ECONOMIC–DEMOGRAPHIC SIMULATION MODELS: A REVIEW OF THEIR USEFULNESS FOR POLICY ANALYSIS

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ABSTRACT

This paper assesses the usefulness of economic–demographic simulation models for policy analysis, emphasizing in particular the relevance of the current state of the art for agricultural development planners. A critical review of eight models defines the range of questions that can be answered with particular models, evaluating the reasonableness of their specifications and the probable quality of their performance. Suggestions concerning further research are also provided.

The primary function of economic–demographic simulation models is to ascertain the quantitative importance of indirect effects of changes in the economic or demographic environment. For example, governmental policies concerning credit availability, which have a direct effect on the rate of growth of agricultural productivity, will have an indirect effect on rural population growth and rural to urban migration. A clarification of such interactions between demographic and economic phenomena is an essential ingredient of an enlightened development planning process.

The five "second-generation" economic–demographic simulation models reviewed in this paper are the FAO model, the Bachue–Philippines model, the Simon model, the Tempo II model, and the Kelley, Williamson, and Cheetham model. The main conclusion of the review is that although none of these models in their present form can offer reliable advice to agricultural policy makers, they may be useful as aids in teaching government officials about the potential long-run consequences of their decisions. Two third-generation models, the Adelman–Robinson model and the Kelley–Williamson representative developing country (RDC) model are also reviewed. Neither of these two models has a significant demographic component, but they are of interest because future economic–demographic simulation models are likely to be constructed around their fundamental concepts.

FOREWORD

Roughly 1.6 billion people, 40 percent of the world's population, live in urban areas today. At the beginning of the last century, the urban population of the world totaled only 25 million. According to recent United Nations estimates, about 3.1 billion people, twice today's urban population, will be living in urban areas by the year 2000.

Scholars and policy makers often disagree when it comes to evaluating the desirability of current rapid rates of urban growth and urbanization in many parts of the globe. Some see this trend as fostering national processes of socioeconomic development, particularly in the poorer and rapidly urbanizing countries of the Third World, whereas others believe the consequences to be largely undesirable and argue that such urban growth should be slowed down.

The formal modeling of demoeconomic processes of development is an "infant industry." A number of efforts to assess progress to date have been attempted. This report is a contribution to that literature. In it, Professor Warren Sanderson of Stanford University presents a critical review of several economic–demographic simulation models that have been developed during the past 15 years to clarify the indirect effects of changes in the economic or demographic environment. By clearly identifying the structure of each model and by pointing out its particular shortcomings of specification, Professor Sanderson has made available to policy makers a useful comparison and evaluation of alternative modeling perspectives.

This report is an expansion and revision of an earlier study prepared for the Policy Analysis Division of the Food and Agriculture Organization. The original paper quickly became a frequently cited reference among demoeconomic modelers; we hope that this revised version will reach a broader audience and stimulate a wider debate.

A list of the papers in the Population, Resources, and Growth Study Series appears at the end of this report.

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1 INTRODUCTION

This is a report on the current state of the art in modeling economic–demographic interactions, with added emphasis on the implications of this work for agricultural development. The god of manuscripts of this sort is undoubtedly Janus, one of whose faces is directed at past research, while the other points the way to future studies. In the spirit of Janus, this paper has two aspects – first, a critical review of selected economic–demographic models of development and second, a set of suggestions concerning further research.

Over the past decade and a half, the population of economic–demographic simulation models of the process of development has virtually exploded. The first such model appeared in 1963, and even by 1970 their number could be counted on one hand. Currently, however, although a complete count is difficult to make, there must be several dozen of these models in existence. Thus, policy makers who currently do not have economic–demographic planning models at their disposal will increasingly want to know whether there are any models that are suitable for their purposes, and those who do have such models at hand will increasingly want to know how their model compares with other similar planning tools. It is to these people that this paper is addressed.

Before we begin the review of the models, however, a brief discussion of their nature and purpose is in order. The primary function of economic–demographic simulation models is in ascertaining the quantitative importance of the *indirect* effects of changes in the economic or demographic environment. The models are not designed to give detailed guidance to policy makers about the direct effects of their decisions. For example, an official interested in increasing agricultural productivity will not find any of the models reviewed here very helpful. Expert advice from individuals specializing in agricultural policies, agronomy, animal husbandry, and pest control is likely to be of far greater use to him. Similarly, a policy maker who is interested in reducing rural fertility will not get much detailed guidance on how to do so from any of the models. For that purpose, he would be better served by consulting public health personnel. The models in this paper are not constructed to address such questions. Their usefulness is strictly limited to a different set of concerns – *interactions* between diverse phenomena.

Policy makers who are concerned, for example, with increasing agricultural productivity may well be interested not only in the direct effects of certain policies on agricultural output, but also in the indirect effects of those policies on rural population growth and rural-urban migration. Policy makers interested in demographic issues, such as policies concerning expenditures on family planning or policies affecting internal migration, may well be interested in the indirect effects of these policies on economic development. It is in such connections that the models may be legitimately employed because they can alert planners to indirect effects that can significantly reduce or enhance the thrust of their policies. The usefulness of these models does not arise from any of their aspects taken in isolation, but rather from the *interactions* between their various components. The proper role of economic-demographic planning models, then, is a modest one. Such models provide the policy maker with one tool, among the many he needs, to make sound judgments about the alternatives available to him.

Viewed in this light, questions concerning what is included in and what is excluded from economic-demographic simulation models can be answered with greater clarity. These models need to be sufficiently articulated to address major policy issues. They need to be strong in the area of economic-demographic interactions, but can be sketchy in certain details relating to the economy and the demography of the country.

Granted that economic-demographic simulation models have a modest place among the tools of development planning, the question naturally arises as to how well existing models perform the limited role for which they are useful. Unfortunately, this straightforward and important question has no simple answer. The models reviewed here are designed to understand the long-run pace and character of the development process, not short-term economic or demographic changes. To test directly whether the quantitative implications of a given model were correct in even one instance would require a lengthy experiment and a substantial amount of analysis of the resulting data. It is possible conceptually to test the models over some past era, but as a practical matter this is generally impossible because historical data are not available and in many cases the relevance of the model specifications for historical anlysis is dubious. Therefore, in evaluating economic-demographic simulation models the direct approach of testing their implications against reality is not feasible.

There is, however, the possibility of indirectly reviewing the usefulness of existing models. To understand how this can be done requires a brief discussion of the nature of those structures. Each of the models is composed of three related parts:

1. A list of parameters and exogenous and endogenous variables
2. A list of equations relating the exogenous and endogenous variables and the parameters
3. A set of values for the exogenous variables and parameters as well as for the initial values of the endogenous variables

The first component defines the set of questions that can be answered by using a particular model. The changes in any set of endogenous variables due to alterations in any exogenous variables and parameters may properly be studied. Since the models have different focuses, it is natural that their lists of exogenous and endogenous variables should differ. Unfortunately, the lists of exogenous and endogenous variables and parameters are bound to be a disappointment to those interested in agricultural planning. The models, with the exception of the one developed by the UN Food and Agriculture Organization (FAO), cannot address many of the questions of great importance for policy purposes.

The third component, the actual figures that are utilized in the versions of the models reviewed here, is not discussed in this paper. There are two reasons for this. First, these data are almost uniformly of poor quality. Indeed, many of the numbers used in the simulations are nothing more than educated guesses. Although guesstimates and approximations are often sufficiently accurate for the purposes of simulation, there is no easily available method for ascertaining whether one set of poor data is preferable to another set of poor data. The second reason for not discussing the input data here is that policy makers who are potentially interested in using a given framework are not as concerned about the figures in any given application as they are about whether the structure of the model can profitably be applied in their particular case.

The second component, the equations, forms the heart of any economic–demographic simulation model. Evaluating the equations provides an indirect basis for judging the likely performance of models. The specifications of the equations can be rated according to three criteria:

1. Do they allow the questions posed by the model to be answered in a meaningful manner?
2. Are they plausible?
3. Are they technically correct?

The first criterion is the most subtle of the three. Suppose for a moment that one important question to be answered by a particular model concerns the relationship between the rate of population growth and the rate of *per capita* income growth. Further, let the production function that relates aggregate output Y to the factors of production land A, labor L, and capital K have constant returns to scale. We may write

$$Y = f(L, K, A \mid T) \tag{1.1}$$

where T represents the technology at any moment in time. Now, if the model assumes that the rates of growth of the capital stock and the stock of land are independent of the rate of growth employment, that the rate of technological change is also independent of the rate of growth of employment (although it may depend on the rate of growth of the capital stock or the stock of land), and that the labor force/population ratio is constant, then decreasing the rate of growth of the population always increases the rate of growth of income per capita.[1] This conclusion obtains regardless of the parameter values. Indeed, it even holds for any constant returns to scale production function. If one did not know that this conclusion was built into the basic structure of the model, one might even be tempted to demonstrate how "robust" it was to parameter changes.

Such a model would not allow the question of the relationship between population growth and per capita income growth to be answered in a meaningful way because the direction of that association is assumed in the specification. Although the frameworks reviewed here are considerably more complex than the simple example above, some of them come quite close to postulating the results of their analyses. A number of such cases are discussed below.

The second principle on which to judge a specification is its plausibility. For example, one of the models assumes that agricultural output depends solely on the number of people employed in the agricultural sector and is independent of the agricultural capital stock and such material inputs as fertilizer, seeds, and water, while another model assumes precisely the reverse. It is implausible, however, to assume that either the marginal product of agricultural labor or agricultural capital is zero in the long run even if one or the other were true in the short run. The results of a model that contains implausible specifications of important relationships should be treated with caution by policy makers. Many, but not all, of these implausible specifications are described in detail below.

The third principle on which to evaluate one or a set of equations is their technical correctness. For example, in one of the models reviewed, two sets of demographic variables related to marriage and fertility are inconsistent with each other. The same model determines the output prices used in its consumption equations inappropriately. Such technical errors should be corrected before its simulation results are seriously considered by policy makers. Several such technical mistakes are revealed in the model reviews below.

Although the implications of the economic–demographic simulation models cannot be directly tested, a good idea of their likely performance can be gathered from an evaluation of their structures. Chapter 2 provides a summary of such evaluations for the seven models reviewed here.

2 OVERVIEW

This paper reviews five second-generation economic–demographic simulation models[2] and assesses their usefulness for agricultural policy formation in developing countries. The main conclusion of the review is that none of these five models in their present form can give serious guidance to an agricultural policy maker. Two third-generation simulation models, those of Adelman and Robinson (1978) and Kelley and Williamson (1979), are also reviewed here. Neither of these two models has a significant demographic component. They are interesting from our present perspective because future economic–demographic simulation models are likely to be constructed using their frameworks. Policy makers interested in economic–demographic simulation models would be well advised to begin with the Kelley–Williamson (1979) model and to expand it where necessary to address issues of relevance to their country.

2.1 THE FAO MODEL

The Food and Agriculture Organization model of Pakistan is the only model reviewed here that has any relevance to agricultural policy questions. The model consists of four segments: agricultural output, nonagricultural output, employment, and demography. Each of these segments and the model as a whole are constructed very simply. Indeed, in concept, the FAO model is the simplest of all the models reviewed. This simplicity is both its principal advantage and its main disadvantage. It allows, on one hand, a complete model to be built with very little actual data. This is a necessary characteristic of any model that is designed for widespread use in less developed countries. On the other hand, however, the simplicity weakens the credibility of the model's implications.

Four types of agriculture are distinguished in Pakistan: small-scale farming in rainfed regions, large-scale farming in rainfed regions, small-scale farming in irrigated regions, and large-scale farming in irrigated regions. In irrigated farming regions a certain amount of acreage is assumed to be withdrawn from cultivation each year and a policy-determined amount of land reclaimed. The government can, at a fixed cost per acre, redistribute land to small farmers or consolidate it into larger farms. In addition, government policy determines the amounts of investment and intermediate inputs such as fertilizer going to agriculture. The specification of the agricultural production process, however, is so simple that the results may not be meaningful. For example, since the production process assumes a constant marginal product of capital (i.e., agricultural capital never encounters diminishing returns even with a fixed quantity of land), it is likely that the optimum agricultural strategy for the government is to concentrate all agricultural investment in one of the four types of farming.

There are a number of omissions from the agricultural submodel that limit its usefulness. Foremost among these is the almost complete lack of attention to technological progress and its differential effects on various forms of farming. Another important omission is any consideration of the agricultural labor force. While it may be argued that labor is a redundant resource in agricultural Pakistan today, it hardly seems useful to assume that no development policy over the course of two or three decades will result in agricultural labor having a positive marginal product.

Output in the nonagricultural sectors[3] is similarly treated with extreme simplicity. Government policy is assumed to determine investment allocations in the modern sector, and all production processes are assumed to be characterized by constant marginal products of capital. Given the fixed relative prices implicit in the FAO model, nonagricultural output is maximized when the government invests in only that sector with the highest marginal product. Again, the quantities of labor used in the nonagricultural sectors of the economy have no influence on their levels of output. Further, the model has no demand functions for the various nonagricultural products except construction. Technological change embodied in new capital is allowed in the nonagricultural sector, but is not implemented in the Pakistani simulations. Disembodied technological change is not allowed to occur.

Besides migration and the specification that the country has a fixed budget in each year to spend on investment, the agricultural and the nonagricultural sectors are essentially unconnected in the FAO model. Migration is taken as depending on, among other things, the relative output–labor ratios in the agricultural and nonagricultural areas. This is taken as a proxy for the relative nonagricultural and agricultural wage rates, which are not determined. How good a proxy it is remains an open question.

The demographic submodel is not implemented in the Pakistani case. Instead, various assumptions are made about population growth rates. The educational system is also omitted from the present model, which may be just as well, since education is assumed to affect only fertility.

In short, the FAO model in its present form is simple enough to implement but not yet complex enough to be realistic. This is a common difficulty with these models, but the FAO model is the most simplistic of the models reviewed here. In particular, the specification of the agricultural sector is simplified to the point of unreality. Policy makers should, therefore, be wary of using the FAO model to guide the formulation of agricultural policy even though it is one of the few models that deals, even in modest detail, with agriculture.

2.2 THE BACHUE–PHILIPPINES MODEL

The Bachue–Philippines model differentiates 13 sectors, among which are domestic food crops, export crops, livestock and fishing, and forestry. This makes Bachue by far the most disaggregated second-generation model and the one with the most specificity in regard to agricultural outputs. Bachue is unlike the other models in that in most of its simulation runs the rate of growth of aggregate output is assumed to be exogenous. The model, therefore, is not designed to answer questions concerning the effects of policy decisions on the rate of economic growth. The focus of the model instead is on the distribution of income. Thus, Bachue is most useful in analyzing the effects of changes in the economic and demographic environment on the distribution of income in those cases where the changes themselves and the resulting alterations in the income distribution have little or no effect on the rate of economic growth. Another respect in which Bachue is unique among the models reviewed here is in its specification of the relationships between inputs and outputs. Except in the case of domestic food production, neither capital nor labor inputs play any role in the derivation of sectoral output levels. The quantity of domestic production in each sector is determined essentially by demand conditions. The quantities of the factors of production are calculated only after output levels are known.

The heart of the economic segment of the Bachue model is a 13 x 13 input–output matrix for 1965 that is assumed to remain unchanged over the simulation period. In order to avoid simultaneity, the final demand for the output of each of the 13 sectors is assumed to be predetermined in each year. Given the vector of final demands, the input–output matrix is used to compute the quantities of output produced by each sector. The usual procedure, given an input–output matrix and a vector of final demands, is to subtract competing imports from the vector of final demands in order to determine the vector of gross outputs. Instead of using this procedure, the model contains a system of simultaneous equations that jointly determine imports and gross outputs. This is a good idea, but the specific equations yield the implication that whenever a sector's exports increase (say, because of an increase in productive capacity), the sector's imports also increase. This hardly seems like a plausible assumption to make concerning all sectors of the economy.

Value-added per unit of output in current prices in the thirteen sectors are allowed to take on only two values, one for goods dominantly produced in rural areas and one for goods mainly produced in urban areas. The ratio of the two value-addeds is determined by the relative supply of and demand for domestically produced foods. On the supply side, labor productivity growth in the domestic food crop sector depends mainly on an exogenous (policy) parameter and to a limited extent on the rural–urban value-added ratio. Labor productivity and employment in the domestic food crop sector alone – capital and intermediate inputs play no explicit role here – determine the supply of domestic foodstuffs. The demand for domestic foods is computed as described above. When demand and supply are not identical in a given year, the relative value-added in the model changes in the following year. Current imbalances are eliminated through foreign trade. The two value-addeds for 1965, however, are inconsistent with those used to create the 1965 input–output table. Further, the output prices derived from the value-addeds are not appropriately used in the deflation of quantities of output measured in monetary units. A detailed procedure for correcting these problems is contained in section 3.2. The level of investment, like the level of aggregate output, is treated as exogenous in most of the simulations of the Bachue model. This has certain immediate implications: saving is essentially unrelated to investment, and investment is unrelated to both the level and growth rate of output in the Bachue model. Further, a technical problem also arises because of the exogenous nature of investment – how to allocate investment funds to sectors whose growth rates have already been determined by the input–output analysis. In Bachue, this is accomplished by using a set of fixed incremental capital–value-added ratios. Unfortunately, nothing guarantees that the aggregate amount of investment so computed equals the exogenous level of investment. This inconsistency is reconciled by an *ad hoc* adjustment of investment demands.

The income distributions in the model are based on (a) the distributions of employment not only across sectors but also with regard to self-employment and wage employment in most of the sectors and (b) the average annual incomes of the people in each category of employment. The methods of deriving the requisite numbers here are complex and in many instances not totally convincing. For example, the average annual incomes are incorrectly computed because of an error in moving from value-added in constant prices to value-added in current prices. To obtain distributions of household income from data on the distributions of employment and average annual incomes requires the transformation of information on the incomes of individuals to information on the incomes of households. Whether the complex procedure used to do this would yield reasonable approximations to true income distributions given correctly computed input data is difficult to ascertain.

The demographic portion of the Bachue model is both reasonably simple and sophisticated. Age-specific mortality and marital fertility rates are computed, as well as age-specific proportions of women currently married and age-specific numbers of people enrolled in school. There are, however, technical errors in this segment of the model as well. For example, the age-specific marital fertility rates and proportions of women currently married are inconsistent with the gross reproduction rate also derived in the model. Once the technical errors discussed in section 3.4 are corrected, the demographic segment of Bachue would easily be superior to those in the other models reviewed here.

The Bachue model has both strengths and weakness. Its attention to the details of the distribution of income and demographic processes is surely to be applauded. On the other hand, the economic portion of the Bachue model is, currently, quite weak, particularly with regard to the relationship between income distribution and economic development. Even some of the details of the income distribution process are technically incorrect. The model will be considerably strengthened when the technical errors are corrected and when serious attention is paid to making output growth and investment endogenous.

2.3 THE SIMON MODEL

The model of economic–demographic interactions created by Simon differs considerably from the other models reviewed here. Like the Kelley, Williamson, and Cheetham and Tempo II models, it has an industrial sector and an agricultural sector. Unlike those models, it was not developed to be applied in particular contexts, but rather as a tool for the study of the effects of population growth on economic development. This focus leads the Simon model to concentrate on relationships that run from population growth to economic development rather than from economic development to population growth. Perhaps the most unusual feature of the Simon model, though, is that in each year total output and total hours of work are chosen so as to maximize the country's social welfare function. This is one approach to making the hours of work done by the inhabitants of a given country endogenous. A more conventional and probably preferable approach to the same end would have been to specify labor supply functions separately in each of the two sectors of the economy. The social welfare function in the Simon model is not a stable one, but rather one that shifts around with changes in per capita income and the dependency rate. Whether a country can realistically be modeled as maximizing a social welfare function and whether that function can reasonably be characterized as shifting in the manner assumed by Simon are at best open questions and at worst unanswerable ones. A policy maker who does not know his country's social welfare function should not think seriously of using the Simon model.

The industrial and agricultural sector are both characterized by Cobb–Douglas production functions that allow for neutral technological progress. Output in each sector is produced using three factors of production: labor in the sector, capital (including land) in the sector, and the country's entire stock of social overhead capital. The elasticity of output with respect to social overhead capital in the two production functions is unity. Social overhead capital is assumed to grow at some fixed fraction of the rate of growth of the labor force! Thus, Simon sees more rapid population and hence labor force growth as increasing the rate of output growth, in part, by its effect of increasing the rate of accumulation of social overhead capital.

The agricultural capital stock in the Simon model is augmented annually by a quantity of investment that depends on the agricultural labor–capital ratio and the stock of social overhead capital in the previous period. The industrial investment specification, on the other hand, is apparently in error because it implies that net investment in industry is always negative. Technological change in the agricultural sector is assumed to proceed at a steady one-half of one percent per year. Technological change in the industrial sector is assumed to occur at a somewhat slower pace. Precisely how much more slowly depends upon the rate of growth of industrial output. For example, if industrial output is growing at ten percent per year, then technological progress occurs at a rate of three-tenths of one percent per annum; if it is growing at one percent per year, then technological progress occurs at a rate of one-tenth of one percent per annum. The rationale for the assumption of slower technological progress in industry than in agriculture is not stated in the Simon model.

The distribution of output between the two sectors of the economy in period t (assuming invariant relative prices) is assumed to depend upon the level of per capita income in period $t - 1$. As per capita income increases, it is assumed that the country automatically becomes more industrialized. There are no demand equations in the Simon model, no specification of the savings rate, no migration rate formulation, no educational structure, nor any information about the distribution of income between labor and capital.

The Simon model is an attempt at obtaining a simulation model that can be used to ascertain the effects of population growth on economic development. Unfortunately, the model makes a number of unconvincing structural assumptions and may contain outright economic errors. No policy maker should be influenced by the Simon model in its present form. Nor is this model a useful framework to develop for policy purposes. There are no interesting agricultural policy questions that can be addressed in the context of the present Simon model.

2.4 THE TEMPO II MODEL

Tempo II is a two-sector model that distinguishes a rural subsistence sector from an urban industrial sector. Industrial output is assumed to be generated by a Cobb–Douglas production process that allows for neutral technological change to occur at a constant rate over time. The inputs are assumed to be unskilled labor, skilled labor, and capital. Of all the models considered here, only Bachue and Tempo II allow education to enhance the productivity of workers.

The output of the agricultural sector, however, is assumed to be produced by labor alone, and no technological change is allowed to occur in agriculture over a simulation period of twenty to thirty years. Thus, agricultural land and capital play no role in the development process. Further, there is no social overhead capital either in the rural area or in the urban area. It is clear, then, that in the world of Tempo II, policy makers cannot increase agricultural output by teaching farmers to employ new techniques, by educating farmers generally, by increasing the capital intensity of agriculture, or by building rural social overhead capital. Indeed, there are no policies of agricultural development that are enlightened by Tempo II.

