2\tau}^{\gamma_1 - 1} L_{2\tau}^{\gamma_2} K_{2\tau}^{\gamma_3} - a + X_{4\tau}\gamma_1 Y_{2\tau}/F_{2\tau} - X_{8\tau}$$

$$+ X_{13\tau} = 0 \qquad (138a)$$

$$V_{F_{3\tau}} = {}^{a}P_{3\tau}\delta_1(1+\varepsilon)^{T}\sigma_3 F_{3\tau}^{\delta 1 - 1} L_{3\tau}^{\delta 2} K_{3\tau}^{\delta 3} - a + X_{5\tau}\delta_1 Y_{3\tau}/F_{2\tau} - X_{8\tau}$$

$$+ X_{14\tau} = 0 \qquad (139a)$$

$$V_{I_{s\tau}} = {}^{a}P_{1\tau}\alpha_2\sigma_s G_{s\tau}^{\lambda} F_{s\tau}^{\alpha_1} L_{s\tau}^{\alpha_2 - 1} + X_{2\tau}\alpha_2 Y_{s\tau}/I_{s\tau} - X_{6\tau} = 0 \qquad (140a)$$

$$V_{L_{1\tau}} = {}^{a}P_{1\tau}\beta_2\sigma_1 G_{1\tau}^{\lambda} F_{1\tau}^{\beta_1} L_{1\tau}^{\beta_2 - 1} K_{1\tau}^{\beta_3} + X_{3\tau}\beta_2 Y_{1\tau}/L_{1\tau} - X_{6\tau}$$

$$- X_{15\tau}{}^{(j)} = 0 \qquad (141a)$$

$$V_{I_{2\tau}} = \alpha\gamma_2(1+\varepsilon)^{T}\sigma_2 F_{2\tau}^{\gamma_1} I_{2\tau}^{\gamma_2-1} K_{2\tau}^{\gamma_3} + X_{4\tau}\gamma_2 Y_{2\tau}/L_{2\tau} - X_{6\tau}$$

$$- X_{16\tau}\omega \qquad (142a)$$

$$V_{I_{3\tau}} = \alpha\delta_2(1+\varepsilon)^{T}\sigma_3 F_{3\tau}^{\delta_1} I_{3\tau}^{\delta_2-1} K_{3\tau}^{\delta_3} + X_5\delta_2 Y_{3\tau}/L_{3\tau} - X_{6\tau}$$

$$- X_{17\tau}\omega = 0 \qquad (143a)$$

$$V_{P_{1\tau}} = \alpha(\tau_s G_{s\tau}^{\lambda} F_{s\tau}^{\alpha_1} I_{s\tau}^{\alpha_2} + \sigma_1 G_{1\tau}^{\lambda} F_{1\tau}^{\beta_1} I_{1\tau}^{\beta_2} K_{1\tau}^{\beta_3}) + X_{10\tau}\psi[Y_{st}(1-\alpha_1) + Y_{1t}(1-\beta_1)$$

$$11\tau\ 1\ Y_{s\tau} - X_{12\tau}\beta_1 Y_{1\tau} + X_{15\tau}\beta_2 Y_{1\tau} + X_{18\tau}[(1-\psi)[(\alpha_2+\alpha_4)Y_{s\tau}$$

$$+ \beta_2 Y_{1\tau}] - C_{1\tau}] + X_{19\tau}(1-\psi)(\beta_3+\beta_4)Y_{1\tau} = 0 \qquad (144a)$$

$$V_{P_{3\tau}} = \alpha(1+\varepsilon)^{T}\sigma_3 F_{3\tau}^{\delta_1} I_{3\tau}^{\delta_2} K_{3\tau}^{\delta_3} + X_{10\tau}[\psi(1-\delta_1)Y_{3\tau} - I_\tau] - X_{14\tau}\delta_1 Y_{3\tau}$$

$$+ X_{17\tau}\delta_2 Y_{3\tau} + X_{18\tau}(1-\psi)\delta_2 Y_{3\tau} + X_{19\tau}[(1-\psi)\delta_3 Y_{3\tau} + I_\tau - I_{1\tau}$$

$$- I_{2\tau} - I_{3\tau}] = 0 \qquad (145a)$$

With the letter X denoting the Lagrangean multipliers, the subscripts on the multipliers indicate the equations and time period with which they are associated.

SOC Accumulation

If in any period t, it is desirable for the government to invest in

subsistence sector SOC from (147) we have the result

$$\lambda^{a} P_{1\tau} \sigma_s G_{s,\tau+1}^{\lambda-1} F_{s\tau}^{\gamma_1} L_{s\tau}^{\gamma_2} + \lambda \sum_{i=t+1}^{\tau} (X_{2i} Y_{si}/G_{si}) = (X_{10t} - X_{18t})(1-\psi)\omega + X_{6t}, \tag{146a}$$

where $X_{2i}$ represents the social marginal value of additional subsistence agricultural production in period $i > t$, $X_{18t}$ is the marginal social value of additional consumer income generated in period t by employing labor in SOC accumulation, and $X_{6t}$ and $X_{10t}$ represent the social opportunity costs of labor and government purchasing power, respectively.

Comparing (146a) with its analogue (90) obtained earlier for the decentralized model, the only difference between the two is that the first term in (146a) is absent from (99). This term represents the value that society places on the marginal value productivity of SOC in postplan productive capacity for the subsistence sector. Since this term is positive, the socially desirability of investing in SOC for sector s is greater, when capacity has a positive value, than in the decentralized model where the social value of terminal productive capacity is not considered.

Turning now to the commercial agricultural sector, the condition that must be satisfied if $\bar{L}_{1t}$ is to be positive is

$$\lambda^{a} P_{1\tau} \sigma_1 G_{1,\tau+1}^{\lambda-1} F_{1\tau}^{\beta_1} L_{1\tau}^{\beta_2} K_{1,\tau+1}^{\beta_3} + \lambda \sum_{i=t+1}^{\tau} (X_{3i} Y_{1i}/G_{1i}) = X_{6t}$$

$$+ \omega(1-\psi)(X_{10t} - X_{18t}) \tag{147a}$$

Comparing (147a) with (146a), we see that society can be indifferent between

the post-terminal marginal productivity of SOC in the two agricultural sectors since the same valuation ($\theta P_{1\tau}$) is applied to both.

Some simplifying assumptions and notation

To simplify notation in the remainder of this section, let $T = \tau + 1$ and define the following variables:

$$\sigma_1 G_{1T}^{\lambda-1} F_{1T}^{\beta_1} L_{1T}^{\beta_2} K_{1T}^{\beta_3} = Y_{1T}/G_{1T} \tag{152}$$

$$\sigma_s G_{sT}^{\lambda-1} F_{sT}^{\alpha_1} L_{sT}^{\alpha_2} = Y_{sT}/G_{sT} \tag{153}$$

and

$$X_{2T} = P_{1T}^{\theta} = X_{3T}. \tag{154}$$

Making the appropriate substitutions into (146a) and (147a), we get[84]

$$\sum_{i=t+1}^{T} (X_{2i} Y_{si}/G_{si}) = X_{6t} + (X_{10t} - X_{18t})(1-\psi)\omega \tag{155}$$

and

$$\lambda \sum_{i=t+1}^{T} (X_{3i} Y_{1i}/G_{1i}) = X_{6t} + (X_{10t} - X_{18t})(1-\psi)\omega. \tag{156}$$

---

[84] If the planning horizon is extended to $\tau + 1$ periods, values for $F_{ST}$ and $L_{ST}$ become "competitively" determined, along with a corresponding output of $Y_{ST}$. If we assume that $F_{ST} = F_{sT}$, and that $L_{ST} = L_{sT}$, the variable defined in (153) is approximately equal to $Y_{ST}$, as it would be if determined competitively. The same considerations apply to (152).