The outputs of both sectors in period t depend upon the quantities of inputs used in production in period $t - 1$. This rather odd specification ensures that the physical outputs in any period are essentially predetermined. Relative output prices are held fixed at unity over the simulation period – a weak assumption made in all the second-generation models except Bachue and the Kelley, Williamson, and Cheetham model – and income in any period is set equal to output in that period. The government, however, is allowed to run a deficit that is covered in part by the printing of money. In that case, aggregate demand, which is simply income plus the monetized portion of the government deficit, must exceed output, causing a generalized inflation to occur. As a practical matter, all elements of aggregate demand (except expenditures on education and family planning services) are reduced proportionally until aggregate demand and supply are again in equilibrium. Tempo II is the only model reviewed here that allows a government deficit to be covered by printing money.

With disposable income held constant, private savings per capita and therefore private investment per capita in the Tempo II model are assumed to be negatively related to the size of the population. This is in direct contradiction to the specification of investment in the Simon model. Since the capital stock in the urban area is the only capital stock in the country, it is determined from a base-period capital stock estimate plus accumulated net investment.

In the agricultural sector, the entire populace is considered as working, and an infant and an adult are each counted as one unit of agricultural labor. In the urban area, the size of the skilled and unskilled labor forces are determined by applying exogenous age- and sex-specific labor force participation rates to the age- and sex-specific numbers of skilled and unskilled workers. The numbers of skilled workers employed and unemployed are assumed to be fixed proportions of the skilled labor force. The number of unskilled workers employed, however, is determined from a very dubious equation that relates this number *negatively* to the size of the unskilled labor force if the ratio of the unskilled labor force to the capital stock is fixed. In other words, if the unskilled labor force and the capital stock were both to grow at, say 2 percent per annum, unskilled employment would *decline* continuously until eventually both it and industrial output would go to zero. This is hardly a realistic specification.

Tempo II is a policy-oriented model and is especially strong in its formulation of family planning policy. It is assumed that only the government spends money on fertility control and then only in the urban area. Further, it is assumed that up to a point the cost to the government of averting a birth remains constant. After that point is reached, the cost to the government of additional births averted rises. The cost to the government of a family planning program depends on how many births the government wishes to avert. With enough money, the government can always attain its fertility control objectives. It is interesting to note in this regard that nothing but the family planning program can affect birth rates in Tempo II, and, since there can never be a family planning program in the rural area, rural fertility rates are immutable for the entire simulation period of perhaps two or three decades.

The only policy that can be sensibly studied in the context of Tempo II is the government's policy toward family planning. Unfortunately, the specification of Tempo II ensures that increases in family planning expenditures will always cause an increased per capita income whenever the cost of averting an additional birth is less than twice the per capita income of the country. Indeed in the long-run, in the Tempo II model, expenditures on fertility control could increase per capita income even if the cost of averting an additional birth were about five or six times per capita income. This result is essentially built into the Tempo II framework by assuming that population growth has no stimulating effects anywhere in the economy. If this is what a policy maker believes, then the Tempo II result on family planning follows without a simulation model. If this is not what a policy maker believes, then he would be well advised not to accept the results of the Tempo II model.

2.5 THE KELLEY, WILLIAMSON, AND CHEETHAM MODEL

The Kelley, Williamson, and Cheetham (KWC) model of dualistic economic development in Japan is by far the most economically sophisticated of the second-generation models reviewed here. It is not designed to be a policy-oriented model, but rather is a model designed to shed light on Japanese economic development. Nonetheless, the KWC model has more potential for policy analysis than any of the other second-generation models that have been reviewed. The KWC model helps one to understand the behavior of a number of interrelated time series concerning Japanese economic growth and in this sense may be considered to be the only successfully tested model reviewed here.

The KWC model divides the Japanese economy into two sectors, an agricultural sector and an industrial sector. In both sectors a CES production function is assumed, with capital and labor as the inputs. This is a more sophisticated formulation than is used in any of the other studies. The importance of this specification is twofold. First, the use of the Cobb–Douglas production functions would constrain the elasticities of substitution between labor and capital to be unity in both sectors – a highly debatable assumption. Indeed, Kelley, Williamson, and Cheetham cite evidence suggesting that the elasticity of substitution is significantly smaller in the industrial sector than in the agricultural sector. The flexibility of the CES specification is not the only reason to prefer it. Perhaps a more important reason is that it allows the incorporation of biased technological change into the model. The KWC model and the Kelley and Williamson (1979) model are the only ones reviewed here that take this vital aspect of economic development into account.

Not only does the KWC model treat the supply side of the economy sensibly, it also treats the demand side in a plausible manner. The demands for the two goods in the economy are derived from a Stone–Geary demand structure. The interaction of the demand side and the supply side of the economy, logically enough, determines the quantities of the outputs produced and their relative price. It is rather disconcerting to realize that in none of the other second-generation models reviewed were outputs determined in any meaningful way by the interaction of supply and demand, nor, with the exception of the Bachue model, were relative prices considered to be endogenous.

This last point is extremely important. Over the course of economic development the terms of trade between industry and agriculture have a tendency to change for a number of reasons. Indeed, many agricultural policies themselves could be expected to affect the relative price of agricultural output. Models that do not have endogenous relative prices are severely handicapped for policy analysis. For example, without knowing the price of agricultural output relative to the price of industrial output, it is impossible to compute the relative wages of unskilled laborers in the two sectors and, hence, essentially impossible to obtain a reasonable migration specification. Similarly, it is impossible to compute relative rates of return to capital in the two sectors. This list can be made substantially longer, but the important point to remember is that policy makers ought not to consider seriously the implications from models of economic–demographic interactions that do not contain any endogenous relative prices. Such models are likely to lead them substantially astray.

Since in the KWC model the price of agricultural goods relative to industrial goods is endogenous, it is possible to compute the incomes of laborers and the return to capital in the two sectors. It is assumed in the KWC model that all labor income is consumed and that a portion of income from capital is saved and reinvested. Two specifications of how investment is allocated between sectors are given in the KWC model. The more relevant formulation assumes that capital stocks in each sector can be derived from an estimate of the base-year stocks and cumulated net investment. Investment in a given sector depends on the sectoral distribution of savings and the relative rates of return on capital in the two sectors. If the rates of return are not too different from one another, savings are assumed to remain in their sector of origin. If the rates of return are sufficiently out of line, some savings will flow from the low-rate-of-return sector to the high-rate-of-return sector. Migration is treated similarly in the KWC model. If the wage in the industrial sector is enough greater than that in the agricultural sector to overcome the cost of migration, then people will move from rural areas to urban areas. The greater the wage gap, the greater will be the migration rate.

Although the KWC model is not policy oriented, its framework is useful for policy analysis. For example, one can test the effect of stimulating agriculture by subsidizing agricultural output or the effect of inducing greater agricultural investment by subsidizing agricultural capital formation. Further, it is straightforward in the KWC model to experiment with policies that affect the rate of bias of technological change in agriculture. The principal weakness of the KWC model in its present form is its demographic specifications. The age structure of the population, for example, is not included in the model at all, and urban and rural fertility rates are taken to be wholly exogenous. The Kelley and Williamson (1979) model, discussed below, is an extension of the KWC model. It is a useful foundation for further development, but in its present form it also lacks much demographic structure.

2.6 THE ADELMAN–ROBINSON MODEL

Two third-generation development simulation models are reviewed here, the Adelman–Robinson model of Korea and the Kelley–Williamson model of a representative developing country. These models are more sophisticated in their economic specifications than are the second-generation models. Like the Kelley, Williamson, and Cheetham model, both of the third-generation models determine output prices, factor prices, and the composition of output simultaneously.

The Adelman–Robinson model of the Korean economy differs from the other models reviewed in this paper in its time horizon. While the other models are concerned with economic–demographic interactions that occur over the course of one or more generations, the Adelman–Robinson model is concerned with a time span shorter than a decade. The focus of the Adelman–Robinson model is on questions concerning the relationships between economic growth, economic policies, and the size distribution of household income. In its concerns and in some of its details, the Adelman–Robinson model is similar to the Bachue model. It is instructive, therefore, to compare and contrast the models in order to see which specifications are most useful in various contexts.

The Adelman–Robinson model is quite large, containing over 3,000 endogenous variables. It contains equations describing the workings of Korean financial markets, both formal and informal, equations representing 29 sectors of the economy, each containing firms of 4 sizes, and equations for the functional distribution of income and for the size distribution of household income of 15 distinct groups of income recipients.

The production functions for the urban commodity-producing sectors of the economy are assumed to be Cobb–Douglas in form. Agricultural output is produced by a two-level two-input CES production function where the factors are assumed to be capital and a labor aggregate, computed using a Cobb–Douglas specification.

Most labor supplies in the model are essentially exogenous. Some endogeneity is introduced, however, for 3 of the 15 categories of income recipients.

The demand for labor is determined from a specification that assumes that all firms are profit maximizers and that, therefore, laborers are paid the value of the marginal product. Instead of computing several hundred wage rates simultaneously, the model determines only one average wage rate for each of the 15 categories of income recipients. This greatly simplifies the computational burden of such a large model. Most of the remaining wage rates in the model are assumed to be fixed multiples of one or another of the 15 wage rates. Thus, in many cases, 78 wage rates are derived from a single average wage rate.

The procedure of computing 78 wage rates as fixed multiples of a single figure computed in the model is unfortunate in the context of a model whose focus is on questions concerning the distribution of income, because it builds into the model a substantial bias in favor of the conclusion that the distribution of income is quite stable.

Survey data are used to translate the functional distribution of income produced by the economic model into the size distribution of household income. The procedure used here and in the Bachue model to perform this function are quite similar. Among the assumptions made in this portion of the model are that the income distributions in each of 15 recipient groups is lognormal and that the (log) variances of about half of these distributions are exogenous to the model. The other half of the distributions have (log) variances that are determined mainly by the fixed multipliers mentioned above. Changes in the national distribution of income in the Adelman-Robinson model, then, must come mainly from alterations in mean incomes of various groups of income recipients and from changes in the occupational composition of the labor force.

In the Adelman-Robinson model, income available for consumption is determined by subtracting from nominal income savings, taxes, and changes in the holdings of money balances. The inclusion of money balances in the model allows Adelman and Robinson to construct a formulation in which the rate of inflation is endogenous. They are certainly to be applauded for recognizing the importance of this problem for contemporary developing countries. Unfortunately, however, desired change in the stock of money holdings by various household groups is not assumed to be a function of changes in that group's economic conditions, but rather to be an exogenous proportion of the aggregate change in the money stock.

Given income available for consumption, the commodity composition of consumption expenditure is based on a system of demand equations in which income and price elasticities are assumed to be constant during any given period. These elasticities are adjusted from period to period for the sake of accounting consistency.

Migration from rural to urban areas is treated very simply in the Adelman-Robinson model. The rate of migration is assumed to depend on the difference between the average incomes of workers in the sectors that are assumed to send the migrants and the average incomes of workers in the sectors that are assumed to receive the migrants. There is no mention in the model of any consideration of cost-of-living differences between urban and rural areas, nor do the characteristics of the income distributions in the urban and rural areas play any role in the migration decision.

The financial sector of the economy is specified in more detail in the Adelman–Robinson model than in any of the other models reviewed here. The function of the financial sector in the model is to allocate investment funds to the various sectors of the economy based on expectations of their future sales, output prices, factor prices, and profitability. The formulation in the model is a detailed one, which takes account of both the formal financial sector and the "curb" market.

The Adelman–Robinson model is a pioneering piece of research that will undoubtedly have a substantial influence on future model builders. In particular, the concern of Adelman and Robinson with the size distribution of household income in addition to the functional distribution of income has already influenced the character of the Bachue model and will certainly influence the shape of many future models as well. It is somewhat unfortunate in this connection that some of the specifications concerning the distribution of income in the Adelman–Robinson model are weak. I am confident, however, that further work in the area will strengthen them.

2.7 THE KELLEY–WILLIAMSON REPRESENTATIVE DEVELOPING COUNTRY (RDC) MODEL

The Kelley–Williamson representative developing country model is an extension of the KWC model discussed above. In the RDC model, as in the KWC model, output prices, factor prices, and the composition of output are all endogenous and simultaneously determined. There are eight sectors in the RDC model in contrast to the two sectors in the KWC model. The chief difference between the models, however, is not in the number of sectors but in the characteristics of the sectors. The RDC model distinguishes between manufacturing, agriculture, urban modern services, urban traditional services, rural traditional services, urban high-cost housing, urban low-cost housing, and rural low-cost housing. The first two of these outputs are assumed to be tradable both internationally and between urban and rural areas, and the third is assumed to be internally tradable, but not internationally tradable. In the remaining five sectors, however, outputs are assumed to be consumed only in the area in which they are produced. Thus, the outputs of a majority of sectors in the RDC model are neither internationally or interregionally tradable. The inclusion of internally nontradable goods differentiates the RDC model from all the other models reviewed here and permits the RDC model to capture aspects of the development process that are more difficult or impossible to study in the other models.

The production functions used to represent the two urban modern sectors (manufacturing and modern services) are two-level CES functions. These functions are consistent with a body of development literature that stresses that skilled labor and physical capital are complementary inputs. The demand for intermediate inputs purchased domestically is assumed to be derived from a set of fixed coefficients, as is the demand for intermediate inputs purchased from abroad. While the two-level CES production functions allow for factor-augmenting technological progress, for unbalanced technological change across sectors, and for complementarity as well as substitutability between the factors of production, the fixed coefficients allow neither for any intermediate input-saving technological change nor for any substitutability of any sort. The fixed-coefficient assumptions could introduce a substantial bias into the output of long-period simulation runs.

The production function representing agriculture is Cobb–Douglas in form with added fixed-coefficient assumptions concerning intermediate inputs. The outputs of the traditional service sectors are assumed to depend only on their levels of labor inputs, and the outputs of the housing sectors are assumed to depend only on the stocks of the various sorts of housing.

Given that capital stocks and aggregate labor supplies are predetermined in any given year and that all factors of production are paid the value of their marginal product, wage rates and the structure of employment are determined conditional on the following three assumptions: (a) unskilled labor in the rural sectors is perfectly mobile between those sectors; (b) skilled labor in the urban modern sectors is perfectly mobile between those sectors; and (c) unskilled labor in the urban areas is perfectly mobile between the two modern sectors and always is paid a constant percentage more than unskilled labor in the urban traditional service sector.

The RDC model makes an important advance over the other models discussed here in its formulation of the structure of savings and consumption. For this purpose, the model utilizes the newly developed extended linear expenditure system (ELES). The advantage of this specification – and it is indeed a substantial one – is that savings and consumption decisions are made in a unified framework and influenced in a consistent manner by income and relative prices. For example, the ELES system framework savings rates may be affected by alterations in the price of food. No other model considered here can capture such effects.

The allocation of investment funds in the RDC model is performed by a dual financial structure. Finance for investment in housing is assumed to originate only in the sector in which the housing is demanded. Further, housing finance is the first-priority use for savings. Only if there are funds left over after housing needs are met is there any nonhousing investment. The financial market in which nonhousing investment funds are allocated is assumed to be reasonably efficient, so that differences in marginal rates of return between sectors are minimized.

There are two aspects of the dynamic portion of the model that deserve mention here: migration and the rate of growth of the skilled labor force. The migration formulation in the RDC model is quite strong. Migrants are motivated to move from rural areas to urban areas because of real income differences. In computing these differences the rural migrants are assumed to take into account both differences in the cost of living between the parts of the country and the income distribution in the urban area and the associated probabilities that they would be able to obtain specified income levels.

Migration, then, plays a far more important role in the RDC model than it does in the other models. Migration in the RDC model affects the level of nonhousing capital formation by affecting the demand for housing and housing finance. On the other hand, migration also causes a set of changes in relative costs of living, which, in turn, reduces migration. No other model has been able to capture the interactions of forces such as these.

In most of the models reviewed here, the rate of growth of the skilled labor force was taken either to be completely exogenous or to depend on governmental policy with respect to expenditures on education. The RDC model, however, takes a position, first used, to my knowledge, by Edmonston *et al.* (1976), that there is an additional source of skilled laborers. When it becomes profitable for them to do so, firms can also train skilled workers. This is, I believe, an important feature to build into any long-run economic–demographic simulation model.

The chief disadvantage of the RDC model from the point of view of a policy maker interested in economic–demographic interactions is that the model in its current state is demographically underdeveloped. The authors discuss some possible demographic extentions of their model, and these would certainly be useful.

Policy makers interested in the construction of an economic–demographic simulation model for their own country would be well advised to begin with the framework of the RDC model and to add to it enough relevant detail to enable it to address questions of interest to them. For example, a policy maker may wish to add some material on income distributions from the Adelman–Robinson model, material on family planning and education from the Tempo II model, and some material on marriage rates from the Bachue model. It is crucial, however, that the additions be made on a consistent and realistic foundation – and this is exactly what the RDC model is.

3 THE BACHUE–PHILIPPINES MODEL

The Bachue–Philippines model, constructed with support from the International Labour Organization, is the largest and most ambitious of the second-generation models. It is composed of roughly 250 behavioral equations and identities (some in matrix form) and contains over 1,000 economic variables and over 750 demographic variables. One might expect a model of this size also to be one of unusual sophistication throughout, but this is not the case with the Bachue model. Instead, it is focused on issues relating to the distribution of income and employment. This is not to say that other matters have been completely ignored. Far from it: the model deals with a wide variety of additional issues. The treatment of those issues, however, is often extremely simplified, in contrast to the detailed consideration given to questions concerning the distribution of earnings and employment. Even in a model as large as Bachue, hard decisions have to be made concerning which aspects of reality should be emphasized and which should not.

3.1 DETERMINATION OF THE LEVELS OF GROSS AND NET OUTPUTS

The heart of the process of output determination in Bachue is a 13-sector input–output table based on 1965 data. The sectors are domestic food crops, export crops, livestock and fishing, forestry, mining, modern consumer goods, traditional consumer goods, other manufacturing, construction, transportation and public utilities, modern services and wholesale trade, traditional services and retail trade, and government services. In any year, say year t, the corresponding vector of final demands for these 13 sectors, $F(t)$, is assumed in the Bachue model to be predetermined. In other words, consumption, investment, and government expenditures in year t are assumed to be independent of output levels and income in year t. This is an important assumption in the model, and we shall return to it several times in the discussion below. The usual procedure, given an input–output matrix and a vector of final demands, is to subtract competing imports from the vector of final demands and to premultiply the difference by the inverse of the Leontief matrix to obtain the corresponding 13 x 1 vector of gross outputs. This procedure is shown in equation (3.1):

$$X^*(t) = (I-A)^{-1}[F(t)-Im(t)] \qquad (3.1)$$

where $X^*(t)$ is the 13 x 1 vector of gross outputs in year t, I is a 13 x 13 identity matrix, A is the 13 x 13 input–output matrix, $F(t)$ is the 13 x 1 vector of final demands in year t, and $Im(t)$ is the vector of competing imports in year t.

The use of this conventional approach, however, requires that the vector of competitive imports be determined prior to the computation of the vector of gross outputs. Because of this, the authors of Bachue–Philippines have used instead a system of three simultaneous equations that jointly determine import and gross output levels. The first is

$$Z(t) = (I-A)^{-1}F(t) \qquad (3.2)$$

where $Z(t)$ is a 13 x 1 vector that represents the *hypothetical* amounts of output that would be produced in year t if there were no competitive imports. The second equation (3.3) relates domestic production in each sector to the hypothetical amount of production that would have occurred in that sector if there were no competitive imports.

$$X_i(t) = \alpha_i(t)\cdot Z_i(t) + [1-\alpha_i(t)]\cdot E_i(t), \qquad i = 1,13 \qquad (3.3)$$

where $X_i(t)$ is the level of gross domestic production in sector i in year t; $\alpha_i(t)$ is an import-substitution coefficient, which changes over time at a prescribed rate; $Z_i(t)$ is the hypothetical amount of gross output in sector i in year t that would have occurred if there had been no competing imports; and $E_i(t)$ is the exogenously determined amount of exports for the goods produced in sector i in year t. The third equation in the output determination segment of the model is used to calculate the sectoral levels of imports.

$$Im(t) = F(t)-(I-A)X(t) \qquad (3.4)$$

where $Im(t)$ is the 13 x 1 vector of imports in year t and $X(t)$ is the 13 x 1 vector of gross domestic output levels in year t. Although the idea of simultaneously determining import and gross output levels is certainly a good one, the implementation of that idea in the three equations above results in the questionable implication that an increase in the export of output of sector i, *ceteris paribus*, always causes imports of that sector's goods to increase. This can be seen in the following numerical example.

Let us consider the consequences of exogenous one-unit increases in exports of the good produced in sector i. To make the argument concrete, assume that it takes 1.5 units of gross output in sector i to produce 1.0 units of net output. This is equivalent to assuming that the ith element of the diagonal of the inverse of the Leontief matrix, $(I - A)^{-1}$, is 1.5. Now, consider the economic impact of a one-unit increase in $E_i(t)$. Since exports are a component of final demand, $Z_i(t)$ must, according to the assumption above, increase by 1.5 units. If $\alpha(t)$ is 0.5 according to equation (3.3), the increase in gross domestic production must be 1.25 units.[4] There is clearly a problem here. To produce the one additional unit of output requires an increase of 1.5 units in domestic gross output, but only 1.25 units are forthcoming according to equation (3.3). How are the additional 0.25 units obtained? In Bachue–Philippines, it must be through an increase in imports.

This same result can also be demonstrated analytically. For ease of exposition, it is assumed that all the $\alpha_i(t)$ are identical and equal to $\alpha(t)$. Nothing significant in the argument is altered by this assumption. In this case, the expression for the import vector becomes

$$Im(t) = [1 - \alpha(t)] \cdot D(t) + [1 - \alpha(t)] \cdot A \cdot E(t) \tag{3.5}$$

where $D(t)$ is a 13×1 vector of domestic demand for the outputs of the 13 sectors in year t. In the Bachue–Philippines model $D(t)$ is determined by conditions in year $t - 1$ and $E(t)$ is exogenous. Therefore, it is legitimate to allow $E(t)$ to increase while $D(t)$ is held constant. Clearly, whenever the ith sector's exports rise, its imports must also do so, as must the imports of all other sectors providing intermediate inputs into sector i.

It is possible that increases in exports cause increases in imports under some circumstances. To elevate this notion to a general rule that must be maintained in the long run seems questionable, however. In any case, policy makers doing simulations of various possible export paths should keep in mind the relationship between imports and exports in the Bachue–Philippines model.

It should be noted in passing here that the $\alpha_i(t)$ in equation (3.3) are determined exogenously for the years 1965 through 1975 and are assumed to change at an exogenously predetermined positive rate thereafter.[5] With the passage of time all the $\alpha_i(t)$ approach unity asymptotically. In other words, it is assumed that the Philippines will come to import less and less as a proportion of its hypothetical (without imports) output levels. Thus, import substitution comes about exogenously without any explicit actions on the part of policy makers. This may be an unreasonable assumption in certain contexts, and in those circumstances it should be revised.

Problems also arise in the dynamic assumptions used in the Bachue–Philippines model. The authors provide readers with three choices of dynamic specifications. The simplest is the pure demand model in which there are no supply constraints. The dynamics of this model may be easily summarized. Begin first with a vector of final demands. This is translated into a vector of gross outputs. From that vector the model determines the distribution of personal income in period t and the distribution of consumption expenditures in period $t + 1$.[6] Since the amount and distribution of investment expenditures and government expenditures are essentially exogenous, knowing the distribution of personal consumption expenditures in period $t + 1$ is sufficient to determine fully the vector of final demands. Given this vector a new vector of gross outputs is determined and the process continues.

This formulation is clearly unusual, to say the very least. Output is produced with absolutely no consideration for any factors of production. Thus, the quantities of capital, labor, land, and skills have no impact on the ability of the country to produce output. Further, this formulation makes no allowance for technological progress.[7] This is, of course, in sharp contrast to the approach taken by Kelley, Williamson, and Cheetham, who maintain that biased technological progress is an important element in the story of Japanese economic development. This view that supply factors play no role in the process of development is not a plausible one. It is supplemented in the Bachue model with alternative specifications that allow some, albeit quite limited, role for supply forces.

In the second option, supply factors are introduced by the assumption that gross national product grows at a constant rate each year. If the growth rate of the computed gross national product falls short of the exogenous growth rate, then all elements of aggregate demand are increased so that gross national product grows rapidly enough. On the other hand, if the growth of computed GNP is too rapid, all elements of aggregate demand are reduced proportionally so that output grows at the exogenously given rate. This option is in some dimensions even worse than the specification in which supply does not enter at all. First, since the rate of growth of GNP is predetermined, supply factors still have no influence on the rate of growth of outputs, just as in the original case. One cannot ask about the effect of encouraging capital formation on output growth because in this framework, as in the first one, input growth has no effect on output growth. In the first framework, at least, one could ask questions about the impacts of various policies on the rate of GNP growth. In the second specification, however, nothing the government does can affect the rate of GNP growth. Any policies that affect the rate of population growth will affect the rate of per capita output growth, because the rate of growth of GNP is fixed. This is not a very plausible framework in which to discuss development planning aimed at increasing the rate of output growth. It may have some use in answering questions about the effect of various policies on the distribution of income given that the policies have no effect on growth. Unfortunately, the important questions concerning the trade-offs between inequality and growth cannot be addressed in this version of the model.

Most of the runs and most of the analysis are based on the second version of the model, in which both the rate of output growth and the quantity of investment in each year are taken to be exogenous. In other words, most of the simulations of the Philippine economy assume that output growth and investment are both unrelated to one another and unrelated to anything else in the model. The authors realize that many people consider these assumptions to be unrealistic in the context of a model of long-term economic and demographic change. Therefore, they have performed some sensitivity experiments with variants of the model that allow the rate of economic growth and investment to depend in part on economic and demographic conditions. The demand-dominated model discussed above is one variant of the basic model that is used in these runs. Since supply conditions play no role in this model and investment is still exogenously determined, its usefulness for policy analysis is dubious. A second variant makes the rate of growth of the economy and the level of investment positively related to the balance of payments surplus (or, equivalently, negatively related to the balance of payments deficit). That form of the model is still demand-dominated, but the constraint on growth is at least related to the character of the development process.

The third variant introduces aggregate supply considerations for the first time. Here the rate of growth of aggregate output is determined by the rate of growth generated by a one-sector two-input Cobb–Douglas production function with an exogenously given rate of technological progress. All the capital stocks in the country are aggregated (in an unspecified manner) into a single capital stock. All laborers in the country are aggregated regardless of their wage rates, location, sex, age, and education. Investment is also made endogenous in this variant of the model and depends basically on the rate of growth of aggregate demand lagged one period. Although these supply-side considerations are quite rudimentary, they are a small step in the right direction. The final variant of the model is identical to this one with the exception that the rate of technological progress is positively related to the rate of population growth.

In broad terms, the feature of the Bachue model that most policy makers will have difficulty accepting is the limited role given to supply constraints in the development process. This is not to argue that the process of long run economic and demographic change is to be wholly accounted for in terms of supply-side forces, only that supply- and demand-side considerations interact in an important fashion. The Kelley, Williamson, and Cheetham model of economic development in Japan provides a good example of one way in which the demand and supply sides of the development process can be successfully integrated. Policy makers interested in using the Bachue model may wish to supplement it with some of the ideas implemented there.

There is one important exception to the observation that the supply side of the Bachue model is underdeveloped. This relates to the specification of production possibilities in traditional agriculture. It is assumed that labor productivity in the production of domestic food crops grows at most at a rate $r(t)$ per year. The precise formulation used in the model is

$$X_1(t)_{\text{max}} = L_1(t)_{\text{est}} \cdot \frac{X_1(t-1)}{L_1(t-1)} \cdot [1 + r(t)] \qquad (3.6)$$

where $X_1(t)_{\text{max}}$ is the maximum possible amount of output of domestic foodstuffs in year t, $L_1(t)_{\text{est}}$ is the estimated labor force in the production of domestic food crops in period t, $L_1(t-1)$ is the actual labor force in the production of domestic foodstuffs in period $t-1$, and $r(t)$ is an endogenous but predetermined rate of growth.[8] The labor force in the production of foodstuffs must be estimated from the experience of past years in order to eliminate simultaneity from the model. The equation determining the estimated labor force in the production of domestic foodstuffs in period t is

$$L_1(t)_{est} = L_1(t-1) \cdot \frac{L_1(t-1)}{L_1(t-2)} \tag{3.7}$$

which simply assumes that the current year's rate of increase in the labor force in that sector will be identical to the previous year's rate. Thus, if the rate of growth of the labor force in domestic food production varies from year to year, $r(t)$ may differ somewhat from the *ex post* maximum rate of growth of labor productivity.

If, after the proportional adjustment of all the components of final demand upward or downward to meet the predetermined rate of aggregate output growth, the production of domestic foodstuffs exceeds the maximum output as determined in equation (3.6), there is a response in terms of imports. Gross output of foodstuffs in period t is set equal to $X_1(t)_{max}$ calculated in equation (3.6), and the vector of gross outputs so amended is then used in equation (3.4) to determine a new vector or imports. In this manner it is assumed that imports adjust in the current period to the output limitation.

The relationship between the actual output of foodstuffs and the maximum possible output in each year is assumed to affect the following year's ratio of agricultural to nonagricultural value-added per unit of output in current prices. To understand how this occurs, it is necessary to discuss the process by which sectoral value-addeds per unit of output in current prices are determined. There are thirteen sectors in the model, but the assumption is made that value-added per unit of output in current prices can take on only two values in a given year, one for the four agricultural sectors (domestic food crops, export crops, livestock and fishing, and forestry) and one for the nine nonagricultural sectors (mining, modern consumer goods, traditional consumer goods, other manufacturing, construction, transportation and public utilities, modern services and wholesale trade, traditional services and retail trade, and government services and activities not elsewhere classified).

Before proceeding to a discussion of how the ratio of the two value-addeds changes, it is useful to stop for a moment to evaluate the plausibility that value-added per unit of output in current prices takes on only two values. On the standard assumption that one physical unit of output is that which can be purchased by one currency unit (in this case, by one million Philippine pesos), value-added per unit of output in current prices for 1965 can be determined from the data underlying the input-output used in the model.[9] These figures are given in Table 1. They show that, although value-added per unit of output is generally higher in the agricultural sectors than in the nonagricultural sectors,

TABLE 1 Value-added per unit of output in current prices by sector: Philippines, 1965[a]

Sectors	Value-added per unit of output in current prices
Agricultural	
Domestic food crops	0.907
Export crops	0.910
Livestock and fishing	0.815
Forestry	0.870
Nonagricultural	
Mining	0.733
Modern consumer goods	0.636
Traditional consumer goods	0.570
Other manufacturing	0.620
Construction	0.650
Transportation and public utilities	0.712
Modern services and wholesale trade	0.831
Traditional services and retail trade	0.765
Government services and activities not elsewhere classified	0.985

[a] Data from: Rodgers *et al.* (1976), pp. IV-17 and IV-18.

constancy is not well approximated. Below, an improved procedure is discussed that makes use of the figures in Table 1.

Let $v_a(t)$ be the single value-added per unit of output in current prices in the agricultural sectors in year t and $v_n(t)$ be the single value-added per unit of output in current prices in the nonagricultural sectors in year t. The ratio of the agricultural value-added to the nonagricultural value-added is given by

$$\frac{v_a(t)}{v_n(t)} = \frac{v_a(t-1)}{v_n(t-1)} + k_1 \left[\frac{X_1^*(t-1) - X_1(t-1)_{\max}}{X_1^*(t-1)}\right] \qquad (3.8)$$

where $X_1^*(t-1)$ is the amount of output of the domestic foodstuffs sector in period $t-1$ after any proportional adjustments in the elements of aggregate demand but before the application of the productivity limit and k_1 is a constant that is set equal to unity in the simulations.

Several aspects of this specification deserve comment here. First, equation (3.8) relates changes in a value-added ratio to the excess demand or supply for domestic foodstuffs. A much more natural formulation would use the excess demand or supply of domestic foodstuffs to influence the relative price of domestic foodstuffs. Second, changes in the value-added ratio are assumed to be influenced only by the relation between the supply and demand for foodstuffs. Supplies and demands for other goods are assumed to have no impact. Third, the hypothesis that k remains constant at unity is quite weak, particularly for such an important link in the argument. There is no empirical evidence to suggest that k is either constant or in the vicinity of unity. Finally, it is not clear that value-added per unit of output in current prices in domestic foodstuffs and export crops changes proportionally, since the price of the latter can be expected to be closely aligned to world prices.

Given the ratio of prices determined in equation (3.8), the level of prices is determined as follows

$$\sum_{i=1}^{4} v_a(t)S_i(t) + \sum_{i=5}^{13} v_n(t)S_i(t) = 1 \qquad (3.9)$$

where $S_i(t)$ is ratio of value-added in constant prices in sector i in year t to aggregate output (in current prices) in that year, and where the sectors numbered 1 through 4 are the agricultural sectors and those numbered 5 through 13 are the nonagricultural sectors.

This process of deflating value-added per unit of output in equation (3.9) is quite unusual. To understand the problems with equation (3.9) requires some preparation. In a model of the kind we are considering there is a relationship between the input–output coefficients, sectoral value-added per unit of output in current prices, and output prices. That relationship is

$$(I - A')P(t) = v(t) \qquad (3.10)$$

where $P(t)$ is the 13×1 vector of output prices in year t, A' is the transpose of the input–output matrix, and $v(t)$ is the 13×1 vector of value-added per unit of output in current prices in year t.

Given the standard assumption that physical units of output are defined to be a quantity whose value is worth one currency unit (one million Philippine pesos, in this case), all the output prices in the base year are unity. Given those base-year prices, equation (3.10) can be used to obtain the value-addeds per unit of output in current prices shown in Table 1. As was discussed above, however, those are not the value-added figures used in the base year. Instead, the authors of Bachue–Philippines utilize their bi-level value-addeds derived from equations (3.8) and (3.9) to determine current output prices as follows:

$$P(t) = (I - A')^{-1} \cdot v(t) \qquad (3.11)$$

This method of price determination is seriously deficient as used in the model. First, if the correct value-addeds for 1965 were used without the level modification in equation (3.9), the current prices in 1965 would all be unity. Equation (3.9), however, raises all the value-addeds by some proportion and all the output prices by the same proportion. If the other equations in the model appropriately take the nonunitary prices into account (which is shown below not to be the case) this procedure is technically correct. When the bi-level value-addeds are used, however, the prices for 1965 without level adjustment are no longer equal to one another or to unity, as is, of course, also the situation after the level change.

The input-output coefficients in the matrix A, though, are computed for 1965 on the assumption that all the output prices are identical. Thus, the base-year prices, value-addeds, and input-output coefficients are inconsistent with one another. This is an important problem, and one that, because of equation (3.8), affects other years as well.

Two further problems affect the price system in Bachue–Philippines. First, because prices are not all unity, a distinction has to be made between expenditures in currency units and quantities of goods purchased. Unfortunately, this is not done in the model. The implicit assumption that output prices are indeed unity pervades much of the model. The result of this is that quantities are generally computed incorrectly. The second problem concerns the income determination segment of the model where an improper deflation causes the income flows to be mismeasured.

Any policy maker interested in using Bachue seriously must correct these problems. The simplest set of corrections to make in the spirit of the Bachue model are, first, to use the value-added per unit of output data from the 1965 input-output table. Next, keeping the within-agricultural and within-nonagricultural relative prices constant, modify the agricultural and nonagricultural price ratio as in equation (3.8). Third, use the new price vector computed in each year to determine value-added per unit of output in each sector in that year by means of equation (3.10). Fourth, use the vector of value-added per unit of output computed in step three with the appropriate base-year figures in the income distribution calculations. This four-step process will ensure that the price, value-added, and income distribution figures used in the model are, at least, consistent.

3.2 DETERMINATION OF THE COMPONENTS OF FINAL DEMAND AND SAVINGS

In all versions of the model except the pure demand-driven case, each component of final demand is computed twice. Generally, the initial values of the final demands for the 13 sectoral outputs are inconsistent with the predetermined level of aggregate output. To avoid this inconsistency and to maintain the predetermined level of output, the final demands for the output of the 13 sectors are altered proportionally. In the discussion below, we treat only the *ex ante* or first-stage values of the components of final demand.

Consumption and Savings

One of the most interesting features of the Bachue model is the treatment of the distribution of income. Household income in the urban and rural areas are divided into deciles, and savings and consumption expenditures are determined separately for each of them. Average household consumption of the output of sector i by households in the dth decile of the income distribution in location k in year t is given by

$$C^*_{idk}(t) = \theta_{id}(t) \cdot \{\alpha_{ik} + \beta_{ik}[Y^*_{dk}(t)_{\text{est}} - S^*_{dk}(t) - T^*_{dk}(t)] + \gamma_{ik} \cdot A^*_{dk}(t) + \delta_{ik} \cdot C^*_{dk}(t)\} \tag{3.12}$$

where $C^*_{idk}(t)$ is the average household consumption of the output of sector i in year t by households in location k in the dth decile of the income distribution; $\theta_{id}(t)$ is a multiplicative factor relating to prices[10]; $Y^*_{dk}(t)_{\text{est}}$ is the estimated average income in year t of households in location k who are in the dth decile of the income distribution[11]; $S^*_{dk}(t)$ is the average household savings accumulated in year t by households in location k who are in the dth decile of the income distribution; $T^*_{dk}(t)$ is the average level of income taxes paid in year t by households in location k in the dth decile of the income distribution; $A^*_{dk}(t)$ is the mean number of adults in location k in year t who live in households in the dth decile of the income distribution; $C^*_{dk}(t)$ is the mean number of children in location k in year t who live in households in the dth decile of the income distribution; and $\alpha_{ik}, \beta_{ik}, \gamma_{ik}$, and δ_{ik} are sector- and location-specific constants. The $\theta_{id}(t)$ in equation (3.12) are defined as follows

$$\theta_{id}(t) = \frac{Z^*_d(t)}{\left\{\left[\frac{P_i(t)}{P_i(0)} - 1\right]\epsilon_i + 1\right\}}, \qquad i = 1, \ldots, 13 \tag{3.13}$$

where $Z^*_d(t)$ is a factor that depends upon all the variables on the right-hand side of equation (3.12), the $P_i(t)$, and the ϵ_i;[12] $P_i(t)$ is an element of the $P(t)$ vector derived from equation (3.11) above; and ϵ_i is a sector-specific constant.

There are several aspects of this specification that require comment. First, the prices used should be from a procedure such as that outlined at the end of section 3.1 above. Second, equation (3.13) is not specified in terms of relative prices, but in terms of the level of a single price. A preferable manner of incorporating prices into demand functions is to use a known system of demand equations such as the Stone–Geary demand structure used in the Kelley, Williamson, and Cheetham model. We shall say more about this below. Third, the denominator in equation (3.13) may over the course of a long simulation period come to approach zero for some goods, causing the resulting pattern of consumption expenditures to become implausible. Fourth, the term $[Y^*_{dk}(t)_{\text{est}} - S^*_{dk}(t) - T^*_{dk}(t)]$ is supposed to equal the average consumption in year t of households in location k in the dth decile of the income distribution. The implicit assumption made here is that taxation has no effect on savings and affects only consumption. This assumption may not be true in many cases. Policy makers who wish to use the Bachue model to analyze policies involving increases or decreases in income taxes should ascertain first whether this particular assumption is appropriate for their countries.

Two important points concerning the consumption specification involve aggregation. First, aggregating across commodities within income deciles, the following equation must obtain:

$$\sum_{i=1}^{13} C^*_{idk}(t) = Y^*_{dk}(t)_{\text{est}} - S^*_{dk}(t) - T^*_{dk}(t) \qquad (3.14)$$

In words, the sum of the average expenditures on all goods in year t by households in location k in the dth decile of the income distribution must equal their average total consumption expenditures. Unfortunately, holding $Z^*_d(t)$ constant and altering any variable on the right-hand side of equation (3.12) will, in general, falsify equation (3.14). The sum of the average expenditures on all goods will no longer equal average total consumption expenditures. This problem must be resolved somehow, and it is in this context that $Z^*_d(t)$ plays a role in the consumption specification. Every time anything affecting consumption changes, $Z^*_d(t)$ and therefore the $\theta_{id}(t)$ move up or down until equation (3.14) is satisfied once more. This could easily lead to quite peculiar results. Suppose, for example, that a certain γ_{ik} is positive. One might think that this implies that when $A^*_{dk}(t)$ rises, $C^*_{idk}(t)$ rises, but this is not necessarily the case. The adjustment factor $\theta_{id}(t)$ may fall sufficiently under some circumstances as a result of the increase in $A^*_{dk}(t)$ that $C^*_{idk}(t)$ will actually fall. Such problems make equation (3.12) a very poor specification of the relationship between consumption levels, incomes, and prices. The weakness of this formulation should not be viewed as the inevitable result of the inherent complexity of the problem. There is a substantial literature on systems of demand functions that aggregate correctly and in which price and income elasticities enter in a consistent and coherent manner. Indeed, in the earliest of the models reviewed here, the Kelley, Williamson, and Cheetham model, such a system is used. For a discussion of those equations see section 7.2 below. It may be useful in future work on the Bachue model to replace the set of consumption equations with a set that has more plausible properties.

The second point regarding aggregation concerns aggregation across income deciles. The object of the consumption specification is to determine the total consumption demand for the outputs of each of the 13 sectors. This can be done by aggregating across income deciles and then summing across locations. It is instructive to note in this regard that none of the parameters in equation (3.12) except the correction factor $\theta_{id}(t)$ depends upon the decile level in the income distribution. If $\theta_{id}(t)$ were totally independent of the decile level, a simple summation across deciles in a particular location would yield a relationship in which total consumption of good i in location k would depend linearly upon total household income in location k, total savings by households in location k, and total taxes paid by households in location k. In other words, were it not for the unusual formulation in which consumption expenditures require the proportional adjustment described above, disaggregation by income level would be irrelevant for the determination of total consumption levels, except to the extent that such a disaggregation is required to compute total savings or total income taxes paid. Indeed, because of this, it is not surprising to learn that the effect of changes in the income distribution on the other endogenous variables in the model is quite small (see Rodgers *et al.* 1976, p. VII.9 and VII.10).

Before leaving the subject of consumption, it is important to make note of an equation that does not appear in the model, one relating consumption expenditures to the number of units consumed. The absence of this equation implies that output prices are thought to be unity. It was shown above, however, that this is not the case. Those interested in using the Bachue–Philippines model should supply the missing equations.

Average household savings in year t by households in location k that are in the dth decile of the income distribution is given by

$$S^*_{dk}(t) = \begin{cases} \alpha_k + \beta_k Y^*_{dk}(t)_{\text{est}} + \gamma_k [A^*_{dk}(t) + C^*_{dk}(t)] & d = 6, 10 \\ 0 & d = 1, 5 \end{cases} \tag{3.15}$$

where the variables are all as defined above in equation (3.15), but α_k, β_k, and γ_k are different constants. There are two important aspects of this savings function to note. First, it is discontinuous. Households in the lower five deciles of the income distribution are assumed not to save anything.[13] Second, the parameters of the savings function are independent of the decile level in the income distribution. Aggregating over the upper five income deciles implies that total household savings is a linear function of the total amount of income earned by households with incomes above the median, the total number of people who live in the households, and the total number of such households. Thus, for the purpose of computing total household savings, discrimination between two income groups is all that is necessary.

Before, we leave the topic of savings, one further set of remarks is in order. There is no direct connection between savings and investment in the Bachue model. In most of the simulation runs, *ex ante* investment is exogenous and thus its magnitude is independent of the amount saved. There is a weak indirect connection between savings and investment in those runs where output growth is predetermined. Increasing savings implies, holding everything else constant, that consumption will fall. If before the increase in savings aggregate demand was equal to aggregate supply, after the increase aggregate demand would be too small and each element of final demand, including consumption and investment, would have to be proportionally increased so that the equality could be maintained. In this manner, changes in savings can have a small impact on levels of investment. In most runs, however, this route for savings to affect the economy is attenuated even further by the assumption that output growth is unaffected by the growth of the capital stocks. The authors reveal on page IV.24 (footnote 1) that model outcomes are insensitive to household savings. The discussion here makes it evident why this is the case. Policy makers wishing to use the Bachue framework ought to consider whether the connections between investment and savings and between capital stocks and outputs are appropriate for their countries. If they are not appropriate, the policy makers may want to consider some of the alternative specifications of these relationships used in the models reviewed here.

Investment

Ex ante investment in Bachue is considered to be exogenous in most of the simulation runs, independent both of savings and the rate of output growth. For the period after 1975, it is assumed that *ex ante* total investment grows at 7 percent per year. Investment, it should be recalled, does not play a significant role in the Bachue model because capital is generally not treated as a factor of production. The capital stocks in various sectors do, however, play a small role in determining the distribution of incomes and the distribution of gross outputs. Two aspects of investment are relevant here. The first concerns the 13 x 1 vector of investment expenditures by sector of production. Actually, there are three such vectors in the model, one for government investment, one for investment in dwellings, and one for other private investment. The total amount of government investment is given as a fixed exogenous fraction of the exogenous amount of total investment. The total amount of investment in dwellings is endogenous, depending on the share of rents in total household consumption. The total amount of other investment is taken as a residual maintaining the exogenous amount of *ex ante* investment. Government investment and other investment totals are allocated to sectors according to fixed exogenous proportions. All investment in dwellings is allocated to the construction sector.

The second aspect of investment to be discussed is the allocation of capital according to sector of application. This is done through the use of a set of fixed incremental capital-output ratios. Clearly, the amount of investment required on the basis of those ratios may not equal the exogenous amount of investment funds available. To resolve this inconsistency, all the incremental capital-output ratios are proportionally increased or decreased so that the amount invested is equal to the amount available for investment. Thus, although the incremental capital-output ratios are nominally fixed, the *ex post* incremental capital-output ratios can vary considerably from year to year. Thus, a shortage of capital can never affect the rate of growth of output or the character of the development process. Fortunately, the allocation of capital among the various using sectors has little impact on the other facets of the model.