From (155) and (156) it is evident that the decision to invest in SOC in either the subsistence or commercial agricultural sector depends on which of two weighted sums of two sets of ratios is larger. These ratios are the output/SOC ratios in each sector. Further, the weights applied to the ratios of the two sectors in each period are the same. That is,

$$X_{2t} = X_{3t} \quad (t=1, \ldots, \tau + 1) \tag{157}$$

since $X_{2t}$ is the marginal social value of agricultural production in the subsistence sector and $X_{3t}$ is the same quantity in the commercial agricultural sector. These two quantities must be equal since agricultural goods produced by the two sectors are perfect consumption substitutes. Thus, the decision to invest in SOC for either sector involves a comparison of two sets of ratios, $Y_{1i}/G_{1i}$ and $Y_{si}/G_{si}$ $(i = t+1, \ldots, \tau + 1)$. These ratios and their influences on the two sums in (155) and (156) mainly are the subject of the remainder of this section.

In dual economies, a substantial portion of the labor force usually is employed in subsistence agriculture and $L_{st} > L_{1t}$. Since the total labor supply is assumed fixed and perfectly inelastic and $L_{st}$ as a residual, it follows that as the supply of labor available for employment in the subsistence sector declines, or $L_{s,t+i} < L_{st}$, $i > 0$, as the economy develops. Assuming for now that the terms of trade (TT) between agricultural and manufactured goods remain constant and that no investment in subsistence SOC occurs in the first t periods (that is, $\bar{L}_{si} = 0$, $i=1, \ldots, t$), then

$$Y_{s1}/G_{s1} \geq Y_{si}/G_{si} \quad (i=2, \ldots, t) \tag{158}$$

since $G_{s1} = G_{si}$ and $Y_{s1} \geq Y_{si}$ because $L_{si} \leq L_{s1}$. From (115) and the assumption of constant TT, the effect of purchased manufactured inputs cannot offset the effect of the decrease in the labor employed in the subsistence sector.

Turning to the commercial agriculture, assume constant TT and no investment in SOC in the first t periods. Thus $G_{1i} = G_{11}$ since $\bar{L}_{1i} = 0$, i=1, ..., t. If there has been no investment in private capital in the agricultural sector in the first t periods (that is, $I_{1i} = 0$, i=1, ..., t), then $K_{1,t+1} = K_{11}$. Combining the assumptions of no private or public investment in the first t periods with the constant terms of trade assumption implies that $L_{11} = L_{1i}$ and $F_{11} = F_{1i}$, and therefore, that

$$Y_{11}/G_{11} = Y_{1i}/G_{1i}; \ (i=2, \ldots, t). \tag{159}$$

The results in (158) and (159) suggest that the absolute rate of decline of the social value of subsistence SOC diminishes over time relative to the absolute rate of decline of the social value of commercial SOC. This can be demonstrated as follows. Define the two sums in (155) and (156) as

$$A_t = \sum_{i=t+1}^{T+1} (X_{2i}Y_{si}/G_{si}) \tag{160}$$ and $$B_t = \sum_{i=t+1}^{T+1} (X_{3i}Y_{1i}/G_{1i}). \tag{161}$$

The absolute rates of decline of these sums between periods t-1 and t are

$$A_{t-1} - A_t = X_{2t}Y_{st}/G_{st} \tag{162}$$ and $$B_{t-1} - B_t = X_{3t}Y_{1t}/G_{1t}. \tag{163}$$

Forming a ratio of these differences and examining the ratio over time where $i > t$

$$\frac{(X_{2t} Y_{st}/G_{st})}{(X_{3t} Y_{1t}/G_{1t})} \geq \frac{(X_{2i} Y_{si}/G_{si})}{(X_{3i} Y_{1i}/G_{1i})}, \qquad (164)$$

with the strict inequality holding if $L_{st}$ declines over time. The significance of (164) is discussed after the implications of some of the foregoing simplifying assumptions are examined.

Relaxing the simplifying assumptions

Relaxing the assumption that no investment of private capital has taken place in commercial agriculture merely augments the result expressed in (164). If investment occurs in commercial agriculture, then (159) is modified to become

$$Y_{11}/G_{11} < Y_{1i}/G_{1i}; \ (i=2, \ldots, t). \qquad (159a)$$

Next, relaxing the assumption that the TT are constant and assuming that the TT move in favor of agriculture ($P_{1,t+i} > P_{1t}$, $i > 0$) has similar effect on (159) since at the higher prices more commercial agricultural production will be forthcoming. Changing of the TT over time, however, has an additional influence on the ratios in (164) via the response of subsistence production to price changes. If the subsistence response is perverse, this tends to augment the inequality expressed in (158) and, consequently also contributes to the decline of the ratios in (164). On the other hand, if supply response is positive, this would tend to offset the influence of the natural outflow of labor from the subsistence sector as the "rest of the economy develops." For present purposes, assume that, if the supply response is positive, this posi-

tive response is not sufficient to offset the effect of the outflow of labor. Thus, even if the TT move in favor of agriculture, $Y_{si}$ will decline in the absence of investment in subsistence SOC.

The remaining possibility is the case where the TT move against the agricultural sectors. Retaining the assumption of no investment in SOC, consider first the case where there is no investment in private capital in the commercial agricultural sector. If there is no investment in agriculture and the price of agricultural goods declines, the output of agricultural goods must fall by nature of the aggregate supply response in these sectors. Not only is this unlikely to occur (because of the nature of the relative marginal social utilities discussed earlier), but also the possibility of aggregate agricultural production falling below the initial output level is explicitly excluded by (123). Therefore, if the price of agricultural goods declines, this decline must be the result of expanded production and not the cause of decreased output. Expanded output of agricultural goods concurrent with declining prices can occur only if there is investment in either SOC or in private commercial capital goods. Thus, if the TT are moving against the agricultural sector and there has not been any investment in SOC, then there must be investment in private commercial agricultural capital. This means that aggregate production is increasing in the face of declining prices. In this situation, $Y_{st}/G_{st}$ must be declining while $Y_{lt}/G_{lt}$ is increasing. This is precisely the same set of results obtained under the assumptions of private investment with constant TT and thus the results are the same as in (164).

The significance of $A_t$ and $B_t$

Turning now to the implications of (164), this inequality suggests that the absolute rate of decline of $A_t$ over time decreases relative to the

absolute rate of decline of $B_t$. Assume again, for the moment, that the TT are constant and that no investment is occurring in private capital in the commercial sector. Assume further that $X_{2t} = X_{3t}$ is constant over time. These assumptions suggest that $B_t$ declines at a constant absolute rate while the absolute rate of decline of $A_t$ decreases.

Plotting $A_t$ and $B_t$ on a graph (where time is treated as a continuum) leads to six possibilities, five of which are shown on Figure 4 (p. 87): (a) $A_t$ is always above $B_t$ and the curves do not cross; (b) $B_t$ is always above $A_t$ and the curves do not cross; (c) $A_t$ crosses $B_t$ once from below; (d) $A_t$ crosses $B_t$ once from above; and (e) $A_t$ crosses $B_t$ twice, first from above and then from below. The sixth possibility is that the curves touch (become tangent) but do not cross.

Relaxing the assumption about investing in private commercial agriculture and allowing the TT to move in favor of agricultural goods has the effect of allowing $Y_{1t}/G_{1t}$ to increase over time, and the influence of (159a) replaces (159) in determining the rates of decline expressed in (164). Graphically, this simply has the effect of bending the straight line $B_t$ so that it becomes strictly concave downward. The net result is that the range of possibilities with respect to crossing combinations remains unchanged. Furthermore, it is asserted that relaxing the assumption that $X_{2t} = X_{3t}$ is constant has no essential influence on the nature of the crossing possibilities since allowing these values to vary over time simply changes the curvature of the two curves and does not alter the number of crossing possibilities.