As with consumption expenditures, investment expenditures are not deflated before they are added to final demand. This should be modified by users of the Bachue-Philippines model.

Government Expenditures

There are several possible ways of treating government expenditures in the model. The most interesting alternative was the one used in the base run. There government expenditures were assumed to be determined by the following equation:

$$G(t) = a \cdot GDP(t-1) \cdot Pop(t)^{0.34} + U(t) \tag{3.16}$$

where $G(t)$ is the amount of government expenditures in period t, a is a constant, $GDP(t-1)$ is gross domestic product in period $t-1$, $Pop(t)$ is the total population of the country in period t, and $U(t)$ are additional expenditures on programs like education and public works. It is interesting to note with regard to this specification that the ratio of $G(t)$ to $GDP(t-1)$ is a positive function of population and the share of those additional expenditures in *GDP*. Thus, even if the latter is constant, the share of government expenditure in *GDP* is assumed to grow over time. Policy makers who are not in a situation in which it is reasonable to expect such an evolution should make appropriate modifications to this specification before they use the model.

Government investment is a fixed fraction of the exogenously determined amount of total investment. What remains of total governmental expenditures is called government consumption. Government consumption is allocated to sectors according to a fixed set of coefficients. Thus if 10 percent of government consumption is spent on domestic foodstuffs in 1965, 10 percent of government consumption will be spent on domestic foodstuffs in 2005. It is mildly curious that the allocation of these expenditures appears to have nothing to do with the quantity and the nature of the expenditures under the category $U(t)$. Thus, for example, increasing the amount of educational expenditures reflected in the $U(t)$ variable will not alter the *allocation* of total government expenditures by sector.

Like other elements of final demand, government expenditures are inappropriately undeflated.

Exports

The final element in final demand is exports. It is assumed, for the years following 1969, that exports in each sector grow at an exogenously given sector-specific rate.

3.3 THE DISTRIBUTION OF INCOME AND EMPLOYMENT

The Bachue–Philippines model exceeds all the other second-generation models reviewed here in the detail and care used in describing the labor market and the distribution of income. As we discussed above, neither the labor market nor the distribution of income has much direct impact on aggregate economic phenomena. For example, in the main version of the model, a more rapidly growing labor force cannot induce more rapid output growth because the rate of growth of aggregate output is considered to be exogenously determined. Nor can a rapidly growing labor force cause profits and therefore investment to increase because, first, profits are not directly related to either the number of workers or their wage rates and, second, total investment is independent of profits (and everything else in the model). Nonetheless, it is still of some interest to ascertain what, if anything, can be said about the effects of various policies on the distribution of income and employment. The question remains open, however, concerning the trade-off between growth and income distribution. Certain policies may worsen inequality for some period of time, but make everyone better off in the long run. Such policies cannot be studied in the context of the Bachue model.[14] Rather, what can be studied are the distributional aspects of some policies abstracting from any impacts they might have on the pace of development.

Labor Force Participation Rates

The Bachue model determines 176 labor force participation rates in each year. For the purpose of computing these rates, people are divided according to the following characteristics: sex (two categories), marital status (two categories – married or not for females and household head or not for males), education (two categories), age (eleven 5-year age groups) and location (two categories). The labor force participation rates for male household heads are assumed to remain constant at their 1965 levels. The remaining labor force participation rates are endogenously determined.

Since the variables that enter the labor force participation rate equations pertaining to groups of workers have a substantial overlap, we shall focus our attention here on the nature of those variables, rather than on the more numerous individual equations. One variable is the proportion in the previous period of the total number of employed people in a given location who work in modern sectors. It is assumed in the model that as this rate rises the labor force participation rates increase for all groups except single females who are above the age of 25 and who live in urban areas. Examples of the meanings of this specification are easy enough to cite It says, among other things, that as production in the rural areas shifts away from food production and moves toward forestry, construction, and transportation and public utilities, the labor force participation rates of married females will rise. This seems to presuppose that there is something about forestry, construction, and transport which induces rural married women to participate more readily in these sectors than they do in traditional agriculture. Whether the sign of this effect is correct must, it seems to me, remain open to serious question. Similarly, the model assumes that the labor force participation rate of urban male non-household heads also rises when the share of total urban employment that is in traditional pursuits diminishes. Yet a substantial number of urban male non-household heads are surely relatively young men (or boys) living at home who could more easily participate in the traditional than in the modern sector.

There is a methodological reason to suspect that many of the postulated directions of effect in the labor force participation equations are incorrect. The signs were not derived by regressing the indicated variables on participation rates, but rather by regressing some other variables on the participation rates and assuming that the coefficients remain basically unchanged when the indicated variable is substituted for the one used in the regression. For example, the effects of the proportion in the previous period of the total number of workers in a given locale who are employed in modern pursuits on labor force participation rates were not determined by a regression in which that variable actually appeared. The corresponding variable in the regression is the "percentage of people in the region of residence . . . who were enrolled in school last year and are working in a modern sector this year" (p. V.8). The relationship between the variable in the regression analysis and the variable in the labor force participation rate equations is sufficiently tenuous that it would not be surprising if a number of the signs in the latter equations are incorrect. This procedure of computing regression coefficients used in the labor force participation equations from independent variables that do not appear in those equations is replicated for two other variables.

The second variable used to explain labor force participation rates in location k in period t is the ratio of the arithmetic mean of disposable income in location k in period $t-1$ to the harmonic mean of the average incomes in the ten income deciles[15] in period $t-1$. Roughly speaking, that ratio is positively related to income inequality. Since this variable contributes positively to the labor force participation rate, income inequality is positively related to labor force participation rates. If output were allowed to be affected by employment, this relation would play a role in the trade-off between growth and income equality.

The third type of variable that is included in the explanation of labor force participation rates is a set of three location-specific employment shares: (a) the share of employment in construction, transportation, and public utilities, (b) the share of employment in modern services, wholesale trade, and government, and (c) the share of employment in the production of traditional consumer goods, traditional services, and retail trade. It is not worthwhile to detail all the assumptions relating these three shares to the labor force participation rates of various groups. Instead, as an example it will suffice to show the assumptions made with regard to the third share. This share is negatively related to the labor force participation rate of urban male non-household heads below the age of 34, but positively related to their labor force participation rates at higher ages. For rural male non-household heads that share is negatively related to labor force participation rates at all ages. For urban married women that share is positively related to labor force participation rates at all ages, but for their unmarried sisters living in urban areas it is negatively related to labor force participation rates. For all rural females, however, that share is positively related to labor force participation rates (except for unmarried females 15–19 years old, where there is no effect).

The final included variable pertains only to married women. It is

$$\left[\frac{Z_a}{MF_k(a) + 1}\right]^{-1} \tag{3.17}$$

where Z_a is an age-specific constant and $MF_k(a)$ is the marital fertility rate for women of age a in location k. This variable is positively related to age-specific fertility rates and is therefore assumed to be negatively related to labor force participation rates of those women.

It should be noted here that labor force participation rates are assumed not to be influenced either by wage rates or by prices. Making labor force participation rates endogenous is a difficult task. The authors of Bachue should be commended for their efforts in this regard even if the resulting specifications leave room for improvement.

The Determination of Aggregate Levels of Employment and Unemployment

By far the most articulated portion of the Bachue model relates to employment and the distribution of income. Because the urban and rural specifications of the functions in this portion of the model are quite similar, undue repetition will be avoided by focusing solely on the formulations relating to the rural area.

The determination of rural employment and unemployment begins in any year with the predetermined size of the labor force and the number of rural households.[16] These figures are affected over time by rural-to-urban migration (or the reverse), but are assumed to be unaffected by events in the current year. Employment is not computed from consideration of the demand and supply of rural workers, but rather from consideration of the relative wage rates in the various rural sectors in the previous year. The computation proceeds in two steps. First, the employment for period t is computed on the basis of relative wage rates in the traditional and modern sectors in the previous year. Next, the estimate of employment for period t is recomputed by averaging the initial estimate of employment and the level of employment in the preceding year.

More specifically, the expressions used in the model are

$$E_r^*(t) = \alpha \cdot \left[\frac{W_1(t-1)}{W_2(t-1)}\right]^{\beta} \cdot L_r(t) \tag{3.18}$$

$$E_r(t) = (0.5) \cdot E_r^*(t) + (0.5) \cdot E_r(t-1) \tag{3.19}$$

$$U_r(t) = \frac{[L_r(t) - E_r(t)]}{L_r(t)} \tag{3.20}$$

where $E_r^*(t)$ is the first estimate of employment in the rural area in period t, $E_r(t)$ is the final estimate of employment in the rural area in period t, $W_1(t-1)$

is the wage rate in the traditional rural sectors in the year $t - 1$, $W_2(t - 1)$ is the wage rate in the modern rural sectors in the year $t - 1$, $L_r(t)$ is the labor force in the rural area in period t, $U_r(t)$ is the unemployment rate in the rural area in period t, and α and β are positive constants.

The question that immediately arises concerns the meaning of those equations. One possible interpretation would be that the labor force measures the number of people who are willing to work at the prevailing wage rates and therefore provides the rural economy with a supply-of-labor curve of infinite elasticity up to $L_r(t)$. Employment then would be determined by demand conditions. But it is not clear under this interpretation why the *demand* for rural labor should be positively associated with the wage rate in the traditional rural sectors, although it seems plausible enough to assume that it is negatively associated with the wage rate in the modern rural sectors. An alternative interpretation is that the demand for rural labor is infinitely elastic. In this circumstance employment is determined by the supply of labor. This requires a new interpretation of $L_r(t)$, however. It would now be the labor force that would be employed at some very high wage. If wages were not sufficiently high, some members of the potential labor force would not work and therefore employment would be reduced. Under this interpretation both the wage rate in the traditional sector and that in the modern sectors should be positively related to employment.

Clearly, equation (3.18) is a mixed case. The implicit assumption seems to be that, with regard to the traditional rural employment, the supply-side effects dominate and, with regard to the modern rural employment, demand-side effects dominate. This is certainly possible. Still, if that is the story the authors wish to tell, it would have been preferable to weight the effects of wage rate changes according to the relative numbers of people employed in the modern and traditional sectors. For example, if modern rural employment accounted for only 1 percent of total rural employment, then a 1 percent increase in the traditional wage rate may possibly have quite a different effect on employment than a 1 percent decrease in the wage in the modern sectors. At present, in equation (3.18), it is assumed that the effects on employment of those two wage changes are identical.

Value-Added Shares

One important step in the process of determining the income distribution in the Bachue model is the division of the total value-added in each sector into a labor and a nonlabor share. In the rural sector this division is done basically by assumption. In all those sectors except one, it is assumed that the share of value-added in constant prices remains forever at the level observed in 1965. With regard to rural transportation and public utilities a different approach is used. The nonlabor share of value-added in that sector is assumed to be a linear function of the percentage of urban modern value-added in total value-added all measured in constant prices. The coefficients of that linear relation are derived from observations in the Philippines in 1965 and several developed countries (particularly Japan) around 1960.

Three points deserve brief mention here. First, as shall be shown below, what follows in the Bachue model requires that the value-added share assumptions be applied to value-added measured in current prices, not constant prices. Second, determining value-added shares as linear functions of the percentage of urban modern value-added in total value-added is extremely restrictive. It gives essentially no scope for short run policies to operate by changing value-added shares. And this leads to the third observation. Valued-added shares are an important determinant of the income distribution. Such a weak specification of how they behave is not consistent with the thrust of the modeling effort. Policy makers interested in using the Bachue framework should certainly pay some attention to improving the assumptions made in this portion of the model.

Distribution of Employment

Bachue distinguishes between two sorts of employment, self-employment and wage employment. Self-employment in rural modern sectors is given by the following equation:

$$E_{si}(t) = f_i \cdot \frac{W_{ni}(t-1)}{[W_{si}(t-1)]} \cdot H_r(t) \qquad (3.21)$$

where $E_{si}(t)$ is the number of people self-employed in the ith rural modern sector in year t; $f_i\{[W_{ni}(t-1)]/[W_{si}(t-1)]\}$ is a sector-specific function whose value is negatively related to the value of its argument, the ratio of average wage income $W_{ni}(t-1)$ to average nonwage income $W_{si}(t-1)$ in the ith rural modern sector in year $t-1$; and where $H_r(t)$ is the number of rural households in year t. The assumption made here is that as wage income increases relative to nonwage income, the number of nonwage income earners decreases. Suppose for a moment we apply this assumption to a hypothetical example in a particular rural modern sector – forestry. For the sake of discussion, let there be two types of forestry workers, those who chop down trees for themselves (self-employment) and those who do the same task for a company (wage-employment), and let their incomes be initially identical. Now, let the income paid to those with wage employment increase exogenously. A demand-side interpretation would be that workers would tend to move into the now higher-paying wage employment and out of self-employment. This is, of course, what is predicted by equation (3.21). A supply-side interpretation would be that the company would hire fewer loggers and thus cause self-employment to rise. This is, of course, the opposite of what is predicted by equation (3.21). But does the demand-side effect *always* dominate in this context? The answer to this is certainly unclear, but the question can provide some guidance to those who may wish to improve upon the specification in equation (3.21).

Wage employment in the rural modern sectors is computed using the following equation:

$$E_{ni}(t) = [V_i(t) \cdot K_i(t)^{-\beta_i} \alpha_i^{-1}]^{1/\gamma_i} e^{\delta_i t} - M_i(t) \quad (3.22)$$

where $E_{ni}(t)$ is the number of people working for wages in the ith rural modern sector in year t, $V_i(t)$ is the value-added in the ith rural modern sector in year t measured in constant prices, $K_i(t)$ is the capital stock in the ith rural modern sector in year t, $M_i(t)$ is the number of wage laborers who leave (enter) the modern rural sectors and take (leave) employment in the export crop sector,[17] β_i is the self-employment share of value-added in rural modern sector i, γ_i is labor's share in value-added, δ_i is a parameter relating to technical progress, and α_i is a constant.

There are several facets of this equation that deserve mention. First, there are two terms on the right-hand side of the equation, one representing the amount of labor that would be required to produce the appropriate amount of value-added if a Cobb–Douglas production function is appropriate. Given the assumption that value-added shares are constant in any given period, this choice seems to be the correct one. After the appropriate employment level is determined, however, a factor is added to that number – the number of people who formerly held jobs in the export crop sector but who will be employed in the modern rural sector in the current year (or the reverse if migration is toward the export crop sector). At first glance this seems rather unusual. If the Cobb–Douglas production function is indeed appropriate, then why should anything be added to the employment figure it generates? The people who come to be employed in the modern rural sectors should be a portion of that total, not added on to that total! The specification in equation (3.22) seems on its face to be roughly analogous to determining the temperature using the following approach. First, find an accurate thermometer and give it adequate time to measure the temperature correctly. Read the thermometer and take as your estimate of the temperature the reading on the thermometer plus or minus some other figure, such as the humidity or the rainfall within the last month.

Although accurate, this characterization is somewhat unfair. We are not dealing here with a neoclassical model of the economy and the distribution of income, but rather with a model that incorporates a number of assumptions that would not be included in such a model. As the authors correctly perceive, solving for employment using the inverted Cobb–Douglas production function would produce wage rate differentials that are terribly unrealistic. Therefore, in order to keep the wage rate differentials within a plausible range while maintaining all the other assumptions made in the model, the authors are forced to modify the Cobb–Douglas production function as they have done. Thus, given the other assumptions in the model, the specification in equation (3.22) may be preferable to the more obvious one in which just the inverted Cobb–Douglas production function is used. To maintain roughly the same story as in Bachue and to allow the inverted Cobb–Douglas production function to determine employment would require that the outputs of the rural modern sectors have different prices. This is not implausible, and individuals wishing to use the Bachue model in the future may wish to compute these relative prices.

Self-employment and wage employment in the export crop sector are separately determined. Wage employment in the export crop sector is computed by dividing labor's share of value added in that sector in *constant prices* by an estimate of the annual income of those employed in that sector. There are two problems with this approach. First, employment cannot properly be determined in that manner. The correct procedure would be to divide labor's share in value-added in *current prices* by the estimate of the average annual income of employees. The second problem relates to the estimate of average annual income. Instead of discussing this difficulty here, however, we will treat it below as one aspect of a more general problem.

Self-employment is calculated using the following equation:

$$E_{se}(t) = \frac{V_{se}(t)}{W_{se}(t)} - M^{*}_{se}(t) + M^{**}_{se}(t) \tag{3.23}$$

where $E_{se}(t)$ is self-employment in the export crop sector in year t, $V_{se}(t)$ is value-added in that sector in constant prices in year t, $W_{se}(t)$ is an estimate of the average annual income of self-employed people in the export crop sector in year t, $M^{*}_{se}(t)$ is the number of self-employed people in the export crop sector in the previous period who are employed in the modern rural sectors in the current period, and $M^{**}_{se}(t)$ is the number of self-employed people in the export crop sector in the current period who worked in the previous period in traditional agricultural pursuits. As was indicated in the preceding paragraph, the correct way to compute employment would be to divide value-added in current prices by an estimate of the average annual income of self-employed people. As employment is calculated in equation (3.23), it will not, in general, equal that figure. It might be argued that the approach taken in equation (3.23) is an alternative to the one suggested above. If that suggestion is to be taken seriously, policy makers interested in using the Bachue model should take care to ensure that the implications for the labor and nonlabor shares of value-added in current prices are acceptable.

Employment in traditional agricultural production is derived as a residual after total rural employment and employment in each of the other rural sectors is obtained.

Distribution of Income

Average annual income estimates in the Bachue model are generally computed incorrectly. They are calculated either directly or indirectly from the following equation:

$$W_{ri}(t) = \frac{V_{ri}(t)}{E_{ri}(t)} \cdot v_i(t) \tag{3.24}$$

where $W_{ri}(t)$ is the average annual income of type r (wage income or self-employment income) in sector i in year t, $V_{ri}(t)$ is the amount of value-added of type r in sector i in year t measured in constant prices, $E_{ri}(t)$ is employment of type r in sector i in year t, and $v_i(t)$ is the value-added per unit of output in sector i in year t in current prices. The correct computation of average annual incomes is accomplished by dividing the appropriate value-added in current prices by the corresponding employment figure. Equation (3.24) is in error because, generally, the appropriate value-added in current prices is not equal to corresponding value-added in constant prices multiplied by value-added per unit in current prices.[18]

Thus, the Bachue model has difficulties both in the determination of the distribution of employment between sectors and in the determination of average annual incomes in each of the sectors. Under some circumstances these problems may be serious, while in others they may be trivial. To be on the safe side, policy makers who are interested in the Bachue framework should correct those problems before trying to obtain meaningful simulation results for their countries.

The data on the distribution of employment and on average earnings in the various sectors are the major inputs into the portion of the model that determines the overall distribution of personal income. That segment is one of the most innovative features of the Bachue model. Rather than describing its entire structure here, we will discuss only the broad outlines of the income distribution determination. Separate distributions for rural and urban households income are computed. It is assumed that both distributions are lognormal and therefore are completely described by two parameters and the mean variance. The means of the two distributions are readily computed given the value-added shares discussed above and the number of households in each of the two areas.[19]

The variances of the two distributions are much more difficult to obtain. First, means and variances of incomes for people employed in the various sectors must be transformed into means and variances of incomes of households where the head is employed in given sectors, and second, the latter figures must be used to determine the appropriate overall variance. As one might imagine, a large number of assumptions are required to go from the data in the model to the variance of the household income distribution. For example, it is posited that in a given sector the incomes of heads and nonheads of households are identical. It is difficult to evaluate a system that is based on such assumptions. Although the assumptions may be technically incorrect, the resulting distributions of income may be good approximations. On the other hand, however, circumstances could arise in which the Bachue procedures may yield poor approximations to income distributions. Policy makers who are interested in using the income distribution feature of the Bachue model should carefully test it on their own data before accepting it as being useful for them.

3.4 THE DEMOGRAPHIC SEGMENT

The Demographic Accounting

The population in the Bachue model is subdivided along four major axes: (a) age (0–1, 1–4, 5–9, 10–14, . . . , 60–64, 65 and over), (b) sex, (c) location (rural and urban), and (d) education (less than primary, at least primary but less than secondary completed, secondary completed or more). The people in each of the categories must be followed across space and through time. The procedures for doing so are well known in the demographic literature. The use of 5-year age groups, however, creates problems because all the single-year data on birth, marriage, and education cohorts are lost. In a footnote on page VI.6 the authors suggest that future versions of the model would be simplified if single-year-of-age acounting were utilized. This is certainly the case, and policy makers interested in adapting Bachue for their own use should take this suggestion of the authors' seriously.

The Determination of the Number of Households in the Urban and Rural Areas

The number of households in the rural and urban areas are determined by applying exogenous rates to population groups disaggregated by age, sex, and location. The authors realize that economic development may change the propensities of various groups to form households, but they have no way to treat this complex phenomenon. Given the inadequate amount of information available, the assumption of constant headship rates may be about as good as any assumption one could make at present. Future work, however, could possibly take adavantage of the fact that the Bachue model also includes marriage rates.

The Determinants of Average Household Size and Composition

The average household sizes in the urban and rural areas are determined simply enough. The total number of people living in each location is divided by the total number ot household heads living in each place. The mode of determination of the latter figure is given in the immediately preceding section. The next aspect of the model that requires computation is the composition of households across varying levels of household income. This is accomplished by use of the following three equations:

$$A_{kd}(t) = A_{kd}(0) \cdot \left[\frac{p_{15^+,k}(t) \cdot p_{15^-,k}(0)}{p_{15^-,k}(t) \cdot p_{15^+,k}(0)} \right] \cdot \frac{F_k(t)}{F_k(0)} \tag{3.25}$$

$$C_{kd}(t) = C_{kd}(0) \cdot \left[\frac{p_{15^-,k}(t) \cdot p_{15^+,k}(0)}{p_{15^+,k}(t) \cdot p_{15^-,k}(0)} \right] \cdot \frac{F_k(t)}{F_k(0)} \tag{3.26}$$

"adjusted so that":

$$0.1 \cdot \sum_{d=1}^{10} [A_{kd}(t) + C_{kd}(t)] = F_k(t) \qquad (3.27)$$

where $A_{kd}(t)$ is the average number of adults in households in the dth decile of the income distribution in location k in year t, $C_{kd}(t)$ is the average number of children in households in the dth decile of the income distribution in location k in year t, $p_{15^+,k}(t)$ is the number of people in location k in year t who are at least 15 years old, $p_{15^-,k}(t)$ is the number of people in location k in year t who are less than 15 years old, and $F_k(t)$ is the overall average household size in location k in year t.

Two aspects of these specifications deserve attention. First, it appears that equations (3.25) and (3.26) by themselves should be sufficient to determine the composition of households in the rural and urban areas by income level. One difficulty with them is that the predicted numbers of adults and children when summed are inconsistent with the aggregate family size. This situation requires the adjustment made in equation (3.27). Unfortunately, the equations for that adjustment do not appear in the monograph. If the adjustment is like the others made in the model, it would be a proportional increase or decrease in all the relevant figures.

This leads to the second point. Adjustments consistent with equation (3.27) can be demographically inconsistent. A preferable way of proceeding would be to make some kind of adjustment that maintains the following two basic identities:

$$\sum_{d=1}^{10} A_{k,d}(t) = p_{15^+,k}(t) \qquad (3.28)$$

and

$$\sum_{d=1}^{10} C_{k,d}(t) = p_{15^-,k}(t) \qquad (3.29)$$

Adjustments performed to ensure that equation (3.27) holds do not necessarily ensure that the two identities above are met. This results in the possibility that the number of adults and children by income level do not necessarily aggregate to the number of adults and children in the relevant population group. This problem affects both the segment of the model dealing with the distribution of income and the portion dealing with savings and consumption. Policy makers wishing to use the Bachue framework should substitute a specification here that ensures that the demographic aggregation is correct.

Education

The Bachue model distinguishes three levels of education, less than primary, primary completed and less than secondary, and secondary completed or more. The major assumptions in the specification are that all children are enrolled in primary school and that their progression through the educational system is determined by a set of governmentally controlled completion rates. To the extent that completion rates are truly exogenous and under the control of the government, this specification is sufficient for modeling purposes. It should be noted in passing, however, that formal schooling is the only route to the development of skills in the labor market. If this is not roughly true in a country of interest to the policy maker, he could expand the specification given in the model.

Fertility

The fertility variable endogenously explained in the Bachue model is the gross reproduction rate. The authors of Bachue reject microlevel fertility equations and use instead an equation estimated on country-wide data. This choice is likely to be a wise one. Microeconomic and microdemographic specifications are unlikely to yield an equation that can predict a demographic transition, but country-wide data may be useful in this regard. The equation in the model has the following form:

$$\begin{aligned} GRR_k(t) &= b_k - 0.0064 \cdot R_k(t-1) + 0.0106 \cdot I_k(t-1) \\ &\quad - 0.0446 \cdot e_k^0(t-1) + 0.0059 \cdot L_A(t-1) \end{aligned} \tag{3.30}$$

where b_k is 5.14 in urban areas and 5.19 in rural areas, $R_k(t-1)$ is the female labor force participation rate in region k in year $t-1$, $I_k(t-1)$ is the percent illiterate in region k in period $t-1$, $e_k^0(t-1)$ is the life expectancy at birth in region k in year $t-1$, and $L_A(t-1)$ is the proportion of employment in agricultural activities (presumably in the country as a whole) in year $t-1$. It should be noted that this specification assumes that the government has no direct role in lowering fertility through programs of dissemination of contraceptive information or devices.

The demographic segment of the model, however, requires a set of age-specific marital fertility rates. Unfortunately, in moving from the gross reproduction rate to these rates, an error of disaggregation is made. The age-specific marital fertility rates are derived as follows

$$MF(a,t) = k_1(a) + k_2(a) \cdot TFR(t) + k_3(a) \cdot M(a,t) \tag{3.31}$$

where $MF(a,t)$ is marital fertility at age a in period t (in the model the dependent and independent variables are also specific for urban and rural location), $TFR(t)$ is the total fertility rate in period t (it equals the gross reproduction rate multiplied by a known constant), $M(a,t)$ is the proportion of women of age a in period t who are married, and the $k_i(a)$ are age-specific constants. The difficulty with this formulation is that the computed marital fertility rates, when used with the proportions married estimated in the model (see the following subsection) do not necessarily aggregate correctly to the total fertility rate. To make this point more precisely, let us write the relationship between marital fertility rates, marriage rates, and the total fertility rate:

$$\sum_a MF(a,t)\cdot M(a,t) = TFR(t) \tag{3.32}$$

where the summation is taken across the reproductive ages.

Multiplying equation (3.31) by $M(a, t)$ yields

$$MF(a,t)\cdot M(a,t) = k_1(a)\cdot M(a,t) + k_2(a)\cdot TFR(t)\cdot M(a,t) + k_3(a)\cdot M(a,t)^2 \tag{3.33}$$

Summing over the reproductive years, rearranging terms, and utilizing equation (3.32) produces the equation

$$TFR(t) = \frac{\sum_a [k_1(a)\cdot M(a,t) + k_3(a)\cdot M(a,t)^2]}{\sum_a [k_2(a)\cdot M(a,t)]} \tag{3.34}$$

The meaning of equation (3.34) is clear enough. Given the marriage rates and the age-specific constants in equation (3.31), the total fertility rate and therefore the gross reproduction rate are determined. To put the matter somewhat differently, under those conditions equation (3.30) is redundant and in general contradictory. Of course, we can consider the gross reproduction rate as calculated in equation (3.30) to be correct. In that case, one of the marriage rates must be determined by equation (3.34). Unfortunately, as is described in the following subsection, all the marriage rates are computed independently. Clearly, equation (3.31) introduces an inconsistency into the model – the age-specific marital fertility rates, marriage rates, and gross reproduction rate are overdetermined. This problem should be alleviated before the impacts on fertility of various policy changes are analyzed.

Marriage Rates

Marriage rates play two roles in the Bachue model, one relating to the determination of female labor force participation, the other relating to fertility. The mean ages at marriage in the rural and urban sectors are determined from linear equations where the dependent variables are the change from 1965 to the current year in the proportion of women with primary education not completed, the change from 1965 to the current year in the proportion of women aged 15–29 with secondary education, and the change from 1965 to the current year in the proportion of women 15–29 in the labor force.

Given the mean age at first marriage, the authors claim to obtain the age-specific proportions married from the standard nuptiality rate table in Coale (1971).[20] Technically speaking, however, that work cannot be used to determine age-specific proportions married but rather age-specific proportions of women *ever* married. This difference is not of much importance where life expectancies are relatively high and where divorce rates are relatively low, but it may be of some importance where these conditions are not met. Even as an approximation, the Coale nuptiality rate formulation is the best possible one to use in this context.

Mortality

Life expectancy at age zero in the rural and urban areas is derived from a linear function of three variables: (a) the inverse of per capita gross domestic product, (b) the inverse of the square of per capita gross domestic product, and (c) the Gini coefficient of income inequality. A separate life expectancy is computed for the urban and for the rural areas. Given the life expectancy at age zero, age-specific mortality rates are determined by using the Coale and Demeny (1966)[21] model West life tables. Although the West tables are probably the most accurate of the Coale and Demeny model life tables, they are not particularly well suited to the Philippine case. The underlying data for those tables come predominantly from high-income, low-fertility countries. The experience of low-income, high-fertility countries is probably captured more appropriately by the model South life tables.

Migration

Bachue is the only model among those reviewed here that deals with gross as well as net migration flows. The gross flow of migration from rural areas to urban areas is decomposed by age, sex, and education, as is the return flow from urban areas to rural areas. The gross rate of migration (specific for age, education, and sex) is given by the product of three terms. The first term depends upon the proportion of women married at the given age, average educational level, distribution of education, and age. The second term depends upon the relative wage rates in the urban and rural areas and upon the coefficients of variation of income in the two regions. The third term varies with the locational distribution of the population. For rural-to-urban migration, it assumes that the propensity to migrate increases until 50 percent of the population is urban and decreases thereafter. For urban-to-rural migration, it is assumed that the propensity to migrate decreases as the proportion of the population in urban areas grows.

3.5 CONCLUSIONS

The Bachue model is, in its present form, of little use to agricultural policy planners. This is the case for two basic reasons. First, the model is not designed to focus on agriculture. It is, therefore, not sufficiently articulated with regard to agriculture to provide interesting policy options for study. For example, inputs into agricultural production have no effect on the level of agricultural output. Thus, the whole set of questions concerning the relations between agricultural outputs and inputs cannot be addressed in the model. Certainly, it is possible to change the rate of labor productivity growth in the rural area, but without some understanding of what is generating this growth, the formulation is not very useful for agricultural planning.

The second reason that the Bachue model may not be very instructive in its present version is that it contains a number of difficulties, some of which are purely technical. For example, the wrong prices are used in the consumption equations, the translation between value-added in constant prices and value-added in current prices is incorrectly made, and the age-specific marital fertility rates and the proportions married at given ages are inconsistent with the total fertility rate in the model. These technical problems need to be remedied before the results of the model can be taken seriously. There is, however, a more basic problem that needs to be considered. Bachue is inherently a demand-dominated model. The supply side of the model – the relationship between output levels and input levels – is assumed to have almost no role in the growth process. The thrust of the model is to explain not the pattern and speed of development under various assumed policies, but to determine the consequences of those policies for the distribution of income. It is legitimate, of course, to ask about the effects of various policies on the distribution of income in the rural sector. But in a model where there are no effects of those policies on growth and, practically speaking, no effects on value-added shares, it is not obvious whether those questions can realistically be answered.

The Bachue model should be applauded for its serious consideration of questions concerning income distribution, but it must be remembered that this focus has been achieved at the expense of other important considerations. Even when the technical problems are resolved, a planner may well have second thoughts about using the model. Merging the income distribution considerations in the Bachue model with the supply elements of other models may be a very useful tack for policy makers interested in models of this kind.

4 THE TEMPO II MODEL

4.1 THE PRODUCTION RELATIONS

Tempo II is among the simpler models considered in this review. It recognizes only two sectors of the economy, a subsistence sector and a modern sector. The production function for the subsistence sector (in essence the agricultural sector) is

$$GPS(t) = k_1 \cdot PS(t-1)^{k_2} \quad (4.1)$$

where $GPS(t)$ is the gross product of the subsistence sector in year t, $PS(t-1)$ is the size of the population (not labor force) in the subsistence sector in period $t-1$, and k_1 and k_2 are constants. The authors of the Tempo II model suggest that k_2 should be less than unity in order to ensure that labor in the subsistence sector always faces diminishing returns.

Several comments on this specification are in order before we move on to a discussion of the production function in the modern sector. First, the agricultural production structure is extremely simplified. Land and agricultural capital are assumed to have no relation to agricultural output. Further, even in the simple two-sector economy of Tempo II there are no intersectoral purchases. In other words, fertilizer or electricity purchased from the modern sector are not inputs into agricultural production. Such a view of agriculture may be based on a perception that agriculture in some less developed countries is carried out with little more than land and labor. Although this may or may not be true today for any given country, it should not be forgotten that economic-demographic simulation models are designed to run for 20 to 30 years into the future. In this perspective, omitting all agricultural inputs except labor from this agricultural production function is not a very convincing assumption. Just as bad, however, is the assumption that there will be no technological change in agriculture over the course of the next two or three decades.

The single factor of production in the agricultural production function is the *population* in the subsistence sector. No attempt is made in Tempo II to define an agricultural labor force or to use information on the age structure of the agricultural population to adjust the population to a number of full-time equivalent workers. The Tempo II approach requires little in the way of data, but also seems to offer little in return. One curiosity of this approach is that agricultural output in period t is assumed to be a function of the agricultural population in period $t-1$. This eliminates the problem that could arise if this year's agricultural output is determined simultaneously with this year's migration flow. But this solution has a cost in terms of the realism of the model.

The production function for the modern sector in Tempo II is written as

$$GPM(t) = Z \cdot (1+q)^t \cdot K^u(t-1) \cdot NE^v(t-1) \cdot NU^w(t-1) \quad (4.2)$$

where $GPM(t)$ is the output of the modern sector in year t, $K(t-1)$ is the capital stock in the modern sector in period $t-1$, $NE(t-1)$ is the number of employed educated workers in period $t-1$, $NU(t-1)$ is the number of employed uneducated workers in period $t-1$, q is a constant reflecting the rate of technological progress, and Z, u, v, and w are also constants. The authors of Tempo II say nothing about restricting the sum of u, v, and w.

It is somewhat curious that the output level in period t depends on input levels in period $t-1$. This formulation makes the modern-sector output in period t completely independent of any economic phenomena in period t. Such a specification may be useful for certain purposes, but it certainly detracts from the realism of the model. It should also be noted here that the modern sector does not utilize anything from the subsistence sector in its own production. For example, the modern sector is not allowed to process food, nor are businessmen in the modern sector allowed to purchase items produced in the subsistence sector for export.

The three inputs used in modern sector production in period t are all determined in period $t-1$. The level of the capital stock in period $t-1$ is easily computed since it is assumed to include all the capital in the entire economy. Tempo II does not allow for such items as roads, fences, or buildings in the agricultural area. The number of employed educated workers in period $t-1$ is calculated as a fixed exogenous proportion of the number of educated people in the labor force in period $t-1$. In other words, the rate of unemployment among educated workers is assumed to be constant in Tempo II.

The determination of the number of uneducated workers employed in period $t-1$ is somewhat more complex. Basically, their number is determined from the following equation:

$$NU(t-1) = \kappa_1 - \kappa_2 \cdot \left[\frac{LFU(t-2)}{K(t-2)}\right] \cdot LFU(t-1) \quad (4.3)$$

where $NU(t-1)$ is the number of uneducated laborers employed in the modern sector in year $t-1$ (but somehow producing output in year t), $LFU(t-1)$ is the size of the labor force of uneducated workers in the urban area in period $t - 1$, and κ_1 and κ_2 are two positive constants. Equation (4.3), unfortunately, is quite implausible. The problem with that specification can be demonstrated in a simple example. Consider for the moment two years t and $t + 20$ and allow the urban unskilled labor force and the capital stock to have grown at the same rate over that period, or, in other words, let $LFU(t)/K(t)$ remain constant over time. In this case equation (4.3) may be rewritten

$$NU(t) = \kappa_1 - \kappa_2^* \cdot LFU(t) \tag{4.4}$$

where

$$\kappa_2^* = \kappa_2 \cdot \left[\frac{LFU(t-1)}{K(t-1)}\right] \tag{4.5}$$

Now in year t suppose $LFU(t) = 100$ and $NU(t) = 90$. One way to obtain this result is to set $\kappa_1 = 100$ and $\kappa_2^* = 0.1$. If $LFU(t + 20) = 200$, we would have the astounding implication that $NU(t + 20) = 80$. In other words, while the labor force doubled, employment shrank by about 11 percent. Indeed, this negative relation between employment and the labor force is evident from equation (4.3). What, if any, sense the equation makes eludes this author.

Tempo II incorporates one innovative feature with regard to the determination of the number of uneducated workers employed in the modern sector. It is an adjustment for the increased "quality" of uneducated labor that comes about over time with development because of increased nutritional levels and decreased morbidity. The equation which incorporates this adjustment is

$$LFUA(t) = LFU(t) \cdot \left\{\left[\frac{GPM(t-1)}{PM(t-1)}\right] \Big/ \left[\frac{GPM(0)}{PM(0)}\right]\right\}^h \tag{4.6}$$

where $LFUA(t)$ is the adjusted labor force size in period t (i.e., the number of equivalent workers given the health and nutritional standards of period 0), $PM(t - 1)$ is the total population in the urban sector in period $t - 1$, and h is a constant bounded by zero and unity.

The authors of Tempo II suggest that the value of $LFUA(t)$ in equation (4.6) can be used in place of $LFU(t)$ in equation (4.3), but because of the problem with equation (4.3), this novel feature of Tempo II may only serve to compound the poor specification.

4.2 THE DISTRIBUTION OF INCOME

Unlike the other models reviewed here, Tempo II makes no distinction between income generated in the urban area and income generated in the rural area, nor is any distinction drawn between labor and nonlabor income. Tempo II recognizes only a single aggregate form of income. Disposable income in period t is computed according to the following equation:

$$DI(t) = GP(t) - TAX(t) + TRFP(t) \tag{4.7}$$

where $DI(t)$ is disposable income in period t, $GP(t)$ is gross national product in period t [$= GPM(t) + GPS(t)$], $TAX(t)$ is the sum of all taxes in period t, and $TRFP(t)$ is the sum of all transfer payments in period t. The Tempo II definition of disposable income thus includes all business income and the depreciation on the entire capital stock.

Because Tempo II virtually ignores the distribution of income, it is not useful for analyzing policies where changes in the distribution of income are likely to be sizable. For example, it may be argued that increases in population growth tend to depress wage rates and increase the shares of profits and rents in national income. If savings rates out of profits and rents were higher than out of wage income, more rapid population growth could cause the aggregate savings rate to rise. None of this story can be captured in Tempo II. This failure to deal with the income distribution is a significant deficiency of Tempo II.

4.3 SAVINGS

The aggregation of all incomes in the Tempo II model limits the sophistication of the savings process. In Tempo II the ratio of savings to disposable income is expressed in the following relationship

$$\frac{S(t)}{DI(t)} = a_1 - a_2 DI(t)^{a_3 - 1} P(t)^{1-a_3} \qquad 0 \leqslant a_3 \leqslant 1 \tag{4.8}$$

where $S(t)$ is aggregate savings in year t, $DI(t)$ is disposable income in year t, $P(t)$ is the size of the population in year t, and a_1, a_2, and a_3 are constants. If a_3 lies in the interior of the unit interval, this equation implies that the savings rate is positively related to disposable income per capita.

The difficulty with this specification is not so much with what it maintains as with what it fails to consider. For example, changes in the distribution of income toward either large firms in urban areas or large farmers in the rural area are assumed to have no effect on savings. Nor does the rate of interest or the rate of inflation – a variable uniquely available in Tempo II – have even the slightest impact on the savings rate. Likewise, the age structure of the population, its rural–urban composition, and its educational distribution all have no impact on savings. In Tempo II, the trend in the savings rate is simply determined by the trend in per capita disposable income.

4.4 THE DETERMINANTS OF FINAL DEMAND

In Tempo II, there is a single equation for calculating the aggregate level of consumption expenditures that may be written

$$C(t) = (1 - a_1)DI(t) + a_2 DI(t)^{a_3} \cdot P(t)^{1-a_3} \qquad 0 \leqslant a_3 \leqslant 1 \tag{4.9}$$

where $C(t)$ is aggregate consumption in year t and where the constants $a_1, a_2,$

and a_3 are the same as in equation (4.8). If a_3 is not unity, consumption increases less than proportionally with disposable income.

It would perhaps have been redundant at this point to comment on the lack of relative prices in Tempo II, except that this attribute of the model, together with its supply-constrained character, yields a rather unfortunate result here. In Tempo II consumption is not disaggregated even into the demand for the two outputs considered in the model. The reason that consumption of agricultural goods is not differentiated from the consumption of goods and services produced in the modern sector is simple enough. Without any relative price in the model, there is no method of ensuring that the demand for either sector's output in any period will be equal to the exogenous quantity produced in that period.[22]

From the perspective of a policy maker the level of aggregation of consumption in Tempo II is likely to cause significant difficulties. Tempo II does not allow the analysis of any policy that involves encouragements or discouragements to output growth from the demand side. For example, Tempo II is incapable of analyzing the direct or indirect effects of a subsidy to agricultural production, of a tax on modern-sector outputs, or even of a tariff on competitive imports. This is certainly one area in Tempo II which should be expanded significantly before the model is used for serious work.

Another shortcoming of the Tempo II model is that it contains no independent specification of the demand for investment. Investment is determined, in Tempo II, from the accounting relationship

$$PINV(t) = S(t) - BOR(t) \tag{4.10}$$

where $PINV(t)$ is private investment at time t, $S(t)$ is savings at time t, and $BOR(t)$ is government borrowing in period t. If the government's deficit were entirely met by domestic borrowing, then equation (4.10) would guarantee that aggregate demand was equal to aggregate supply.

In an economic-demographic simulation model, however, determining private investment from an accounting relationship is inappropriate because this procedure leads to the omission from the model of all factors that influence the process of growth and development by affecting the profitability of investment. Tempo II is thus incapable of analyzing any policy that works through the stimulation of investment. It would be a considerable improvement in Tempo II if the elementary distinction between the determinants of *ex ante* and *ex post* investment was made.

The allocation of investment between sectors in Tempo II has been reduced to a trivial problem by assuming that there is only one capital stock – the capital stock of the modern sector. Tempo II, then, cannot be used to analyze policies that have the effect of redirecting private investment among sectors of the economy.

Government expenditures in Tempo II are divided into eight categories: education, family planning, general transfer payments, health, social overhead capital, direct government investment, defense, and general government. Expenditures in each of these areas except education and family planning are exogenous policy variables and may be changed over time.

Expenditures on education and family-planning services are computed within a goal-oriented framework. There, instead of specifying the amount of money to be spent on a given social program, the policy maker sets the target levels of educational attainment and fertility reduction he wishes to achieve and the simulation model determines both the cost of achieving each goal and the impacts on the development process of reaching those ends. The costs and benefits of pursuing various policies can be more easily seen in this framework than where government expenditures are treated as being purely exogenous. This aspect of the Tempo II model is one that could profitably be incorporated into the next generation of economic–demographic simulation models.

Government revenue is determined in Tempo II through the use of the equation

$$TAX(t) = \tau \cdot GP(t) \tag{4.11}$$

where $TAX(t)$ is government revenue from taxation in period t, $GP(t)$ is gross national product in period t, and τ is the tax rate. The deficit in the government budget is simply the difference between its revenues from internal taxation and government expenditures. This deficit is financed in an intriguing manner in the world of Tempo II. It is assumed that small deficits are entirely covered by borrowing from domestic savings. The size of the budget deficit that can be financed in this fashion is limited to some fixed fraction of total domestic savings. If the deficit exceeds the limit, the excess is financed in essence by the creation of new money, thus causing inflationary pressure. The treatment of general inflation in Tempo II is discussed in section 4.5 below.

Neither exports, imports, nor capital flows are incorporated into the Tempo II framework.

4.5 GENERAL EQUILIBRIUM ASPECTS

Tempo II is a supply-dominated model. Output in the current period is derived from the quantities of the factors of production determined in the previous period. Since consumption and investment are treated as national aggregates in Tempo II, it would seem to be a simple matter at first to guarantee that *ex ante* aggregate demand equaled *ex ante* aggregate supply. This is especially true since the *ex post* equilibrium condition that aggregate savings is equal to aggregate investment is invoked as an *ex ante* relationship determining the amount of aggregate investment. Tempo II, however, incorporates two features that allow *ex ante* aggregate demand to differ from *ex ante* aggregate supply. First, the government can cover a portion of its deficit by printing money. In the absence of external aid this causes the aggregate demand for goods and services in any given year to exceed the quantity of goods and services produced in that year. The second reason why *ex ante* aggregate supply and demand may deviate from one another involves the existence of long-term external aid. In Tempo II, long-term external aid supplements the domestic supply of goods and services. If the government does not finance its deficit by adding to the supply of money, such aid causes a tendency for aggregate supply to exceed aggregate demand.

Of course, *ex post* aggregate demand must equal *ex post* aggregate supply, and for this Tempo II includes a mechanism that guarantees the *ex post* equality even when the *ex ante* equality does not obtain. Let us explore this mechanism for a moment. Suppose that the ratio of *ex ante* aggregate supply (including long-term external aid) to *ex ante* aggregate demand in year t is given by $R(t)$. Since Tempo II is a supply-dominated model, the discordance between *ex ante* aggregate demand and aggregate supply is eliminated by multiplying all the elements on the income side of the national accounts (for example, disposable income, consumption, investment, and government spending) by $R(t)$. As the authors of Tempo II suggest, this simple strategem can be made more sophisticated by positing that the components of final demand are affected to varying degrees in the course of aggregate demand–supply adjustment.