The criterion involved in the decision of whether to invest in one or both of subsistence and commercial agriculture is the magnitude of $\lambda A_t$ and $\lambda B_t$ relative to the social opportunity cost of using government funds in alternative uses as expressed in (155) and (156). In terms of Figure 4, this

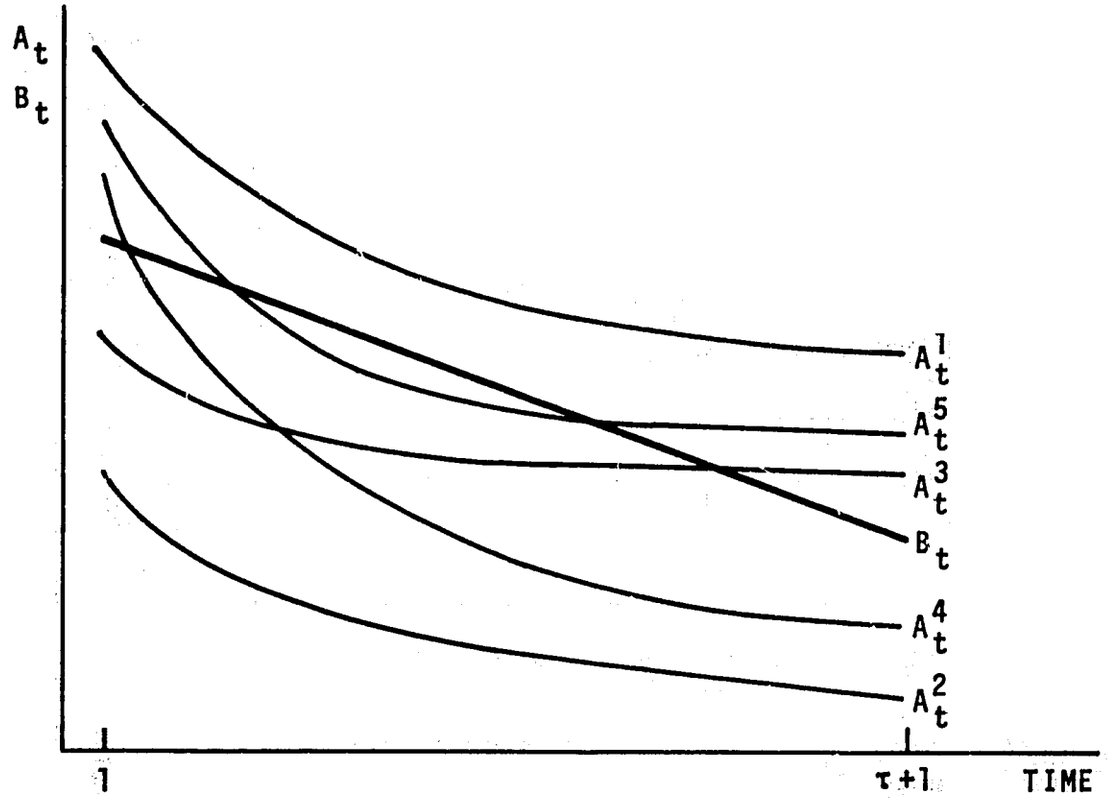


Figure 4 $A_t$ and $B_t$ with assumptions of no investment and constant TT

means that, if the social opportunity cost in any one period is sufficiently low, investment may occur in one or both of the SOC alternatives. The case where it is socially desirable to invest in commercial SOC is illustrated in Figure 5 (p. 98), where $C_t$ denotes the net social-opportunity cost as defined by the right hand side of (155) or (156). The $A_t$ and $B_t$ curves represent only one of the possibilities with respect to relative locations. At time t=t', the social benefit to be derived (at the margin) from investing in SOC in commercial agriculture exceeds that of investing in subsistence SOC. If, as illustrated, the value of $C_{t'}$ lies between $B_{t'}$ and $A_{t'}$, then it is socially desirable to invest in commercial SOC but not in subsistence SOC in period t' If $C_{t'}$ was less than $A_{t'}$, then it would be desirable to invest in SOC in both sectors. These considerations exemplify the importance of the relative location of the $A_t$ and $B_t$ curves.

In discussing the possible shapes of the two curves it was assumed that no investment in SOC would take place. When this assumption is relaxed, the problem becomes slightly more complicated because the curves begin to shift. Consider the following case, which is illustrated for time t' in Figure 5. Given the positions of the $A_t$ and $B_t$ curves relative to $C_{t'}$, it is desirable to invest in commercial SOC in period t'. Such an investment, however, shifts the location of the $B_t$ curve since, by definition, $B_t$ is a weighted average of the ratio of commercial production to commercial SOC. Increasing the value of the denominator in this ratio tends to shift the curve downwards. The downward influence, however, is partially offset by the increase in output of commercial agriculture associated with the increased SOC and the correspondingly higher level of purchased manufactured and labor inputs. The effect is that the ratio $Y_{1t}/G_{1t}$ must fall if $G_{1t}$ is increased because of the diminishing marginal productivity of SOC.

Expanded commercial sector SOC has a further downward influence on $B_t$.

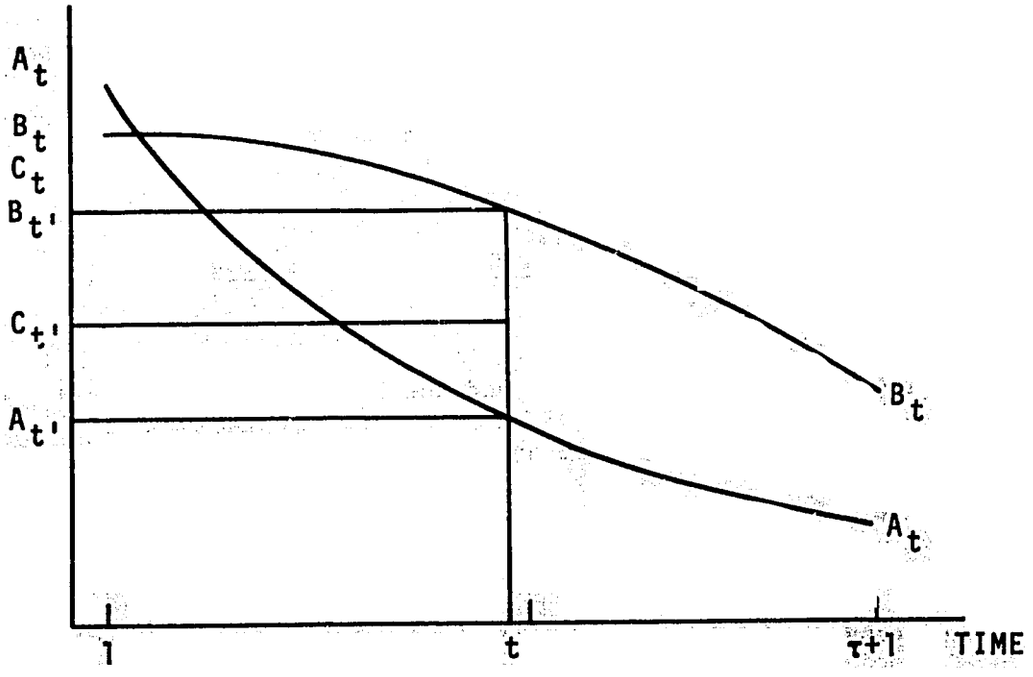


Figure 5. The decision to invest in SOC

Expanded agricultural output results in a decline in the marginal social value of agricultural goods in all subsequent periods, and it is this value ($X_{3t}$) that forms the weights in $B_t$. Since the marginal social value of agricultural output is the same for the commercial and subsistence sectors, investment in commercial SOC also tends to shift the $A_t$ curve downward.

Turning now to the question of the extent of the downward shift, $B_t$ must continue to shift downward until the value of $B_{t'}$ falls to the level $C_{t'}$. This is apparent from (154). If there are sufficient government funds available to drive $B_t$ as low as $A_{t'}$, then simultaneous investment in both subsistence and commercial SOC becomes socially desirable. Thus, if in any period t, investment occurs in both $G_{s,t+1}$ and $G_{1,\ t+1}$, then $A_t = B_t$ as is apparent from (155) and (156).

Economic considerations influencing the desirability of investing in subsistence versus commercial SOC

Having discussed the general shape and the importance of the relative locations of the $A_t$ and $B_t$ curves, we now examine the economic factors which determine the relative locations of these curves and attempt to isolate features of dualistic economies which make one curve lie above (or below) the other. In discussing the determinants of the location of these curves, it is preferable to start with the terminal period of the plan ($\tau$) and work towards the start of the planning period since the value of $A_t$ includes all the terms of $A_{t+i}$ ($i > 0$) plus some additional terms.

Letting $T = \tau + 1$, it is apparent from (152)-(154), (160), and (161) that

$$A_\tau = P_{1\tau}{}^{\theta}\sigma_S G_{s\tau}^{\lambda-1} F_{s\tau}^{\alpha 1} L_{s\tau}^{\alpha 2} \qquad (160a) \qquad B_\tau = P_{1\tau}{}^{\theta}\sigma_1 G_{1T}^{\lambda-1} F_{1\tau}^{\beta 1} L_{1\tau}^{\beta 2} K_{1T}^{\beta 3}. \qquad (161a)$$

It is the relative magnitude of these two terms that determines the relative values of the ordinates corresponding to the abscissa value of $\tau + 1$ for the two curves $A_t$ and $B_t$ in Figures 4 and 5. Since we are only interested in relative magnitude, the common factors $P_{1\tau}\theta$ can be ignored.

With the production function intercepts presented earlier, we have $\sigma_s = \bar{\sigma}_s B_s^{\alpha 4}$ and $\sigma_1 = \sigma_1 B_1^{\beta 4}$ where $B_s$ and $B_1$ are the quantities of land in the subsistence and commercial agricultural sectors, respectively. The relative size of $B_s$ and $B_1$ will vary greatly from country to country. The portion of the land that is farmed by mechanized means in many of the underdeveloped countries, however, is small relative to that which is farmed by traditional means. Since the land in the traditional sector frequently is more intensively farmed than land in plantations or larger units, we assumed that the productivity of land in the subsistence sector is higher than in the commercial sector. Another interpretation is that the share of the output attributable to land ($\alpha_4$) is larger in the subsistence sector than in the commercial sector ($\beta_4$). Based on these assumptions, we have

$$B_s^{\alpha 4} > B_1^{\beta 4}. \tag{165}$$

If the commercial sector uses modern and more productive techniques than the subsistence sector, the influence of land will be offset to some extent by the larger "index of technology." In other words, $\bar{\sigma}_s < \bar{\sigma}_1$ because more modern and efficient practices are being used on commercial farms. An additional offsetting factor is the influence of mechanization in the commercial sector. This influence is represented by $K_{1T}^{\beta 3}$. From (21) and (23) we have $\beta_2 Y_{1t}/L_{1t} > (\alpha_2 + \alpha_4) Y_{st}/L_{st}$, and since $\beta_2 < (\alpha_2 + \alpha_4)$, it follows that $Y_{1t}/L_{1t} > Y_{st}/L_{st}$. Even though it is assumed that $L_{st} > L_{1t}$, since $\alpha_2 < \beta_2$, it is impossible to

determine on the basis of these assumptions, whether $L_{st}^{\alpha 2}$ exceeds $L_{1t}^{\beta 2}$ in any particular period. Finally, from (115) and (116) and the assumption that $\alpha_1 = \beta_1$, it follows that $Y_{1t}/F_{1t} = Y_{st}/F_{st}$. Consequently, the magnitudes of $F_{st}^{\alpha 1}$ and $F_{1t}^{\beta 1}$ are proportional to the relative magnitudes of $Y_{st}$ and $Y_{1t}$.

Bringing these considerations together, it follows that the larger the relative size of the subsistence labor force relative to the commercial labor force, the larger $A_T$ will be relative to $B_T$. Similarly, the larger $B_s^{\alpha 4}$ relative to $B_1^{\beta 4}$, the larger $A_T$ will tend to be relative to $B_T$. Counterbalancing these two items, the larger the capital stock in commercial agriculture ($K_{1T}$) and the greater the disparity between the productivity of subsistence and commercial techniques ($\bar{\sigma}_s$ versus $\bar{\sigma}_1$), the larger $B_T$ will tend to be relative to $A_T$. The influence of purchased inputs varies with the relative size (measured in terms of output) of the two sectors. Thus, the relative values of $A_T$ and $B_T$ vary directly with the relative sizes of all the foregoing factors. The only exception is the size of $G_{sT}$ compared with $G_{1T}$. The relative sizes of $A_T$ and $B_T$ vary inversely with the relative quantities of SOC available in the two sectors.

Why are we concerned with the values of $A_T$ and $B_T$ since these are terminal values and no further investment in SOC can occur during the plan? The reason is that $A_T$ and $B_T$ form the base for all earlier values of $A_t$ and $B_t$. This becomes obvious when $A_{T-1}$ and $B_{T-1}$ are considered. We have from (162) for the subsistence sector

$$A_{T-1} = X_{2T} Y_{sT}/G_{sT} + A_T \tag{160b}$$

and, from (163), for the commercial sector

$$B_{T-1} = X_{3T} Y_{1T}/G_{1T} + B_T. \tag{161b}$$

Thus, the larger $A_\tau$ relative to $B_\tau$, the larger $A_{\tau-1}$ will be relative to $B_{\tau-1}$. In comparing the two additional terms in (160b) and (161b), the same factors of components have the same influence as in $A_\tau$ and $B_\tau$. This becomes obvious when these terms are rewritten as

$$Y_{S\tau}/G_{S\tau} = \bar{\sigma}_S G_{S\tau}^{\lambda-1} F_{S\tau}^{\alpha_1} L_{S\tau}^{\alpha_2} B_{S\tau}^{\alpha_4} \quad (166) \qquad Y_{1\tau}/G_{1\tau} = \bar{\sigma}_1 G_{1\tau}^{\lambda-1} F_{1\tau}^{\beta_1} L_{1\tau}^{\beta_2} K_{1\tau}^{\beta_3} B_1^{\beta_4}. \quad (167)$$

Finally, replacing $\tau$ by $t$ in (166) and (167), it is obvious that the same variables and parameters have similar influences throughout the entire period.

## PRIVATE CAPITAL ACCUMULATION

The allocation of private investment funds in this model is governed by the criterion of social desirability. This criterion differs from the criterion (maximization of the expected income earned on the capital stock in the subsequent period) used in the decentralized model. The application of the social desirability criterion to the investment alternatives is summarized in the first-order conditions (149)-(151). The social desirability of transferring revenue from the tax budget to the private savings budget is summarized in condition (146).

### The relative social desirability of investment alternatives

To simplify the analysis, notation similar to that used in the previous section is introduced. Letting $T = \tau + 1$, define

$$X_{4T} = \theta\theta, \quad (168)$$

$$X_{5T} = P_{sT}\theta, \quad (169)$$

$$\sigma_2(1+\epsilon)^T F_{2T}^{\gamma_1} L_{2T}^{\gamma_2} K_{2T}^{\gamma_3 - 1} = Y_{2T}/K_{2T}, \quad (170)$$

and

$$\sigma_3(1+\varepsilon)^T F_{3T}^{\delta_1} L_{3T}^{\delta_2} K_{3T}^{\delta_3 - 1} = Y_{3T}/K_{3T}. \tag{171}$$

Using this notation and the definitions of $X_{3T}$ and $Y_{1T}$ in (152) and (154), we can rewrite parts of the conditions in (149)-(151) in simplified form as

$$\beta_3 \sum_{i=t+1}^{T} (X_{3i}Y_{1i}/K_{1i}) \leq X_{9t} + X_{19t}P_{3t} \tag{149a}$$

$$\gamma_3 \sum_{i=t+1}^{T} (X_{4i}Y_{2i}/K_{2i}) \leq X_{9t} + X_{19t}P_{3t} \tag{150a}$$

$$\delta_3 \sum_{i=t+1}^{T} (X_{5i}Y_{3i}/K_{3i}) \leq X_{9t} + X_{19t}P_{3t} \tag{151a}$$

The remainder of the conditions in (149) require that if investment in $K_{1,t+1}$ is to be desirable in period t (i.e., it is deemed desirable for $I_{1t}$ to be positive), then the LHS of (149a) must be equal in magnitude to the RHS of (149a). In other words, if investment is socially desirable in period t, then the discounted present marginal social value productivity of private capital in commercial agriculture in all successive periods, plus the social value of post-plan productive capacity, must be equal to the social-opportunity costs of using investment goods and private savings in this manner. Similar interpretations apply to (150a) and (151a).