The economic logic of modifying *ex ante* aggregate demand so that it comes into equality with aggregate supply is not treated in detail in Tempo II, but there is a suggestion of the mechanism by which at least part of the adjustment takes place. In Tempo II, the rate of inflation between periods $t-1$ and t is described by the equation

$$INFL(t-1, t) = R(t)^{\alpha} - 1 \qquad \alpha > 0 \tag{4.12}$$

where $INFL(t-1, t)$ is the rate of inflation between periods $t-1$ and t, and α is a constant. If *ex ante* aggregate demand exceeds aggregate supply $[R(t) > 1]$, then inflation occurs, and if *ex ante* aggregate demand falls short of aggregate supply $[R(t) < 1]$, then deflation follows. It may easily be imagined that changes in the rate of price inflation could play a role in the adjustment of aggregate demand to aggregate supply, but the precise nature of this role is left unspecified in Tempo II. Perhaps in further work on this model, the link between inflationary pressures and changes in real quantities demanded can be better articulated.

It should be noted before we leave this topic that while the treatment of inflation is hardly complete (for example, the effect of inflation upon the savings rate is not considered), it is at least a first recognition of a basic fact of life in many developing countries. It is interesting to observe in this context that in Tempo II long-term external aid tends to have a deflationary effect on the economy because it adds to aggregate supply without affecting government policies. Were some link made between long-term aid and monetary expansion, this deflationary effect could disappear.

4.6 THE DEMOGRAPHICS

The Demographic Accounting

The demographic accounting in Tempo II is done on a cohort basis. The framework distinguishes people by sex, by location, and by single years of age from age 0 to the ages 65 and above. It presumably should also classify people according to their educational attainment, but no mention is made of this. Very little of the age detail is used in the economic portion of the model.

Labor Force Participation Rates

In Tempo II no attempt is made to define the agricultural labor force. In essence, it is considered to be the entire agricultural population. Labor force participation rates of educated and uneducated workers in the urban sector are determined in a comparably simple fashion. It is assumed in Tempo II that age-, sex-, and education-specific labor force participation rates are fixed constants invariant both to policy manipulation and to economic and demographic developments. The educated and uneducated urban labor forces are determined by applying these exogenous labor force participation rates to the numbers of people in the relevant age, sex, and education categories.

The treatment of labor force participation rates in Tempo II is a particularly simple one. Before a policy maker can be expected to believe 20- or 30-year simulations based on the assumption that labor force participation rates by age, sex, and education will not change over that span, he deserves some relevant empirical evidence on this point. Without such a demonstration, he may properly remain skeptical of this portion of the model.

Education

Education in Tempo II, like family planning, is treated as a special service in that the government is assumed to have target (age- and sex-specific) enrollment rates for primary, secondary, tertiary, and professional education. The only question that arises, then, is how much all this education is going to cost. The problem of providing the education does not arise in the model. To simplify the story slightly, the cost of education (in base-year prices) may be written as

$$TCE(t) = \sum_{i=a_0}^{a_1} [EN(i, t) \cdot P(i, t) \cdot ce(i)] \tag{4.13}$$

where $TCE(t)$ is the total cost of education in year t, a_0, and a_1 are the initial and terminal ages of public education, $EN(i, t)$ is the exogenous enrollment rate for people of age i in year t, $P(i, t)$ is the total number of people of age i in year t, and $ce(i)$ is the cost in base year prices of educating an i-year-old person.[23] The real costs of a year of education at each age level are assumed to remain constant.

There are several puzzling aspects of the education specification in the context of the full model. The most immediate question concerns the constancy over time of the real cost of providing a year of schooling at each level. The educational system uses skilled manpower intensively, and one would expect that the real cost of a year of schooling would be affected by the real earnings of educated workers. As a country developed, one would expect both an increase in the real earnings of educated workers and an increase in the real cost of education. The assumption in Tempo II that the real cost of education remains fixed over time is liable to suggest to policy makers that development strategies involving increasing human capital are quite a bit less costly than they are likely to be in reality.

In Tempo II, there are two types of labor in the modern sector, educated and uneducated labor. Yet the schooling system potentially produces people with quite a variety of educational backgrounds. The relation between this array of schooling levels and the bipartite distinction between educated and uneducated labor is unclear in Tempo II. Surely one can easily imagine classifying anyone with n years of schooling or more as an educated worker and anyone with fewer years of schooling as an uneducated worker, but any such classification may produce highly misleading results in the simulations. For example, if after 20 years of sustained effort most of the workers could be classified as educated workers, further expenditures on education may appear to have a spuriously low return because few additional people are being moved from the category "uneducated" to the category "educated." More disaggregation by educational level would be useful here.

Fertility and Family Planning

Fertility is treated in very simple fashion in Tempo II. The model uses sets of age-specific fertility rates for the urban and rural areas and derives the number of births in any year by applying these rates to the relevant numbers of females by age and summing across the reproductive age span. This approach is a good one thus far, but the most important issue is the determinants of the age-specific fertility rates. Here Tempo II is extremely weak. These fertility rates are treated as if they were influenced by only one variable in the model, family-planning expenditures. Education, income, mortality rates, and health conditions have no impact on fertility in the world of Tempo II.

Even the specification of the impact of the family-planning program is very limited in Tempo II. The family-planning program in Tempo II is assumed to cover only females in the urban sector. Thus, over the entire 20- to 30-year simulation period, the government is prevented from providing any family planning services in rural areas. This assumption is dubious for many developing countries. Since family-planning expenditures are the only determinant of age-specific fertility rates in the Tempo II framework and there are no such expenditures permitted in rural areas, rural fertility rates are completely exogenous in Tempo II. For a model whose use is to provide information about the relationships between economic and demographic variables, this specification is egregious.

In Tempo II, the proportion of fertile urban women using contraception affects the number of births according to the equation

$$\frac{BU(t)}{BU^*(t)} = 1 - PU(t-1) \qquad (4.14)$$

where $BU(t)$ is the actual number of births in the urban area in time period t, $BU^*(t)$ is the hypothetical number of births that would have occurred in the urban area in time period t had no contraception been employed, and $PU(t-1)$ is the proportion of fertile urban women who were using contraception in period $t - 1$.[24] Since the proportion of users is an exogenous policy variable, the government has the power to reduce urban fertility to any level it chooses. The only constraining factor is the cost of this fertility reduction.

Given the mandated proportion of urban women between the ages of 15 and 49 using contraception and the number of these women, the cost of the fertility reduction is determined by the average cost per user. It is assumed in Tempo II that all such costs are borne by the government. The annual real cost to the government of an urban woman using contraception is assumed to be constant as long as the rate of use is below some critical value. When the rate exceeds the critical value the annual real cost to the government per user is assumed to increase linearly with the rate of contraceptive use. Clearly this is an *ad hoc* formulation. A policy maker should carefully consider whether such a framework is appropriate for his country over a 20- to 30-year horizon.

Mortality Rates

All mortality rates in Tempo II are assumed to be exogenous. Neither government public health projects nor rising levels of income and education are allowed to have any effect on mortality rates.

4.7 DYNAMIC CONSIDERATIONS

Economic growth and development occurs in the Tempo II model because of technological progress in the modern (urban) sector, labor force growth, the growth of the stock of educated manpower, the growth of the capital stock, and the reallocation of unskilled labor from the rural sector to the urban sector. Most of these processes are treated quite simply in Tempo II. Technological change in the urban modern sector is both Hicks- and Harrod-neutral and occurs at a constant exogenous rate. The stock of (urban) capital grows through the annual addition of net investment. There is no problem of allocating investment funds between competing uses because only a single aggregated capital stock appears in the model. The stock of educated manpower grows at a rate determined by the government, and, since the education of rural residents does not affect agricultural output, the question of intersectoral educational strategies does not arise.

The migration specification in the Tempo II model is also reasonably simple. It is assumed that the annual flow of migration can be determined from the following equation:

$$M(t) = \alpha[r(t-1)]^{\beta} \cdot PS(t) \tag{4.15}$$

where $M(t)$ is the net migration from rural to urban areas in period t, $r(t-1)$ is the ratio of the income of employed unskilled workers in the urban area in period $t-1$ to the average output of all members of the agricultural population in period $t-1$, $PS(t)$ is the number of people in rural areas in period t, and α and β are constants. The ratio $r(t-1)$ is defined as

$$r(t-1) = \left[\frac{w \cdot ZM(t-1)}{PMU(t-1)}\right] \bigg/ \left[\frac{ZS(t-1)}{PS(t-1)}\right] \tag{4.16}$$

where $ZM(t-1)$ is the output of the modern (urban) sector in period $t-1$, $ZS(t-1)$ is the output of the subsistence (rural) sector in period $t-1$, $PMU(t-1)$ is the number of unskilled workers in the modern sector in period $t-1$, $PS(t-1)$ is the number of people in the subsistence (rural) sector at time $t-1$, and w is share of the value of output paid to unskilled workers in the modern sector.[25]

There are several debatable features of this migration specification that need to be brought to the attention of its potential users. Let us start with the simplest problem and progress toward more subtle ones. In equation (4.15), the migration stream and the rural population base from which it derives have the same date. The question that must be answered here is whether the rural population in period t includes or excludes the migrants in period t. The answer in turn has implications for other equations in the model.

Several more substantive issues arise concerning the rate of rural–urban migration. First, the rate of rural outmigration is assumed to be independent of the age and sex structure of the rural population. Thus, a rural population with a large proportion of young adults in their late teens and early twenties will, in Tempo II, have the same migration rate as a population composed dominantly of elderly people. Such a formulation is not terribly realistic. Further, the rate of migration in period t is assumed to depend only on conditions in period $t-1$. Whether this is an appropriate simplification may depend on the particular application.

Another problem with the migration rate formulation is that it does not recognize the existence of migration costs. Let us assume for the moment that $r(t-1)$ correctly measures the relevant incomes of potential migrants. When $r(t-1) = 1$, there is no economic incentive for migration to continue, yet the rate of rural outmigration will be greater than zero. Indeed, migration to urban areas will continue even when rural incomes exceed urban (unskilled) incomes by a considerable margin. Migration will stop only when the average income of unskilled workers in the urban areas goes to zero. Given a Cobb-Douglas production function for the output of the urban modern sector, zero average income of unskilled workers can occur only when output is itself zero. Thus, in the Tempo II model, the existence of nonzero output in the urban area guarantees migration from rural to urban areas even if wages are higher in the countryside than in the city. A more plausible specification such as that found in the KWC model forces migration to a halt when the difference between urban income and rural income falls below some critical value.

In addition to its failure to recognize costs of migration, the Tempo II model also fails to make a distinction between output measured in physical terms and the value of output. It is natural to think that, for potential migrants, one attraction of urban areas is the higher level of income there. The ratio $r(t-1)$ in equation (4.15) is supposed to capture this effect, but it does not if the relative prices of rural and urban sector outputs change with development. In equation (4.15) $r(t-1)$ is the ratio of two numbers of *physical units*, not the ratios of two income levels. If the relative price of the outputs remain unchanged, the output ratio will serve as an acceptable proxy, but if the terms of trade change over time, $r(t-1)$ will no longer serve as a proxy for the proper income ratio and migration will be poorly predicted.

4.8 POLICY QUESTIONS

The Tempo II model is not suited for the analysis of any questions concerning the agricultural sector. The government cannot encourage technological progress in agriculture because it is assumed that there is no technological progress in agriculture. The government cannot improve the productivity of agricultural labor through education because it is assumed that education has no influence on the productivity of rural laborers. The government cannot increase agricultural output through the provision of social overhead capital in the rural area because the Tempo II model does not include an agricultural capital stock. The government cannot directly influence the rate of population growth in the rural areas because the model assumes that all family planning expenditures are made in the urban areas.

What questions then can be addressed meaningfully in the Tempo II framework? It is sensible to ask only about certain aspects of family-planning programs and educational policy – but even in these limited areas the answers are not very informative. For example, one need not actually perform the simulations to observe that, in the context of Tempo II, increases in expenditures on family planning almost automatically bring about an increase in per capita income. To see this, consider an economy with an average per capita income of $500 where the elasticity of the output of the modern sector with respect to its capital stock is 0.25. Further, let us consider the effect of an expenditure of an additional $\$X$ on the family-planning program in year t where $\$X$ is the amount required to avert one birth. In year $t + 1$ the population is one person lower than it otherwise would have been (for simplicity, mortality is ignored here) and the capital stock is $\$X$ lower than it otherwise would have been. Output in the modern sector, however, is approximately only $(0.25) \cdot (\$X)$ less than it would have been. If $(0.25) \cdot (\$X)$ is greater than the per capita income of \$500, the expenditure on the family-planning program would have caused a diminution in real per capita income, and if, on the contrary, $(0.25) \cdot (\$X)$ is less than \$500, per capita income would have increased. The crucial point is that family planning expenditures immediately increase per capita income if the cost of averting *one* birth is less than \$2,000 or less than four times the average per capita income in the country. Since any family-planning program is likely to require less than four times the average per capita income to avert a single birth, the short-run effect of family planning expenditures is clearly a foregone conclusion.

The longer-term implications of reducing fertility all work in the same direction. A smaller population is associated with a higher savings rate, faster rate of growth of the urban capital stock, and, therefore, higher urban wage rates for unskilled workers. This causes migration from rural areas to urban areas to increase, and, since the marginal product of labor is higher in the urban areas than in the rural areas, it causes, in turn, an increase in per capita income. Thus, the specification of Tempo II essentially builds in the conclusion that increases in expenditures on family-planning programs cause increases in per capita income.

In brief, the framework of Tempo II is not sufficiently articulated to provide the policy maker with much valuable information about the direct or indirect effects of policy changes.

5 THE SIMON MODEL

5.1 PRODUCTION RELATIONS

In the Simon model, there are two types of goods produced, industrial-sector output and agricultural-sector output. Industrial output is specified as resulting from the Cobb–Douglas production process

$$Q_I(t) = A_I(t) \cdot K_I^{0.4}(t) \cdot M_I^{0.6}(t) \cdot J(t) \tag{5.1}$$

where $Q_I(t)$ is industrial output in time period t, $A_I(t)$ is the value of the industrial "technology" index in period t, $K_I(t)$ is the industrial capital stock in period t, $M_I(t)$ is the number of man-hours of labor spent in the industrial sector in period t, $J(t)$ is an index of the quantity of social overhead capital in the country as a whole in period t.[26] The agricultural production function is also Cobb–Douglas. It is expressed as

$$Q_F(t) = A_F(t) \cdot K_F^{0.5}(t) \cdot M_F^{0.5}(t) \cdot J(t) \tag{5.2}$$

where the variables are defined analogously to those in the industrial production function, with the exception that $K_F(t)$ includes land.

The Simon model, then, allows for neutral technological change in both the agricultural and the industrial sector and formally treats the role of social overhead capital in production. The motivation behind this specification is to be applauded. For all the discussion in the literature about the role of the government in providing social overhead capital, the Simon model is the only one of those considered here that treats this form of capital explicitly. The details of the incorporation of social overhead capital into the model, however, leave something to be desired. First, the social overhead capital variable $J(t)$ enters both production functions with an exponent of unity. In other words, it is possible to double or quadruple output in both sectors of the economy by doubling or quadrupling social overhead capital without *any* increase in the utilization of labor or the services of the private capital stock. Whether social overhead capital has such a potent effect on output remains to be demonstrated.

An economist's presumption would be that social overhead capital, like any other input, would eventually encounter diminishing returns to scale. It should also be noted in passing that the stock of social overhead capital is not disaggregated by sector. Thus the building of a rural road will not only increase rural output, but will directly increase industrial output as well.

This process by which social overhead capital is assumed to grow is also rather puzzling. Simon writes that

$$\frac{J(t+1)-J(t)}{J(t)} = 0.20 \cdot \left[\frac{L(t)-L(t-1)}{L(t-1)}\right] \tag{5.3}$$

where $L(t)$ is the labor force in the entire country in period t. The stock of social overhead capital, according to this formulation, automatically grows whenever the labor force grows. No difficulty is ever encountered in the Simon model in obtaining the needed social overhead capital – it drops like manna from heaven whenever the labor force grows. Policy makers who are interested in the process by which the social overhead capital comes into being may want to elaborate this portion of Simon's model. It is interesting to note before moving on that it is possible to interpret the relationship between the growth of the stock of social overhead capital and the growth of the labor force as a relationship between labor force growth and the pace of technological progress. If one believed that economies of scale due to the increasing specialization of the labor force occurred as the labor force increased in size, then the specification in equation (5.3) seems a bit more reasonable.

The capital stocks in the Simon model, as in the other models reviewed here, are determined by the cumulative addition of net investment to base year estimates of the values of the capital stocks. The determination of net investment by sector is discussed below. Given the indices of technology in the two sectors, the level of social overhead capital, and the capital stocks, the outputs of the sectors are determined once the labor inputs are known. In the Simon model, the labor inputs and sectoral outputs are determined simultaneously in a complex manner unique to this model. It is the explication of this mode of determining output that shall concern us for the next few pages.

5.2 SOCIAL INDIFFERENCE CURVES AND THE DETERMINATION OF AGGREGATE AND SECTORAL OUTPUT LEVELS

The Simon procedure for computing sectoral and aggregate output levels has three steps. First, the relative quantities of physical output of the two sectors in period t are postulated to depend upon income per consumer equivalent in period $t - 1$. In symbols

$$\alpha(t) \equiv \frac{Q_I(t)}{Q_I(t) + Q_F(t)} = 0.35 + \left[\frac{\hat{Y}(t-1) - 75}{925}\right] \cdot 0.65 \tag{5.4}$$

where $\tilde{Y}(t-1)$ is income per consumer equivalent in period $t-1$ and $\alpha(t)$ is the proportion of total output in period t contributed by the industrial sector. Since Simon assumes that total output in period t, $Q(t)$, can be obtained by summing the physical quantities of outputs in the two sectors[27] [i.e., $Q(t) = Q_I(t) + Q_F(t)$], equation (5.4) may be rewritten using equations (5.1) and (5.2) as follows:

$$M_I(t) = \left[\frac{\alpha(t)\cdot Q(t)}{A_I(t)\cdot K_I^{0.4}(t)\cdot J(t)}\right]^{1/0.6} \tag{5.5}$$

and as

$$M_F(t) = \left[\frac{[1-\alpha(t)]\cdot Q(t)}{A_F(t)\cdot K_F^{0.5}(t)\cdot J(t)}\right]^{1/0.5} \tag{5.6}$$

Hence

$$M(t) \equiv M_I(t) + M_F(t) = \left[\frac{\alpha(t)\cdot Q(t)}{A_I(t)\cdot K_I^{0.4}J(t)}\right]^{1.67} + \left[\frac{[1-\alpha(t)]\cdot Q(t)}{A_F(t)\cdot K_F^{0.5}J(t)}\right]^{2.0} \tag{5.7}$$

Equation (5.7) provides Simon with a relationship between "aggregate output" $Q(t)$ and aggregate labor input $M(t)$.

One point on this output–labor frontier is chosen by society according to a social welfare mapping, which shifts around over time according to economic conditions. At any time t, Simon posits that we can write the jth member of the family of social indifference curves as follows:

$$\log\left[\frac{Q(t)}{L(t)}\right] = \alpha^*(t) + \beta_j^*\cdot\left[\frac{M(t)}{L(t)}\right] \tag{5.8}$$

where $L(t)$ is the total labor force in period t and β_j^* is a constant related to the index j,

$$\alpha^*(t) = \exp\{[0.4 - 0.2\cdot(\tilde{Y}(t-1) - 75)/925]\cdot \tilde{Y}(t-1)\cdot C(t)/L(t)\} \tag{5.9}$$

and where $C(t)$ is the number of consumer equivalents in year t. The expression in equation 5.8 is supposed to capture the effects of relative aspirations, current standard of living, and the dependency ratio on social tastes for goods and leisure. In practice it may simply be said that $\alpha^*(t)$ depends upon the last period's per capita income and the current period's dependency rate. Given equations (5.8) and (5.7), the nation chooses a level of labor and output that maximizes its utility.

The determination of output via the process of maximizing a social welfare function is unique to the Simon model for good reason. Other model builders had in mind the ultimate objective of specific national applications of their models. This immediately rules out the Simon approach because of the impossibility of estimating the parameters of families of shifting social welfare functions. Simon, however, has built his model for the purpose of analysis, not ready applicability. But even for Simon's purposes, it is debatable whether the maximization of a social welfare function is the best framework to use. There can be no question on general grounds that one element of an economic–demographic simulation model should be the determination of the number of hours of work per labor force member per year. The conventional way of incorporating this into such a model would be to specify for each sector of the economy a supply of hours of work function that would relate hours of work supplied in the sector to the size of the sector's labor force, the dependency rate in the sector, the wage rate in the sector, and the nonlabor income (if any) accruing to workers in the sector. There is a substantial literature both theoretical and empirical to guide such a specification. There is, on the other hand, no literature that even suggests the existence, let alone the stability, of social welfare functions of the sort posited by Simon. Given the evidence at hand, prudence requires that the Simon social welfare function formulation be considered with an open, but a skeptical, mind.

One serious problem in the Simon model relates to the specification of net industrial investment. According to Simon, net industrial investment in period t may be written

$$NI_I(t) = 0.0275 \left[\log_{10}\left(\frac{Q_I(t) - Q_I(t-1)}{Q_I(t)}\right)\right] [1 - 0.5 \cdot YOU(t)] \cdot K_I(t) \tag{5.10}$$

where $NI_I(t)$ is net investment in the industrial sector in period t, $Q_I(t)$ is industrial output in period t, $YOU(t)$ is an index of the youth dependency burden in the entire country in period t, and $K_I(t)$ is the capital stock in the industrial sector in period t. The youth dependency burden is defined so as to be positive if the burden in year t is greater than in the base year and negative if the dependency burden is less than in the base year.

Clearly, this is a very odd specification for a number of reasons. First, net investment must always be *negative* except for extremely high values of the youth dependency rates. This occurs because $\log_{10}([Q_I(t) - Q_I(t-1)]/[Q_I(t)])$ is always negative when industrial output is growing. Further, the greater the youth dependency burden, other things being equal, the greater (less negative) is the quantity of net investment. This is exactly the reverse of the usual assumption that a greater dependency burden reduces capital formation. Is the specification in equation (5.10) an outright error that arose because Simon did not realize that the logarithm of a positive number less than unity is always negative? Perhaps. Possibly some other equation was used in the simulation program and the text is in error. Either alternative, however, suggests that extreme caution be exercised in interpreting any results from the Simon model.