Economic factors affecting private investment

Making detailed comparisons among the desirability of the three private investment alternatives is more difficult than analyzing the two alternatives

available for investment in SOC. This enhanced difficulty results from the greater asymmetry involved in the choices among the private investment alternatives. One troublesome aspect of this asymmetry is that the products produced by the three sectors all have their own marginal social value. Thus, comparison among physical characteristics is no longer sufficient as in the decision between investing in either $G_1$ or $G_s$. The relative values of $X_{3t}$, $X_{4t}$, and $X_{5t}$ must be considered in comparing the relative magnitudes of the LHS of (149a)-(151a).

The allocation of the private savings among the three alternative sectors requires that investment must occur in at least one of these sectors in every period. This differs from the problem of deciding between $G_1$ and $G_2$ for SOC investment. In the allocation of government funds, it was possible that investment might not occur in either $G_1$ or $G_s$ in a particular period since the entire tax budget could be transferred to the private savings fund and used to accumulate private capital. No similar transfer option is possible for private savings. Consequently capital must be accumulated in at least one sector. Thus, the social opportunity cost of placing capital $(X_{9t} + X_{19t}P_{3t})$ cannot exceed the largest of the terms on the LHS of conditions (149a)-(151a) If investment occurs in more than one sector, the values of the LHS of the conditions (149a)-(151a) corresponding to these sectors must be equal. Investment, however, will be socially desirable only in those sectors for which the value of the LHS of the conditions equals the social opportunity cost. This equality will prevail only in those sectors with the larger values on the LHS. Thus, it becomes important to determine which economic factors contribute to increasing the value of the LHS of the conditions.

The share of capital One of the more obvious elements to be considered is the relative magnitudes of the three parameters $\beta_3$, $\gamma_3$, and $\delta_3$. From (149a)

-(151a) it is obvious that the larger any one of these parameters is relative to the other two, the relatively more desirable it becomes to have a higher (rather than lower) capital:output ratio in that sector. In other words, the larger the share of output attributable to capital in a particular sector, the higher the optimum capital:output ratio becomes relative to other sectors.

Social valuation of outputs The desirability of increasing the capital:output ratio in the various sectors is strongly influenced by the social values attached to the outputs of the three sectors $X_3$, $X_4$, and $X_5$. The social value of capital-goods production ($X_5$) is an indirect or imputed social value since capital goods do not enter the welfare function directly except in the evaluation of post-terminal productive capacity. Since in this model, capital goods are not consumed, production of capital goods is socially desirable only from the standpoint of the increased production and consumption of agricultural and manufactured goods made possible through the accumulation of capital in subsequent periods. At the other extreme, agricultural output is used for consumption purposes only. Consequently, the social value of agricultural production is derived strictly from direct consumption benefits, and no indirect value is imputed to agricultural production in this model. Between the extremes exemplified by agricultural and capital goods is the social value of manufactured production. Since manufactured goods are used both for consumption and as a factor of production, $X_4$ contains elements of both direct and indirect social value. The differences in the nature of the social values of the products of these sectors results from the different contributions the three types of output make to social welfare. A positive social value on capital goods production expresses a concern for expanded future consumption, while a positive value for agricultural or manufacturing production expresses a concern for present welfare.

In summary, during the initial periods of the plan it may be expected that $X_{2t} = X_{3t} > X_{4t}$. But, the magnitude of this inequality will decrease over time unless the production of manufactured goods expands sufficiently rapidly relative to agricultural production so that the $C_{1t}/C_{2t}$ declines enough to offset the different rates at which the marginal welfares diminish.

It is more difficult to make meaningful comparisons of $X_{5t}$ and $X_{3t}$ or $X_{4t}$ than to make comparisons between $X_{3t}$ and $X_{4t}$. Comparisons involving $X_{5t}$ require consideration of the social value of present versus future consumption since the value of $X_{5t}$ is an imputed value derived from the expansion of consumption of manufactured and agricultural goods. An intertemporal problem arises because the social payoff for production of capital goods in period t cannot be realized as expanded consumption before period $t + 1$. Thus, if society places a higher premium on present consumption relative to future consumption, the value of $X_5$ will be lower. The magnitude of $X_{5t}$ is strongly influenced by the social rate of discount, $\rho$, to be chosen by the policy-maker to reflect society's intertemporal preferences with respect to consumption. An increase in the social rate of discount will result in a decline in the social value of capital accumulation, $X_5$. The other parameter in the model, which reflects society's intertemporal preferences, is the weight given to post-plan productive capacity, $\theta$. This terminal productive capacity must, to some extent, be acquired at the expense of current consumption. Consequently, an increase in the magnitude of $\theta$ leads to a concomitant increase in the social value of capital goods production, $X_5$. Thus, the value of $X_5$ is determined to a large extent by the social rate of discount and the relative emphasis given to terminal productive capacity. Finally, the problem of comparing the relative magnitudes of $X_3$ and $X_4$ with $X_5$ involves such diverse considerations such as levels of production of the three goods as well as the relative rates of

expansion of $C_{1t}$ and $C_{2t}$. The most difficult problem, however, arises from the intertemporal aspects of current versus delayed consumption.

The rate of technical change and SOC accumulation The only terms on the left-hand side of (148a)-(152a) remaining to be considered are the output/capital ratios. From (106)-(108) we have

$$Y_{1t}/K_{1t} = \sigma_1 G_{1t}^{\lambda} F_{1t}^{\beta 1} L_{1t}^{\beta 2} K_{1t}^{\beta 3}/K_{1t}, \tag{172}$$

$$Y_{2t}/K_{2t} = \sigma_2 (1+\epsilon)^t F_{2t}^{\gamma 1} L_{2t}^{\gamma 2} K_{2t}^{\gamma 3}/K_{2t} \tag{173}$$

and

$$Y_{3t}/K_{3t} = \sigma_3 (1+\epsilon)^t F_{3t}^{\delta 1} L_{3t}^{\delta 2} K_{3t}^{\delta 3}/K_{3t}. \tag{174}$$

Since the numerators of the ratios in (172)-(174) involve different units of account, the only meaningful comparisons among them involve factors that change the relative magnitudes of these ratios over time.

The most obvious factor is the rate of technical change, $\epsilon$, in the manufacturing and capital goods sector relative to the rate of SOC accumulation in commercial agriculture. The "effective" rate of SOC accumulation is

$$\frac{G_{1,t+1}^{\lambda} - G_{1t}^{\lambda}}{G_{1t}^{\lambda}} = \left[ \frac{\bar{I}_{1t}}{\bar{G}_{11} + \sum_{i=1}^{t-1} \bar{I}_{1i}} \right] \geq 0 \tag{175}$$

Since $\epsilon > 0$, the productive influence of SOC accumulation in commercial agriculture may be greater than, equal to, or less than the exogenous rate of technical change in the manufacturing and capital goods sectors. Denote the LHS of (175)

as $\Delta G/G$. If $\Delta G/G > \epsilon$, then private capital accumulation in the agricultural sector is relatively more desirable than if $\Delta G/G < \epsilon$, the larger the rate of increase of the output:capital ratio in a sector, the relatively more desirable it will be to expand the capital stock in that sector. While $\epsilon$ is a constant, $\Delta G/G$ may vary over time. Consequently SOC accumulation will have a varied influence over time on the relative desirability of private investment in commercial agriculture.