5.3 TECHNOLOGICAL CHANGE

The same problem concerning the logarithm of a positive number less than one occurs in the specification of the rates of technological progress in the industrial and the agricultural sectors. In the base run Simon specified the rate of technological progress in the agricultural sector at one-half of one percent per annum. In symbols,

$$A_F(t+1) = 1.005 \cdot A_F(t) \tag{5.11}$$

In the industrial sector, the rate of technological progress was assumed to be lower than in the agricultural sector. The specification is

$$A_I(t+1) = Q_I(t)\left[1.005 + 0.002 \log_{10}\left(\frac{Q_I(t) - Q_I(t-1)}{Q_I(t)}\right)\right] \tag{5.12}$$

Since $\log_{10}([Q_I(t) - Q_I(t-1)]/Q_I)$ is a negative number, the rate of technological progress in the industrial sector in the base run is less than one-half of one percent per annum. Judicious modification of the parameters in equations (5.11) and (5.12) can easily allow technological progress to be more rapid in the industrial sector than in the agricultural sector, but no such results are reported in Simon's article.

5.4 DEMOGRAPHICS

There are no demographic specifications in the Simon model of any interest. Education is assumed to play no role in economic development. Labor force participation rates and fertility are assumed to be exogenous. Mortality rates are assumed to be a function of per capita income only – there are no public health expenditures in the model. Finally, migration does not depend on rural–urban income differences – such differences do not appear explicitly in the model – but rather adjust to whatever they need to be to make equation (5.4) true.

5.5 CONCLUSIONS

The Simon model, then, is not in its present form of much use to policy makers. Unusual formulations such as the assumption that net investment in the industrial sector is generally negative make the model grossly inapplicable to contemporary developing countries. Further, the specification that output and labor in any one period are determined so as to maximize a social welfare function is also problematical. The Simon framework, then, does not appear to be a useful one for further development. Policy makers interested in a more meaningful framework should begin with the Kelley–Williamson Representative Developing Country model described in Chapter 9.

6 THE FAO MODEL

The Food and Agriculture Organization's application of its systems simulation model to Pakistan is the simplest of the models reviewed here. Its simplicity is both its chief virtue and its chief defect, for while it is the easiest of all the models to implement, the FAO model is in many respects overly simplifed. This is unfortunate particularly because the FAO model is the only one of the group that purports to give serious guidance to agricultural policy makers.

6.1 AGRICULTURE

Eight productive sectors are incorporated into the FAO model: agriculture, small-scale industry, large-scale industry, capital goods industry, construction industry, traditional services, modern services, and government services. The agricultural sector itself is broken down into four subsectors: small-scale farming in rainfed regions, large-scale farming in rainfed regions, small-scale farming in irrigated regions, and large-scale farming in irrigated regions. Output growth in all sectors of the economy, including each of the agricultural subsectors, is assumed to be controlled by the government through its role in the allocation of investment funds.[28]

The government has a number of avenues for affecting agricultural production. It can consolidate small rainfed farms into large rainfed farms, consolidate small irrigated farms into large irrigated farms, decompose large irrigated farms into small irrigated farms, reclaim unused land for use in irrigated farming, invest in any of the four distinguished types of agriculture, and spend money on intermediate inputs. While this variety of agricultural policy instruments is certainly useful to agricultural planners, there are instruments omitted whose importance for agricultural planning are at least of equal consequence. In particular, the omission of all price variables from the FAO model means that no agricultural policy that affects agricultural output by affecting the relative price of farm produce can be considered.

The lack of any relative prices in a model of economic development poses serious problems, and these difficulties are magnified in a model that is to be useful for agricultural policy making. First of all, no change in the relative price of agricultural and industrial goods with economic development is allowed to occur in the model. To the extent that such a change does occur, the model is in error. Second, the model cannot be used to consider any agricultural pricing policies. For example, one might expect that a government subsidy to agriculture, say through the setting of a minimum sale price for important agricultural products, would, within a few years, cause the quantities of the subsidized commodities produced to increase. Further, resources might well be diverted from the production of the nonsubsidized products to the production of the subsidized ones. Yet no such effects of output pricing policies can be considered in the FAO model. Similarly, agricultural input pricing policies cannot be considered in the model. For example, there is no way of asking about the effects on agricultural output of a subsidy on fertilizer.

The FAO model is not unique in its assumption that all relative prices remain fixed forever. This assumption is made in three of the five second-generation models reviewed here. It is a poor assumption – one that is highly unlikely to approximate reality – and one potential problem area with all the models that incorporate it.

The agricultural policies that are allowed in the FAO model, unfortunately, are placed in such a simplified context that their operation does not appear to be closely linked with reality. In the FAO model, agricultural output is not related to agricultural inputs by a production function. Instead there is a set of land accounting equations and a set of equations determining yields per acre. The land accounting equations are straightforward. In the Pakistani simulations it is assumed that there is a fixed amount of land used in production in the rainfed regions. Small rainfed farms may be converted into large rainfed farms but not the reverse. Land in irrigated farming, on the other hand, is not assumed to be constant. Each year a certain amount of irrigated land is assumed to be withdrawn from cultivation, and a certain amount of irrigated land is, at a cost, reclaimed by the government. The net effect of these two forces may be either positive or negative. Both land consolidation and land distribution may occur in areas of irrigated farming.

Agricultural policies also are allowed to affect yields per acre. The expressions used to determine current yields have the form

$$Y(j,t) \;=\; Y(j,t-1) + \alpha_j \cdot \left[\frac{IN(j,t-1) - DIN(j,t-1)}{LA(j,t)}\right] + \beta_j \cdot IT(j,t) \tag{6.1}$$

where $Y(j,t)$ is the yield per acre on farms of type j in period t; $IN(j,t-1)$ is gross investment on farms of type j in period $t-1$; $DIN(j,t-1)$ is the cost of land consolidation, distribution, and reclamation on farms of type j in period $t-1$; $LA(j,t)$ is the amount of land used in the jth type of agriculture in year t; $IT(j,t)$ is the annual increment in the quantity per acre of intermediate inputs; and α_j and β_j are constants. The yield per acre on farms of the jth type in period t, then, depends upon the yield per acre of that type of agriculture in the previous period, net investment in that type of farming in the previous period, the amount of land used in the jth type of farming, and the quantity of intermediate inputs used in period t.

This specification of the determinants of agricultural productivity has a number of drawbacks. First, agricultural labor plays no role in producing output in the FAO model. It may be argued that agricultural labor is a redundant factor of production in many less developed countries today. But the assumption that labor will never attain a positive marginal product any time in the next thirty or so years regardless of the development strategy followed seems dubious at best. A second problem concerns the lack of capital depreciation in the FAO model. Investments in agriculture are unrealistically assumed to yield nondiminishing returns over the entire simulation period. Third, the specification assumes that lands whose status have altered immediately have the yields associated with the current agricultural type. In other words, if it is government policy to invest only in large consolidated farms in rainfed farming areas, such investment would raise the yield per acre on large consolidated farms. Further, if the government consolidated small holdings that had received no government investment, the yield per acre on the new consolidated farms still would equal the yield per acre on the consolidated farms on which investment took place. Since the cost of consolidating land (or distributing it) is fixed per acre regardless of yield differentials, the FAO model makes it appear as if changing the size of holdings provides the fruits of investment where none occurred.

A fourth sort of problem with the specification of the agricultural production arises because of the linearity of equation (6.1). There are three aspects of this difficulty that need to be discussed here – an obvious point and two somewhat more subtle ones. It is clear from inspecting equation (6.1) that there are no diminishing returns in the short run either to investment in any form of agriculture or to the incremental use of intermediate inputs. Thus, for example, the marginal yield gain per additional unit of fertilizer is assumed to be the same regardless of the level of incremental fertilizer use. It may be argued that in traditional agriculture the point of long-run diminishing returns to capital and intermediate inputs is so far in the future that it can safely be ignored in the simulations, but it is not clear that this argument is compelling with regard to diminishing returns in the short-run.

One somewhat less immediate result of the linearity of equation (6.1) concerns the relationship between incremental intermediate input use and the level of net agricultural output. The equation used in computing the latter is

$$ON(j,t) = OG(j,t) \cdot \left[\frac{ON(j,t-1)}{OG(j,t-1)}\right] - IT(j,t) \cdot LA(j,t) \qquad (6.2)$$

where $ON(j, t)$ is the net output of the jth type of agriculture in year t and $OG(j, t)$ is the gross output of the jth type of agriculture in year t.

It is quite likely that agricultural planners would use the FAO model to determine that incremental quantity of intermediate inputs in any year that would maximize net output. To see what advice the model would give them, multiply equation (6.1) by $LA(j, t)$ and substitute the resulting expression in place of $OG(j, t)$ in equation (6.2). This procedure produces the equation

$$ON(j, t) = k^* + IT(j, t) \cdot LA(j, t) \cdot \left[\beta_j \frac{ON(j, t-1)}{OG(j, t-1)} - 1\right] \qquad (6.3)$$

where

$$k^* = [Y(j, t-1) \cdot LA(j, t) + \alpha_j \cdot IN(j, t-1) - \alpha_j \cdot DIN(j, t-1)] \cdot \left[\frac{ON(j, t-1)}{OG(j, t-1)}\right] \qquad (6.4)$$

Clearly, if $\beta_j[ON(j, t-1)/OG(j-1)] - 1 < 0$, the net output of agriculture of the jth type is maximized in year t when $IT(j, t)$ is zero. If that expression is positive, net output is maximized when the incremental quantity of intermediate inputs is *infinite*! It should perhaps be noted in passing that unwary policy makers can be led significantly astray by this formulation. It certainly should be modified before serious analysis with the model is undertaken. One approach to mitigating this difficulty would be to assume that the costs of and returns from the use of intermediate inputs were not constant but rather varied with the quantities of those inputs consumed.

The third problem related to the linearity of equation (6.1) is closely akin to the one just analyzed. Suppose policy makers were to utilize the FAO model to determine the strategy that would maximize agricultural output[29] in a particular future year, given an exogenous annual series of total net agricultural investments. What advice would the model provide in such a situation? The answer is that, in general, to attain its goal the government should *at most* invest in *only one* of the four types of agriculture and *at most* in only one type of land conversion.[30] It is even possible that the government should spend its entire agricultural investment on a single activity. Thus, the linearity of equation (6.1) has a tendency to produce the implication that specialization is preferable to diversification.

Fortunately, the agricultural sector is embodied in a model that may help alleviate some of the specification's shortcomings. In the FAO model it is possible that the amount of investment in agricultural investment in a given year would depend in part on the level of agricultural output in previous years. In this case, the assumption made in the discussion above that the quantities of agricultural investment are exogenous does not hold, and the implications cited do not necessarily follow. Even though on purely technical grounds it is not possible to guarantee that the optimum agricultural policy involves specialization in investment, such a result is not an unlikely one. What, then, can an official ascertain about agricultural policy from experimenting with the FAO model? If his simulations suggest that the government strongly support only one or two types of agriculture, can he trust them? The answer, unfortunately, is that he should not. Such results are likely to arise because of the overly simplistic specification of the agricultural production process. If the simulations suggest that more should be spent on intermediate inputs like fertilizer, should he follow that suggestion? The answer, unfortunately, is uncertain. Net output is maximized by using either no additional amount of intermediate inputs or an infinite amount of them. In brief, the agricultural portion of the FAO model is too restrictive to be of much use in dealing with those questions it is designed to answer.

6.2 INDUSTRY

The nonagricultural portion of the FAO model is also quite simple. Seven nonagricultural sectors are distinguished in the model: small-scale industry, large-scale industry, capital goods industry, construction industry, small-scale services, large-scale services, and government services. Net output in each sector in year t depends upon net output in that sector in period $t-1$ plus the product of an exogenous amount of net investment and a fixed incremental output–capital ratio. The outputs in the six nongovernmental sectors are aggregated together by means of a set of invariant prices. Embodied technological progress may be introduced in the nonagricultural sector by systematically altering the incremental output–capital ratios, but no technological change is assumed to occur in the Pakistani simulations.

This specification of the determinants of nonagricultural production does have the advantage of being very easy to operationalize. It also shares the disadvantages discussed above in terms of the agricultural production relations. Further, omitting skilled and unskilled labor entirely from the nonagricultural production process involves implicit assumptions that hardly seem warranted, especially in a model that has a time horizon of several decades. It should also be noted here that demand conditions play no role whatsoever in the determination of output levels.

The implicit assumptions concerning constant returns to scale have been discussed above. In the nonagricultural portion of the economy, as opposed to the agricultural one, it is possible to prove that the government policy should direct investment toward only one nonagricultural sector, the one with the highest incremental income–capital ratio. To see this, it is necessary to note that net output in nonagricultural sector j at time t years after the beginning the simulation is simply

$$ON(j, t) = ON(j, 0) + \sum_{\tau=1}^{t} IN(j, \tau) \cdot \kappa(j), \qquad (6.5)$$

where $ON(j, t)$ is the net output of the jth sector t years after the beginning of the simulation, $IN(j, \tau)$ is investment in the jth sector in year τ, and $\kappa(j)$ is the incremental output–capital ratio in sector j. Further, since all relative prices are fixed at unity, aggregate nonagricultural output in year t, $\overline{ON}(t)$, may be written

$$\overline{ON}(t) = \sum_{j=1}^{6} ON(j, 0) + \sum_{j=1}^{6} \sum_{\tau=1}^{t} IN(j, \tau) \cdot \kappa(j) \qquad (6.6)$$

Given any amount of investment in the nonagricultural sector, it is clear that aggregate nonagricultural output in *every* year of the simulation period is maximized by investing only in that sector with the highest marginal product of capital. Since nonagricultural output is maximized in every year by investing in only one sector, this strategy will be the one chosen to meet any policy goal. Policy makers experimenting with the FAO model as applied to Pakistan will find that economic growth will proceed fastest when the government policy induces investment only in small-scale industry and, since it has an identical incremental capital–output ratio, large-scale modern services.

The linear output specifications in the FAO model build in an important conclusion about whether developing countries should concentrate their resources in encouraging agricultural or industrial growth. To answer this question in the context of the FAO model is reasonably straightforward. It translates into asking whether the rate of return on investment in its most productive agricultural use is greater or smaller than it is in its most productive nonagricultural use. Let us consider how this question is answered in the Pakistani case. In small-scale industry and the modern service sector the rate of return on investment is 33 percent. These are the highest rates of return available in the nonagricultural sector with the exception of the construction industry.[31] The rate of return on an investment in rainfed agriculture, on the other hand, holding the stock of land in rainfed agriculture constant, is 80 percent per annum.[32] Clearly, development should be based on rainfed agriculture and not on industry. Indeed, the optimum development strategy in the FAO model is to spend nothing on industrial growth.

It should be noted in passing that a country that can invest substantial amounts of money at rates of return in the neighborhood of 80 percent per annum without the risk of diminishing returns should without much strain be able to enjoy stupendous rates of economic growth. Indeed, a policy maker experimenting with the FAO model will soon discover that the secret of achieving spectacularly high sustained rates of economic growth is simply to invest all the government's funds in rainfed agriculture or, if he prefers a more balanced development strategy, in large farms in rainfed regions, small-scale industry, and modern services.

6.3 FINAL DEMAND

The FAO model does not deal with factor payments of any kind. Therefore, policies that affect demographic or economic variables through changes in wage rates, profits, or rents cannot be analyzed in the context of the model.

This neglect of factor payments is related in a formal way to the FAO model's neglect of relative output prices. Since factor payments do not appear in the model, any effects arising from changes in the functional distribution of income cannot be studied.

In the FAO model, the entire income side of the national income accounts is ignored. Per capita private consumption in period t is assumed to be equal to the product of per capita private consumption in period $t-1$ and a multiplier that depends upon the rate of growth of per capita income. It is stipulated in the FAO model that per capita private consumption can never decline. Government consumption grows each year by an amount determined by the product of the amount of money the government invested in itself in the previous year and a constant incremental consumption–investment coefficient.

Investment (net and gross because there is no depreciation) is defined to be equal to the value of gross domestic product minus private and governmental consumption plus net imports. The value of net imports in the FAO model is considered to be a policy variable set by the government, so net investment is known once aggregate output and total consumption are determined. All investment funds are assumed to be allocated according to exogenous policy rules. No mention is made of whether the fixed rates of return to capital are used in the allocation decisions.

A dollar invested in any of the sectors in year t is assumed to result in a fixed derived demand for the output of the construction industry.[33] Further, since a fixed proportion of the output of the construction industry is to be used for purposes other than net investment, it is clear that there will generally be either excess demand or excess supply in the construction industry.[34] To solve this problem, which typically arises in fixed-price models when elements of both the demand and supply side are considered, the FAO model introduces an *ad hoc* adjustment, which unfortunately does not always perform its intended function.

The adjustment works in the following manner. If in any year either (a) the derived demand for construction exceeds the supply of construction output available to meet that demand or (b) the supply exceeds the demand by some predetermined amount, then the investment allocation to construction in the *previous* year is altered. Further, the investment allocation to every other sector of the economy in the *previous* year must be modified in order to keep total investment constant. This process of reallocating investment allocations only refers to the year prior to the current one. A regression in this manner back to the first year of the simulation is explicitly forbidden. The object of this *ad hoc* procedure is, it appears, to ensure that the difference between the derived demand for construction and the supply available to meet that demand is small and nonpositive. Generally, this *ad hoc* adjustment will not yield the desired result except in the last year of the simulation. Worse still, there is a set of conditions that a policy maker may encounter while experimenting with the FAO model under which the adjustment procedure completely breaks down.

Let me support these two assertions with some simple analysis. First, let us assume that, by adjusting the investment allocations in year $t-2$, the construction industry is in equilibrium in year $t-1$. Now, let there initially be excess demand for the output of the construction industry in period t. To eliminate the excess demand in period t, investment allocations in period $t-1$ must be altered in favor of the construction industry. But before this alteration of investment flows the construction industry was in equilibrium! Generally, these changes in investment patterns will cause the construction industry, which in period $t-1$ had neither significant excess demand or supply, to develop one or the other. Thus, the construction industry adjustment for period t causes the construction industry in period $t-1$ to be out of equilibrium, the construction industry adjustment for period $t+1$ causes the construction industry in period t to be in disequilibrium, and so on until finally the only year in which the construction industry is in equilibrium is the last one in the simulation period.

As strange as this adjustment process now must appear, it has an even worse feature – it can break down entirely. Let us begin again in the situation in which the construction industry is in equilibrium in period $t-1$ but initially in a state of excess demand in period t. Clearly, we must return to period $t-1$ and allocate more money to investment in the construction industry, and this money must be taken away from investments in other sectors. It is possible, however, that further investment in construction in period $t-1$ will result in an *increase* in the derived demand for construction in period $t-1$.[35] But this increase in demand cannot be met with the capacity on hand in period $t-1$! Thus, it may be impossible to reallocate funds in period $t-1$ to meet an incipient situation of excess demand in period t. What happens to the FAO model when such a situation occurs is not discussed. Policy makers nonetheless should be aware of this problem.

The FAO model does contain a few equations on foreign trade. The major assumption there is that the balance-of-payments deficit, or, equivalently, the balance-of-trade deficit – there are no capital flows in the model – is exogenously determined by the government through its control over exports. The equations make no mention of the country's exchange rate or of a long-run balance-of-payments constraint.

6.4 EMPLOYMENT

Although employment has no effect on output in the FAO model, output growth does influence the growth of employment in large-scale industry, construction, capital goods production, and large-scale modern services (excluding the government). Increases in employment in any of those sectors is posited to be determined by the product of the increase in sectoral output and a sector-specific incremental employment–output ratio, defined as the change in employment divided by the change in output. These ratios are not held constant, but rather change according to a ratchet-type mechanism. In order to understand how the incremental employment–output coefficients vary, let us define $e(j, t)$ to be the incremental employment–output coefficient for industry j in period t. The equation determining $e(j, t)$ may be written

$$e(j,t) = e(j,t-1)\cdot\{1+\min(0,\beta(j)\cdot[u(t-1)-u(t-2)])\} \qquad (6.7)$$

where $\beta(j)$ is a positive constant specific to sector j and $u(t-1)$ is the unemployment rate in the large-scale modern sectors[36] in period $t-1$.

Equation (6.7) says that if the unemployment rate in the modern large-scale sectors drops by one percentage point, say from 10 to 9 percent from period $t-2$ to period $t-1$, then the incremental employment–output ratio in period t will be smaller than its value in period $t-1$ by $\beta(j)$ percent. If, alternatively, the unemployment rate in the modern large-scale sectors increases from period $t-2$ to $t-1$, then the incremental employment–output ratio in period t will be unchanged from its previous period's value. In brief, increases in the unemployment rate do not affect the incremental employment–output ratios, while decreases in the unemployment rate cause those ratios to decline. If the unemployment rate had a tendency to move cyclically around a constant trend, the $e(j, t)$ would have a tendency to continue declining until their low values caused the unemployment rate *in the model* to begin a secular increase. The high predicted unemployment rates in the Pakistani simulations, however, cannot be attributed to this mechanism, since in those simulations the $\beta(j)$ were all set equal to zero.

Regardless of whether the $\beta(j)$ are set equal to zero or not, the relationship between capital, labor, and output would be much more plausible if some production function were consistently used. In that framework it is much easier to formalize the concept of the proximate determinants of the quantity of labor demanded.

6.5 LABOR FORCE

The aggregate labor force in the FAO model is determined by weighting the entire population by a set of constant age- and sex-specific labor force participation rates. Neither the possibility that labor force participation rates could vary over time as economic development occurs nor the possibility that labor force participation rates can vary by rural or urban residence is discussed. The growth of the aggregate labor force, then, is determined by purely demographic factors. In order to define the unemployment rate in the modern large-scale sectors of the economy, the labor force in these sectors must be defined. Conceptually this is not a straightforward task because it is unclear whether the labor force in the modern large-scale portion of the economy should be considered to be the entire urban labor force or whether a more restricted definition should be used. In practice, however, this problem disappears. Labor force surveys yield data on employees in modern large-scale industries and on all people seeking jobs but not currently employed. This combination is taken to be the base-year observation on the size of the labor force associated with modern large-scale industries.

Subsequent to the base year, it is assumed that the labor force associated with modern large-scale industries has two sources of growth: natural increase and transfers from the remainder of the labor force. The natural increase of this modern labor force is assumed to be identical to the rate of increase of the aggregate labor force. It is possible to argue that the "natural" rate of growth of the modern labor force is likely to be lower than the rate of growth of the aggregate labor force, because the former is more urban and more educated than the latter. The magnitude of any error introduced by that assumption, however, will be trivial relative to the other problems in the model.

The specification of the number of people transferring to the modern labor force from the remainder of the labor force is given in equation (6.8)

$$TR(t) = TR(t-1)\left[\frac{LFR(t)}{LFR(t-1)}\right]\cdot\left[\frac{GR(t)}{GR(t-1)}\right]\cdot PD(t) \qquad (6.8)$$

where $TR(t)$ is the number of people transferring to the modern labor force in period t, $LFR(t)$ is the number of people in the residual labor force in period t, $GR(t)$ is a gravity constant for period t whose role in this equation is discussed below, and $PD(t)$ is a constant that depends upon the relative growth rates of the output per labor force member in the modern large-scale sectors compared with that in the remainder of the economy.