Changes in the terms of trade The remaining elements in (172)-(174) that can alter the output:capital ratios are the inputs of manufactured goods and labor. From (115)-(121) it is apparent that the influence of these factors is determined over time by TT. Since $P_{2t} = 1$, the output:capital ratio in the manufacturing sector may be treated as a numeraire. If $P_{1t}$ increases over time, it will become profitable to employ larger amounts of labor and manufactured inputs in this sector, which will tend to increase $Y_{1t}/K_{1t}$ relative $Y_{2t}/K_{2t}$. This increase in the output:capital ratio in commercial agriculture will tend to make investment in this sector relatively more desirable than investment in manufacturing. The opposite result ensues if $P_{1t}$ declines over time. Similarly, changes in $P_{3t}$ over time will have analogous implications for the relative desirability of investing in the capital-goods sector. Thus as the TT move in favor of a particular sector, this will tend to make investment in that sector socially more desirable because it becomes profitable to employ more variable factors of production in that sector.

## PRIVATE INVESTMENT VERSUS SOC ACCUMULATION

The total funds available for SOC accumulation are the tax revenues collected in the particular period. The government budget constraint is given in (113). The funds available for private capital accumulation are the income earned by the existing capital stock plus any funds transferred from the

government budget. The private savings budget is given in (123). The transfer of funds from the government budget to the private savings budget must satisfy the first-order requirements in (146). These conditions may be rewritten as

$$X_{19t} \leq X_{10t}; \quad I_t(X_{19t} - X_{10t}) = 0; \quad I_t \geq 0 \tag{146a}$$

and require that the marginal social value of private capital investment ($X_{19t}$) must not exceed the social value of a marginal increment in SOC accumulation ($X_{10t}$). This relationship can be maintained by transferring government funds to the private savings budget if the social pay-off to private savings exceeds that to SOC accumulation. Furthermore, the marginal social value of investment in these two alternatives must be equal if transfer of funds from the government to the private budget is desirable.

Suppose that $\bar{L}_{st}$, $I_t$, and $\bar{I}_{1t}$ are all positive in period t, then (115) will be satisfied and the left side of (149a) will equal the right side. In addition, we have $X_{19t} = X_{10t}$. Eliminating these two variables from (147a) and (155), we have

$$\frac{\beta_3 \sum_{i=t+1}^{T+1} (X_{3i}Y_{1i}/K_{1i}) - X_{9t}}{P_{3t}} = \frac{\lambda \sum_{i=t+1}^{T+1} (X_{2i}Y_{si}/G_{si}) - X_{6t}}{(1-\psi)\omega} + X_{18t} \tag{176}$$

and the marginal social benefit of private investment in commercial agriculture must equal that for SOC accumulation in the subsistence sector. Relaxing the assumption that $I_t$ is positive weakens (176) so that LHS $\leq$ RHS.

Turning to the interpretation of individual terms in (176), the first

left term represents the discounted marginal value productivity of private capital stocks in commercial agricultural production in subsequent periods of the plan, deflated by the price of investment goods in period t. The second term on the left of it is the social opportunity cost of so using investment goods in period t, deflated by the cost of purchasing these goods. The first term on the right indicates the present social marginal-value productivity of SOC in subsistence agriculture production in subsequent periods of the plan per unit of net government labor cost. The second term is the social opportunity cost (per unit of government purchasing power) of using labor for SOC accumulation in period t. Finally, the last term on the right is the marginal social benefit derived from the increased consumer income resulting from the employment of labor in SOC accumulation.

The relative importance of the social opportunity cost of using capital goods per unit of private savings expended ($X_{9t}/P_{3t}$) and the social opportunity cost of using labor per unit of government expenditure ($X_{6t}/\{1-\psi\}^{\omega}$) will be influenced by the capacity of the capital goods industry and the size of the labor force. As the capacity of the capital goods industry increases relative to the size of the labor force, the social opportunity cost of using investment goods will decline relative to the social opportunity cost of using labor. This suggests the transfer of funds from the government budget to the private savings budget will be relatively more attractive in an economy that has a larger productive capacity in the capital goods industry. The opposite, of course, is true in an economy that has relatively more labor in proportion to capital goods capacity.

## AN ANALYSIS OF THE IMPACT OF FOREIGN AID

Foreign aid can take various forms and can be put to alternative uses by the recipient country. One principal reason for aid is assistance to the

recipient country in economic development. Another is short-run relief in emergencies. Frequently, however, the form of the aid and the conditions under which it is provided are geared to benefit to the donor country.

The models in this study do not allow an analysis of loan repayment for aid. However, outright gifts of specific commodities to the recipient countries can be analyzed. Since one of the principal forms of commodity aid has been in the form of food, the major portion of this section is concerned with a "comparative statics" analysis of a grant of food aid in one time period on the recipient country. Alternative methods of utilizing and distributing the food are analyzed. Some implications for other forms of commodity aid are drawn and some intertemporal considerations on development and resource allocation are discussed.

Three methods of food distribution are considered. The first and simplest is when food is given as a grant to the consumer. Under the second method considered, food is used by the government as wages in kind in the development of SOC. Under the third distribution method is the case where the government sells the food and then uses the market revenue, as indistinguishable from tax revenue. The economic consequences of these three alternative distribution methods are analyzed within the framework of a partial equilibrium model.

## Grants of Food to Consumers

Outright grants to consumers are assumed to be made for humanitarian reasons. Recipient consumers do not pay for the food. The aggregate consumer budget is augmented by an amount equal to its value. Assuming changes in the output and prices of manufactured and capital goods resulting from food aid to have a negligible effect on consumer income, we denote the aggregate budget constraint as

$$I = g(P, Y_s, Y_l) + PA \tag{177}$$

where I denotes aggregate consumer income, P denotes the price of agricultural output (food), and A represents the amount of food aid. Since a large portion of the total labor force is employed in the agricultural sectors, consumer income is considered a function of the price and level of output (employment) in these sectors.

Total demand for food is, given the population, a function of the relative price of food and consumer income. Thus, we have

$$D = f(P, I). \tag{178}$$

The total supply of food is the sum of domestic production and food aid, or

$$S = h(P, L_s) + A, \tag{179}$$

where domestic supply is a function of the price and the amount of subsistence employment. For equilibrium it is required that D = S. To determine the effect of varying the amount of food aid, differentiate D = S with respect to A and we get

$$\frac{\partial f}{\partial P}\frac{\partial P}{\partial A} + \frac{\partial f}{\partial I}\left\{\left(\frac{\partial g}{\partial P} + A\right)\frac{\partial P}{\partial A} + P\right. = \frac{\partial h}{\partial P}\frac{\partial P}{\partial A} + 1. \tag{180}$$

If aid depresses the price of agricultural goods ($\partial P/\partial A < 0$), theoretically the total quantity of food purchased will not increase by the amount of the aid since an offsetting decline in domestic production will be determined by

the responsiveness of farmers to price changes and the responsiveness of prices to changes in the amount of aid. The latter will involve the responsiveness of (a) consumer demand for food to changes in prices and (b) the income changes resulting from price changes and grants of food aid.

Multiplying both sides of D = S by P, differentiating with respect to A, and collecting terms we get

$$(D + PA + P\frac{\partial f}{\partial P} + P\frac{\partial f}{\partial I}\frac{\partial a}{\partial P})\frac{\partial P}{\partial A} + P^2\frac{\partial f}{\partial I} = (S + P\frac{\partial h}{\partial P})\frac{\partial P}{\partial A} + P. \quad (181)$$

Equation (181) indicated whether the total value of food tends to increase or decrease when the amount of aid is altered. If the sum of the terms on either side of the equation is negative, the total value of the food consumed decreases as the amount of aid increases. Dividing the left-hand side of (181) by D, we get

$$\{1 + \frac{PA}{D} + \frac{P}{D}(\frac{\partial f}{\partial P} + \frac{\partial f}{\partial I}\frac{\partial a}{\partial P})\}\frac{\partial P}{\partial A} + \frac{P^2}{D}\frac{\partial f}{\partial I}. \quad (182)$$

the term $\frac{P}{D}(\frac{\partial f}{\partial P} + \frac{\partial f}{\partial I}\frac{\partial g}{\partial P})$ defines the price elasticity of demand for food which Mellor suggests is approximately -0.9 for low-income countries [38, p. 72]. Since $1 + \frac{PA}{D} \geq 1$ and $\frac{\partial P}{\partial A} < 0$, the term $\{\ \}\frac{\partial P}{\partial A}$ will be negative unless this price elasticity estimate is too low. The likelihood that this term is negative will increase as $\frac{PA}{D}$ increases. The term $\frac{P^2}{D}\frac{\partial c}{\partial I}$ will be positive unless food is an inferior good. Thus, if the term enclosed as $\{\ \}$ is positive, the likelihood that the total value of the food consumed decreases as the amount of food aid is increased will be larger as the proportion of total food represented as aid increases. In other words, an increase in the amount of aid is

expected to cause the total value of food consumed to decline as the ratio of food aid to domestic production increases.

The principal effect of food aid as a grant is an increase in consumer welfare in the period of the aid. If the aid is a "once in a lifetime" effort and prices of agricultural goods are depressed for one period, a misallocation of private investment resources could result under the assumptions of the decentralized model. It also is conceivable that aid of this nature reduces the social value of marginal agricultural production ($X_2$ and $X_3$) in the centralized model. In case the government anticipated receiving this food aid, there would thus be a reduced incentive to invest in agricultural SOC in preceding periods relative to the incentive that would exist if no aid was anticipated. If the government planning authority anticipated receiving food aid throughout the duration of the planning period and no adjustments were made in the objectives of the plan, the resulting terminal capital structure also would differ (as compared with no aid received or anticipated).

Food Aid for Work Projects or Wages in Kind

Under this method of food distribution, recipients work on projects to earn food in the form of wages on SOC projects and laborers are from the subsistence sector. This method should reduce current agricultural production more than would food as a grant.

The amount of labor that can be hired through the use of the food as wages in kind is

$$(1 - \Psi)(\bar{L}_s + \bar{L}_1) = PA, \tag{183}$$

and substituting into (12) we get

$$L_s = L_o - L_1 - L_2 - L_3 - PA/\omega(1-\psi). \tag{184}$$

Thus,

$$\frac{\partial L_s}{\partial A} = -\frac{P}{\xi} - \frac{A}{\xi}\frac{\partial P}{\partial A} \tag{185}$$

and from (179) we get

$$\frac{\partial S}{\partial A} = \left(\frac{\partial h}{\partial P} - \frac{A}{\xi}\frac{\partial h}{\partial L_s}\right)\frac{\partial P}{\partial A} - \frac{P}{\xi}\frac{\partial h}{\partial L_s} + 1, \tag{186}$$

where $\xi = \omega(1 - \psi)$. Since $\partial h/\partial L_s > 0$ by assumption, the magnitude of (187) must be less than the value of the right side of (181). Consequently, the price decrease resulting from this type of distribution must be less than that due to a simple food grant since the demand side of (182) remains unchanged. The intra-period price effect of this type of distribution food is smaller, than if the food is given as a grant, because domestic production falls to a greater extent as a result of labor transfer from the subsistence sector. The result is a relatively smaller pay-off as compared to a direct grant within the period when food is used to employ labor on SOC work projects because consumption increases less than under a grant. In succeeding periods, however, there will be some additional social pay-off from the increased production possible because of the added SOC available for productive purposes.

## Market Sales of Food

The centralized model discussed previously considers two alternative uses for additional government revenue when the recipient country sells the food in the open market. The added revenue can be used to employ labor for SOC

accumulation or to purchase capital goods for investment in private capital accumulation. The first of these two alternatives is identical with the "wages in kind distribution method" considered in the preceding section.

The intraperiod consequences of using the revenue generated by food sales to purchase capital goods are more complex. The increased demand for capital goods will result in a higher price for capital goods. The result will be expanded production in this sector and a subsequent withdrawal of labor from the subsistence sector. Thus, (184) is replaced by

$$L_s = L_o - L_1 - L_2 - L_3 - \bar{L}_s - \bar{L}_1, \tag{187}$$

where $\bar{L}_s$ and $\bar{L}_1$ may be zero. Differentiating (187) with respect to aid we get

$$\frac{\partial L_s}{\partial A} = \frac{\partial L_3}{\partial P_3}\frac{\partial P_3}{\partial A} < 0. \tag{188}$$

The absolute magnitude of (188) is expected to be less than that of (185) since the revenue from food sales also must cover expenses such as additional manufactured inputs and more hired labor. Differentiating (179) under these assumptions we have

$$\frac{\partial S}{\partial A} = \frac{\partial h}{\partial P_1}\frac{\partial P_1}{\partial A} - \frac{\partial h}{\partial L_s}\frac{\partial L_3}{\partial P_3}\frac{\partial P_3}{\partial A} + 1. \tag{189}$$

The demand side of the system also requires modification since aggregate consumer income is no longer augmented by the value of the food aid. The additional food must be purchased out of income earned in other employment. Thus, equation (177) is replaced by

$$I = g(P_1, P_3), \tag{190}$$

where $P_3$ is included because output and production in the capital goods sector must be considered. Differentiating (178) with respect to food aid we get

$$\frac{\partial D}{\partial A} = \frac{\partial f}{\partial P_1} \frac{\partial P_1}{\partial A} + \frac{\partial f}{\partial I} \left(\frac{\partial q}{\partial P_1} \frac{\partial P_1}{\partial A} + \frac{\partial q}{\partial P_3} \frac{\partial P_3}{\partial A}\right). \tag{191}$$

Compare (189) with the right side of (182): Since $\frac{\partial h}{\partial L_s} \frac{\partial L_s}{\partial P_3} \frac{\partial P_3}{\partial A} > 0$, a change in P resulting from aid will cause the change in the quantity produced domestically, plus the amount of aid, to be larger if the aid is distributed in the form of grants (rather than sold in the market and the revenue used to purchase capital goods). The chain of results is this: Since purchase of capital goods causes an expansion of capital goods production, labor will be drawn out of the subsistence sector. A leftward shift in the domestic supply curve then will occur. Make a similar comparison between (191) and the left side of (181). The change in the quantity consumed under food grants will be larger than when food is sold in the market. There is an obvious reason for this disparity. When food is given as a grant, effective consumer income increases by the value of the food aid. A rightward shift in the demand curve occurs. Food sold in the market results in a smaller income effect and, hence, a smaller rightward shift in the demand curve. The net implication of these two sets of relative changes is that the quantity of food consumed will increase more when the aid is distributed in the form of grants than when it is sold in the market and the revenue so generated is used to purchase capital goods. The relative influence of the two distribution methods on the price of food will depend on the relative magnitudes of the demand and supply shifts.

Comparisons Among the Three Distribution Alternatives

The intraperiod relationships among the prices and quantities of agricultural goods under the three distribution methods are compared diagrammatically as in Figure 6 (p. 110). Demand and supply curves in the absence of aid are represented by the curves $D_o$ and $S_o$, respectively. They result in a price of $P_o$ and quantity consumed of $Q_o$.

Distributing food in the form of grants results in the largest shift in the supply curve since employment in the subsistence sector remains unchanged. Thus, $S_g = S_o + A$, where $S_g$ represents the total supply curve and $S_o$ represents the domestic supply curve that prevails if no aid is given. Since granting the food to consumers has the effect of bolstering consumer income, the demand schedule shifts to the right and becomes $D_g$. The resulting demand supply curves give a price-quantity configuration where $P_g < P_o$ and $Q_o < Q_g$. The equilibrium price under grants will be lower than under no aid unless the marginal propensity to consume food out of income is unity. In other words, if the recipients of food grants divert some of the income previously spent on food to the consumption of non-food commodities, a drop in price will result.

Turning now to the work projects form of distribution, the income effect is identical to that of grants, and $D_w = D_g$. The domestic supply curve will shift to the left since labor is transferred from the subsistence sector to SOC projects, but the shift is not sufficient to offset the influence of the aid under the assumptions embodied in (21).[85] Consequently, the equilibrium quantity consumed will increase and be greater than the quantity in the absence

[85] From (6), (21) and (184), we get $\frac{\partial Y_s}{\partial A} = -\alpha_2 \sigma_s G_s^{\lambda} F_s^{\alpha_1} L_s^{\alpha_2 - 1} \left(\frac{P}{\bar{S}}\right) > -1$.

Thus, the leftward shift of the domestic supply curve is not sufficient to offset the rightward shift of the total supply curve by the aid, $\frac{\partial A}{\partial A} = 1$.

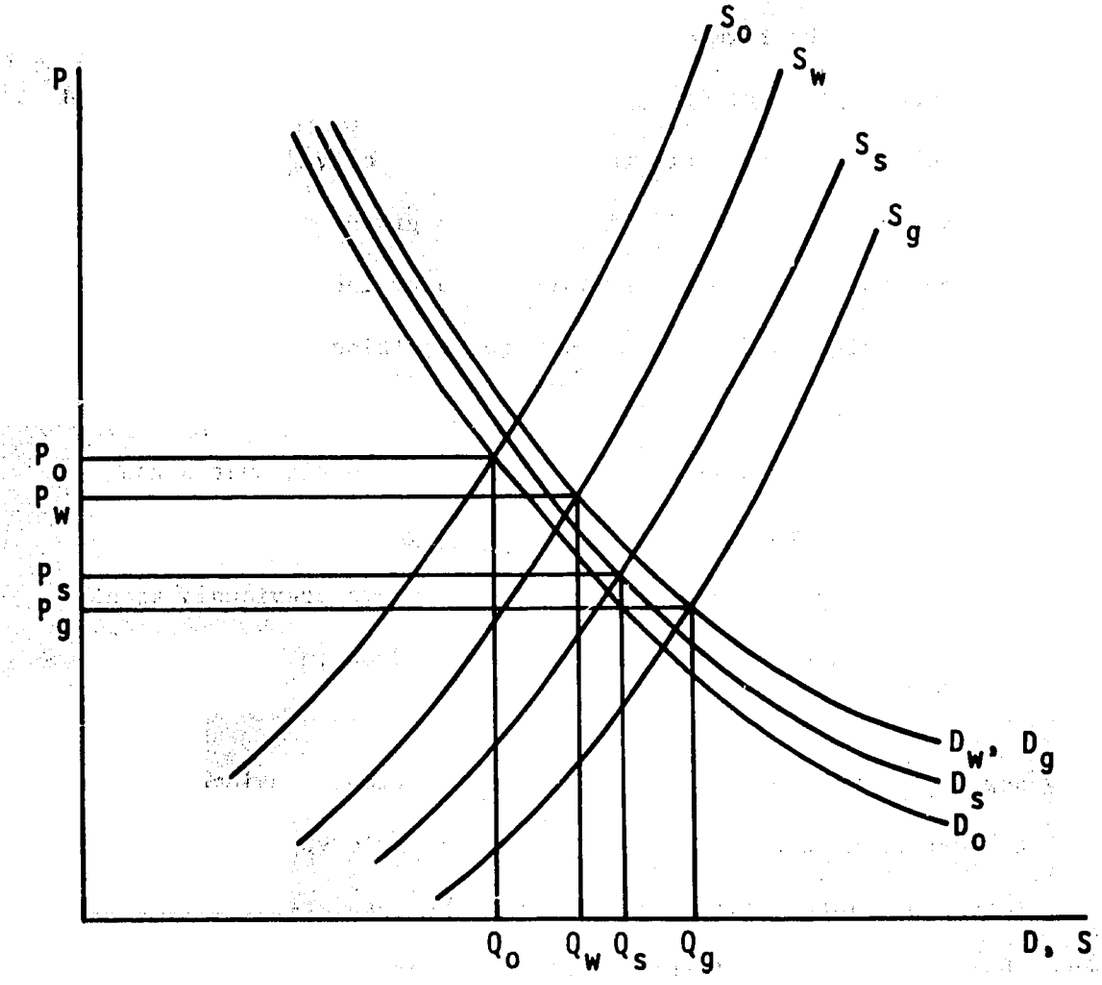


Figure 6. Prices and quantities of food consumed under alternative distribution methods

of aid. The increase in quantity consumed, however, will be less than that realized when food is in the form of consumer grants. This leads to an equil ibrium, $P_w$ and $Q_w$, with $P_o \geq P_g$ and $Q_o < Q_w < Q_g$.

Food aid through sales in the market place with the revenue used to hire subsistence labor to work on SOC projects affects the economy exactly as if the food was distributed as wages in kind because the revenue earned from the sales is all paid out in wages. Thus, the effect on consumer income is the same as in the wages in kind distribution and exactly the same amount of labor can be hired from the subsistence sector leading to identical demand and supply shifts. If the revenue from government food sales is used to purchase capital goods, however, the domestic supply schedule for agricultural goods will shift to the left by a smaller amount than in the case of wages in kind distribution, as is evident from comparing (189) and the RHS of (181). The demand curve does not shift as much since all the additional food must be purchased out of income earned in employment. Thus, income is augmented only to the extent that the increased purchase of capital goods bids up the price of capital and, hence, leads to increased employment in the capital goods industry where the return to labor is higher than in the subsistence sector. This income effect is smaller than that experienced with the grants or wages in kind distribution methods. Hence, $D_s$ must lie between $D_o$ and $D_w$. For the same reason, the new supply schedule $S_s$ must lie between $S_w$ and $S_g$. The resulting equilibrium price, $P_s$, and the quantity $Q_s$, have the properties that $P_o > P_w > P_s$ and $Q_o < Q_s < Q_g$. The equilibrium magnitude of $P_s$ relative to $P_g$ and $Q_s$ relative to $Q_w$ will depend on the extent of the shifts in the supply and demand sced-ules. These orderings may change if labor hired in each case comes from an urban or rural pool of unemployed workers, and not from subsistence agricul-tural workers.

Based on the assumptions underlying this study, and with no insulation from the market, food aid should depress the price of agricultural goods, regardless of the method of distribution. Similarly, food aid will tend to reduce the social value of a marginal increment of agricultural expansion. If a country was assured of receiving a certain amount of food aid for several periods and the government anticipated this aid in formulating its development plan, the incentive to expand the productive capacity of the agricultural sectors would be less than if no food aid was anticipated. If the food aid terminated unexpectedly, the economy would probably have a somewhat different capital structure than if the termination of aid was foreseen. This suggests that, if an economy begins to rely on and to expect food aid, the economic incentives to develop the agricultural sectors are reduced. One way to insure that some development of these sectors does occur is to stipulate that the food must be used on work projects designed to assist in the development of agriculture. For example, the food could be used to develop an irrigation system or a rural road system to facilitate the marketing of produce.

## Commodity Aid in General

Many effects of food aid discussed in the preceding section apply to any type of commodity aid that can be consumed directly. In terms of the models of this study, granting manufactured goods as aid would tend to move the terms of trade against that sector. Also, as long as a country is receiving this type of aid and expects to continue receiving it, there will be a reduced incentive to develop the sector. The social pay-off for expanding the productive capacity is reduced because the commodity aid serves as a substitute. Stipulations such as these will be good policy, however, only if a measure of self-sufficiency in the production of the commodity is desirable.

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