Another way of viewing this is to rewrite equation (6.8) as

$$\frac{TR(t)}{LFR(t)} = \left[\frac{TR(t-1)}{LFR(t-1)}\right]\cdot\left[\frac{GR(t)}{GR(t-1)}\right]\cdot PD(t) \qquad (6.9)$$

Recursively substituting the expression for the transfer rate in equation (6.9) into the right-hand side of that expression yields

$$\frac{TR(t)}{LFR(t)} = \left[\frac{TR(0)}{LFR(0)}\right]\cdot\left[\frac{GR(t)}{GR(0)}\right]\prod_{\tau=0}^{t} PD(\tau) \qquad (6.10)$$

Thus, the current transfer rate depends upon the transfer rate at the beginning of the simulation period, the gravity constant in period t relative to its value at the beginning of the simulation period, and the product of all the $PD(\tau)$ from the beginning of the simulation period up through year t.

In the FAO model, the gravity multiplier is defined by the following equation

$$GR(t) = \sigma_M(t)\cdot[1-\sigma_M(t)] \qquad (6.11)$$

where $\sigma_M(t)$ is the fraction of the total labor force in the modern sectors in year t. Clearly, $GR(t)$ is a symmetric function of $\sigma_M(t)$ over the interval [0, 1] that reaches a maximum at $\sigma_M(t) = 0.5$. The rate of transfer then increases, other things constant, as $\sigma_M(t)$ becomes closer to one-half, and decreases as it deviates more from that figure. Whether this assumption is generally accurate remains to be demonstrated. A policy maker using the FAO model should check the plausibility of the specification of the gravity multiplier for his own country.

The productivity differential term $PD(t)$ is computed using the following expression

$$PD(t) = 1 + \gamma \cdot \left[\frac{r_M(t)}{r_r(t)} - 1\right] \tag{6.12}$$

where $r_M(t)$ is the rate of growth over the previous period of output per labor force member in the modern sectors (excluding the government), $r_r(t)$ is the rate of growth over the previous period of output per labor force member in the remainder of the economy, and γ is a positive constant.

6.6 THE DEMOGRAPHICS

The demographic portion of the FAO model was not implemented in the Pakistani case because of lack of data. A family of population projections was used in its place. The following comments on the demographic specification are based on the prototype model (see pp. 100–104 of FAO 1976). The basic population accounting system can be improved. It does not maintain any information by single years of age and thus cannot age the population in a straightforward manner by applying single-year-of-age survival rates. The use of age-aggregated data makes the demographic accounting less precise than it would be if the simpler alternative of maintaining the age detail were followed. The impact of this imprecision, however, will be quite small in general.

The education accounting equations are similar to the demographic accounting equations. There is no behavioral content in either set. Educational policy can be seriously treated in the FAO model only after careful consideration is given to how education affects other variables in the model, for example, labor productivity and rural–urban migration.

The basic fertility variable in the prototype model is the general fertility rate.[37] The basic equation determining the general fertility rate is

$$\frac{GFR(t)}{GFR(t-1)} = 1 - a_1 \cdot ED(t-1) - a_2 \cdot JF(t-1) \tag{6.13}$$

where $GFR(t)$ is the general fertility rate in time t, $ED(t-1)$ is a term related to the average educational level of adults in period $t-1$, $JF(t-1)$ is a rough proxy for the rate of change of job opportunities for women in the modern sectors between period $t-2$ and period $t-1$, and a_1 and a_2 are positive constants. The precise definitions of $ED(t-1)$ and $JF(t-1)$ are given below. Before they are discussed, however, two aspects of equation (6.13) deserve attention. First, it should be noted that the process of urbanization is assumed to have no impact on fertility levels. Any policy maker who uses this equation should check to see if this is an appropriate assumption for his country. Second, holding $ED(t-1)$ and $JF(t-1)$ constant, the rate of change in the general fertility rate is constant. If that rate of change is positive, the general fertility rate continues to increase indefinitely and in the limit approaches positive infinity. If that rate of change is negative, the general fertility rate continues to decrease indefinitely and in the limit approaches zero. The implausibility of these inferences suggests that the relationship between the general fertility rate and its determinants ought in future work to be made more realistic.

The variable $ED(t)$ is defined by the following equation:

$$ED(t) = \max [EA(t), EA(t) \cdot \phi(t)] \tag{6.14}$$

where $EA(t)$ is the average adult level of education in period t and $\phi(t)$ is a population policy multiplier. In the FAO model there is no cost associated with changing $\phi(t)$, and thus the government can always obtain any general fertility rate it wishes by choosing an appropriate level of $\phi(t)$. Population policy is vastly more complex than this. It is clear, on this account alone, that serious work concerning population policy cannot be done in the context of the FAO prototype model.

The variable $JF(t)$ in equation (6.13) is supposed to be closely related to the rate of change of job opportunities for women in the modern sectors. The equation defining this variable is

$$JF(t) = \max [0, \rho_M(t) - \rho_F(t)] \tag{6.15}$$

where $\rho_M(t)$ is the rate of growth between period $t-1$ and t of employment in the modern sectors and $\rho_F(t)$ is the rate of growth of the number of females in the reproductive ages in the population as a whole between period $t-1$ and period t. The difference between the two growth rates is not unambiguously a measure of the job opportunities for women, since the proportion of women in the reproductive ages who can take advantage of job openings in the modern sectors is likely to change over time. Further, $\rho_M(t)$ can rise, but if the number of males seeking the new jobs rises even faster, opportunities for women may even decline. In addition, it is not clear why, if $\rho_M(t) - \rho_F(t) < 0$ implies a decline in fertility (relative to the situation where $\rho_M(t) - \rho_F(t) = 0$), then $\rho_M(t) - \rho_F(t) > 0$ does not imply a relative increase in fertility.

Mortality rates in the prototype model are to be generated from a model life-table system, given a value of the life expectancy at birth. The trend in this life expectancy may be determined either exogenously or endogenously given per capita consumption and government service investment. Policy makers should be warned that the endogenous determination of life expectancy in the FAO model may be inappropriate for their countries.

The rural–urban migration process is identical with the sectoral switching process discussed above except that the residual labor force is replaced by the rural population and the modern labor force is replaced by the urban population. With the appropriate modifications, the comments made above about the switching process apply as well to the specification of urban–rural migration.

6.7 CONCLUSION

In summary, the FAO model, although it is simple to implement, suffers from the disadvantages of that virtue. The linearity of the production relationships, the elimination of labor's role as a determinant of output levels, the lack of any capital depreciation, the absence of any demand structure, the lack of attention to the distribution of income (among other things), all strongly suggest that the policy prescriptions of the FAO model be treated very cautiously.

7 THE KELLEY, WILLIAMSON, AND CHEETHAM MODEL

Of the five second-generation models, the earliest one is the Kelley, Williamson, and Cheetham (KWC) model of dualistic economic development in Japan from the mid-1880s to the First World War. In addition to being the earliest of the second-generation economic–demographic simulation models, the KWC model provides the best framework for policy analysis among all of them.

7.1 THE RELATIONSHIPS BETWEEN INPUTS AND OUTPUTS

The KWC model recognizes two sectors of the economy: an agricultural sector and an industrial sector. The former is considered to be entirely rural, while the latter is assumed to be entirely urban. The functions relating inputs to outputs in the two sectors are restricted constant elasticity of substitution production functions. In the industrial sector, the production function may be written

$$y_I(t) = A_I\{[e^{\lambda_K t} K_I(t)]^{\rho_I} + [e^{\lambda_L t} L_I(t)]^{\rho_I}\}^{1/\rho_I} \qquad (7.1)$$

where $y_I(t)$ is the number of physical units of industrial output in period t, $K_I(t)$ is the capital stock in the industrial sector in period t, $L_I(t)$ is employment in the industrial sector in period t, λ_K is the rate of capital-augmenting technological progress in the industrial sector, λ_L is the rate of labor-augmenting technological progress in the industrial sector, ρ_I is a constant related to the elasticity of substitution between labor and capital in the industrial sector,[38] and A_I is a constant. The production function for agricultural output is analogous to the industrial production function and may be written

$$y_A(t) = A_A\{[e^{\mu_K t} K_A(t)]^{\rho_A} + [e^{\mu_L t} L_A(t)]^{\rho_A}\}^{1/\rho_A} \qquad (7.2)$$

where all the variables and parameters are defined like those in the industrial production function except that they all refer to agriculture.

Since these production functions are among the key elements of the KWC model, it is useful to discuss them in some detail. These constant elasticity of substitution production functions are the most sophisticated production functions used in any of the models reviewed here. This production structure has the advantage that it allows the elasticity of substitution between capital and labor to be different in the two sectors of the economy. It has a further advantage that differential rates of factor-augmenting technological progress may occur for a given factor across sectors and for the factors in a given sector. Indeed, an important element in the analysis of Japanese economic development in the KWC model is the sectoral difference in the bias of technological change. Such a phenomenon cannot be captured in any of the other production structures.

Both production functions assume constant returns to scale in any period. Further, it is assumed implicitly that agricultural production requires no inputs from the industrial sector (except agricultural capital) and that industrial production requires no raw materials from the agricultural sector. Someone interested in agricultural policy questions may want to modify these two assumptions. In particular, inputs from the modern sector such as fertilizer and electricity should be allowed to play a role in agricultural production. Similarly, agricultural inputs into industrial production should be allowed, if only to represent food processing. It should be noted that land does not explicitly appear in the agricultural production process. To the extent that land policy is important in a particular case the KWC model would have to be modified to reflect that.

As general as the KWC production structure appears, it does have one relatively subtle difficulty of which policy makers should be aware. The CES production functions in the KWC model are restricted in a special way – and this restriction has important implications for the interpretations of the CES parameters. A general two-input CES production function can be written:

$$y = A\{\delta K^{\rho} + (1 - \delta)L^{\rho}\}^{1/\rho} \tag{7.3}$$

where y is output, K is capital, L is employment, and A, δ, and ρ are constants. In the KWC production functions, the constant δ does not appear. The disappearance of that parameter implies that $\delta = 0.5$ and that its effect is captured in the constant term A. This is an extremely rigid restriction to put on a CES production function. Among other things, it implies that if the elasticity of substitution is close to unity, then the factor shares must be close to 50 percent and, conversely, if the factor shares do not approximate one-half, the elasticity of substitution cannot approximate unity.

Real-world data, however, may well be generated by a production process that has factor shares nowhere near one-half, but that still has an elasticity of substitution approximating unity. To see what effect such a situation would have, we performed the following conceptual experiment. Hypothetical data were generated by a Cobb–Douglas production function where labor's share was 75 percent, capital's share was 25 percent, and there was no technological progress. A CES production function of the type used in the KWC model was then fitted to these data. The result was that it was possible to produce with such data CES parameter estimates which indicated (a) an elasticity of substitution considerably below unity and a labor-saving bias in technological change and (b) an elasticity of substitution considerably above unity and a labor-using bias in technological change. These configurations are the assumptions made for industry and agriculture respectively in the KWC model. Thus, policy makers should be cautious about statements made concerning elasticities of substitution and biases in the rates of factor-augmenting technological progress on the basis of CES production functions from which the distribution parameter δ is absent.

7.2 THE DISTRIBUTION OF INCOME, SAVINGS, AND CONSUMPTION

Payments to the four factors of production in the KWC model are made according to the values of their marginal products. The functional distribution of income, as we shall see below, plays an important role in determining the aggregate saving rate in the economy. It may be argued by some that the neoclassical assumption that factors of production are paid the values of their marginal products does not hold in contemporary less developed countries and that therefore the KWC approach ought to be abandoned. Although the premise of this argument may certainly be true, the conclusion hardly follows from it. Distortions in factor markets can easily be introduced into the KWC framework. Indeed, one addition to the KWC model that policy makers may wish to make is to formalize the factor market distortions that they believe to be most important in their own countries.

Given a sensible functional distribution of income, it is relatively easy to progress to a plausible specification of savings behavior. In the KWC model, the simplest possible saving equations are introduced. It is assumed that there is no saving out of labor income and that a fixed proportion of income from capital is saved. It is possible, of course, to envision a more complex specification of the determinants of savings, and, indeed, such an addition may be useful in the context of policy analysis for certain countries.

Given the functional distribution of income in the economy and the relative prices of industrial and agricultural goods, the KWC model determines the demands for those goods using a modified Stone–Geary system of demand equations. In this aspect of model building the KWC model towers above the others discussed here. The KWC model is the only one in which the prices of goods play a plausible role in influencing the quantities of goods demanded. There are six basic consumption demand equations in the KWC model:

$$D_{Ij}^{L}(t) = \frac{\beta_{Ij}[W_j(t) - \delta] \cdot L_j(t)}{P(t)} \qquad (j = I, A) \qquad (7.4)$$

$$D_{Aj}^{L}(t) = [\beta_{Aj}W_j(t) + (1 - \beta_{Aj})\delta] \cdot L_j(t) \qquad (j = I, A) \qquad (7.5)$$

$$D_I^K = \frac{\Pi_I[(1-S)k(t) - \delta]}{P(t)} \cdot \hat{K}(t) \qquad (7.6)$$

$$D_A^K = [\Pi_A(1-S)k(t) + (1-\Pi_A)\delta] \cdot \hat{K}(t) \qquad (7.7)$$

where $D_{ij}^L(t)$ is the demand for the goods of sector i by employed workers in sector j in year t, D_i^K is the demand for the goods of sector i out of capital income received in period t, $W_j(t)$ is the per worker labor income of people employed in sector j in period t, $L_j(t)$ is the number of people employed in sector j in year t, $P(t)$ is the ratio of the price of industrial goods to the price of agricultural products, S is the savings rate out of income from capital, $k(t)$ is the average amount of capital income per recipient of capital income in year t, $\hat{K}(t)$ is the number of recipients of capital income in period t, and β_{II}, β_{IA}, β_{AI}, β_{AA}, Π_I, Π_A, and δ are constants.

It is not necessary to discuss the properties of the Stone–Geary system of demand equations here. There are, however, two points worth mentioning briefly. First, the Stone–Geary system is quite flexible. With only minor modifications in the equations it is likely that a policy maker can specify a system of demand relations that is appropriate for his country. Second, since the constants in the demand functions differ by income type, changes in the functional distribution of income alter both the aggregate savings rate and the pattern of demand. The impact of these differential consumption patterns on the pace and character of the development process may be quite important, and they should not be overlooked by policy makers or model builders.

7.3 GENERAL EQUILIBRIUM CONSIDERATIONS

Given the functional distribution of income and the relative price of industrial goods, savings and the consumption demands for the economy's two products are determined. Since it is postulated that all savings are invested and that all investment is manifested by a demand for the industrial good, these conditions determine the vector of final demand.[39] The relative price ratio $P(t)$ is computed so that the output of each of the two sectors exactly equals the quantities of those products demanded. The KWC model, then, is, technically speaking, a general equilibrium model in which the relative price ratio, output levels, consumption, investment, and functional distribution of income are all determined simultaneously.

The advantages for policy analysis of having a general equilibrium framework, even if there are distortions, are numerous. A model in which the terms of trade between industry and agriculture are endogenous allows a policy maker to analyze decisions whose primary impact is on those terms of trade. Endogenous factor incomes allow policy makers to consider the effects of policies that primarily affect various income flows. Indeed, in the framework of the KWC models one can determine what the effect will be on relative output prices of a government's attempt at changing consumers' purchasing patterns. When both the supply and demand sides of the economy are allowed to interact properly in a model, it is much easier to use that framework to pose and answer policy questions than if only the demand or only the supply side of the economy is present in the model. It is the successful integration of the supply and demand sides of the economy that sets the KWC model apart from the other second-generation models studied here and that makes it a good foundation on which to add further developments.

7.4 DYNAMIC ASPECTS

Several dynamic aspects of the KWC model remain to be discussed. Of particular importance are the problems of allocating investment expenditures across sectors and determining the volume of rural–urban migration. The formal specifications of both these processes are identical in KWC models, so for convenience they will be discussed together. For each of those two facets of the model, an equilibrium and a disequilibrium formulation are given. The equilibrium specification of the investment allocation problem begins with the assumption of costless capital mobility. That assumption implies that the value of the aggregate capital stock in the country plus the amount of investment in the current year is treated as an annual flow variable that is allocated to the two sectors so as to equalize the rate of return on capital across the sectors in each year. The equilibrium formulation of the migration problem starts with the assumption of costless migration. In this case, the inference is that the labor force divides itself across sectors so as to equalize wage rates in the two sectors.[40] Neither of these equilibrium formulations, however, is very persuasive.

In reality, neither capital mobility nor labor mobility is perfectly costless. In order to represent formally the kind of imperfect capital and labor mobility that occurs in reality, the KWC model provides two disequilibrium formulations. Capital mobility in this latter view is allowed only in the allocation of current investment funds. Capital, once put in place, is considered forever immobile. The total amount of money invested in each sector depends upon the distribution of savings by sector of origin and upon the relative rates of return in the two sectors. The basic equations of the disequilibrium framework are

$$S_{II}(t) = \$_I(t) \quad \text{if} \quad r_A(t) - r_I(t) < \tau \tag{7.8}$$

$$S_{II}(t) = \$_I(t)\, e^{\mu[r_I(t) - r_A(t) + \tau]} \quad \text{if} \quad r_A(t) - r_I(t) \geqslant \tau \tag{7.9}$$

$$S_{IA}(t) = 0 \quad \text{if} \quad r_A(t) - r_I(t) < \tau \tag{7.10}$$

$$S_{IA}(t) = \$_I[1 - e^{\mu[r_I(t) - r_A(t) + \tau]}] \quad \text{if} \quad r_A(t) - r_I(t) \geqslant \tau \tag{7.11}$$

$$S_{AA}(t) = \$_A(t) \quad \text{if} \quad r_I - r_A(t) < \tau \tag{7.12}$$

$$S_{AA}(t) = \$_A(t)\, e^{\mu[r_A(t) - r_I(t) + \tau]} \quad \text{if} \quad r_I(t) - r_A(t) \geqslant \tau \tag{7.13}$$

$$S_{AI}(t) = 0 \quad \text{if} \quad r_I(t) - r_A(t) < \tau \tag{7.14}$$

$$S_{AI}(t) = \$_A(t)\cdot[1 - e^{\mu[r_A(t) - r_I(t) + \tau]}] \quad \text{if} \quad r_I(t) - r_A(t) \geqslant \tau \qquad (7.15)$$

where $S_{ij}(t)$ is the savings generated in sector i invested in sector j in time period t, $\$_i(t)$ is the total savings generated in sector i in period t, $r_i(t)$ is the rate of return on capital in sector i earned in period t, and μ and τ are constants that can be affected by governmental policies.

Although this specification appears rather cumbersome, it is truly quite simple. Since the explication is identical for investment generated in each sector, it will be sufficient to discuss only investment in the industrial sector. All investment generated in the industrial sector is assumed to be invested in the industrial sector unless there is a rate-of-return differential favoring agriculture of at least τ percentage points. As the rate-of-return differential favoring agriculture grows larger, the fraction of urban savings invested in the rural area grows larger and asymptotically approaches unity as the differential approaches infinity. This is a plausible representation of the allocation of investment funds even where capital markets are poorly developed.

The disequilibrium formulation of the migration process works in much the same manner. The motivating force behind rural–urban migration is the expected income differential between urban and rural areas. The rate of rural-to-urban migration is assumed to be

$$m(t) = 1 - e^{\rho w^*(t)} \qquad (7.16)$$

where $m(t)$ is the rate of rural–urban migration in year t, $w^*(t)$ is rural–urban income differential adjusted for the costs of migration and ρ is a constant.[41]

Given the sectoral allocation of investment and the determination of rural–urban migration, there remains only one dynamic element of the model left to discuss – the rate of growth of the labor force. In the KWC model, the rates of growth of the industrial labor force and the agricultural labor force are exogenous parameters. Thus, except for migration, the KWC model does not allow for any influences running from the economy to the demography of the country. Policy makers interested in a full-scale demographic–economic simulation model will have to supplement the KWC model here with formulations that are relevant to their country.

7.5 CONCLUSION

The KWC model, in its present form, is strong economically but underdeveloped demographically. This is clearly appropriate for the purposes of the model builders, but it is inappropriate from the perspective of those interested in economic–demographic interrelationships. Agricultural policy makers in particular will find that there is much of interest that can and should be incorporated into the KWC framework in order to make it useful for them.

8 THE ADELMAN–ROBINSON MODEL OF KOREA

It is useful to consider here two third-generation models, the Adelman–Robinson model of Korea and the Kelley–Williamson model of a representative open-economy developing country. Neither of these models has a well-articulated demographic aspect, and therefore they do not technically belong in a review of economic–demographic simulation models. It is useful, however, to investigate their structures, because it will be on frameworks such as these that the third generation of economic–demographic simulation models will be constructed. Reviewing these two models, then, allows us a glance into the future.

The Adelman–Robinson simulation model of the Korean economy differs from the second-generation economic–demographic simulation models reviewed above in that it has a medium-term focus. The simulation period is never allowed to be longer than 9 years. As a consequence of this focus many of the economic–demographic linkages highlighted in the other models are omitted from this one. The Adelman–Robinson model also differs from the other models reviewed here in its detailed consideration of the country's financial and monetary structures. These differences are quite significant and make comparison of the Adelman–Robinson model with the others somewhat difficult. The central question addressed by the Adelman–Robinson model, however, is the same as that addressed by the Bachue model, the relationship between economic growth and the distribution of income. Therefore, it will be useful to ascertain how two quite different models approach the same problem.

The Adelman–Robinson specification is divided into three stages. The effects of the financial structure of the Korean economy on the allocation of nominal investment funds are determined in stage I. These allocations are allowed to depend on expectations of future sales and prices, which may or may not be subsequently realized. Stage II is a static general equilibrium model that takes the results of stage I as given. This portion of the model not only determines relative prices endogenously but also determines the rate of inflation. The third stage is composed of dynamic equations that take the results of the second stage and update endogenous variables so that the model can return to stage I. In the presentation of the model below, we shall discuss stage II first, and then stages III and I.

8.1 PRODUCTION RELATIONS

The Adelman-Robinson model differentiates between 29 sectors of the Korean economy: rice, barley, and wheat production; other agricultural output; fishing; processed foods; mining; textiles; finished textile products; lumber and plywood; wood products and furniture; basic chemical products; other chemical products; petroleum products; coal products; cement; nonmetallic and mineral products; metal products; nonelectrical machinery; electrical machinery; transport equipment; beverages and tobacco; other consumer products; construction; electricity and water; real estate; transportation and communications; trade and banking; education; medical services and other services; and personal services. In each of these 29 sectors, the model delineates four firm (farm) sizes; thus it requires 29 x 4 or 116 separate production formulations.

Two types of production functions are used in the model, Cobb-Douglas and two-level CES. The Cobb-Douglas specification, used in the 18 nonfarm, nonservice sectors, is

$$X_{is}(t) = A_{is}(t)K_{is}^{\alpha_{is}}(t) \prod_{\lambda=1}^{n_{is}} L_{is\lambda}^{\beta_{is\lambda}}(t) \tag{8.1}$$

where $X_{is}(t)$ is the physical output of firms of size s in sector i in period t, $A_{is}(t)$ is the productivity constant for firms of size s in sector i in period t, $K_{is}(t)$ is the relevant capital stock, and $L_{is\lambda}(t)$ is the amount of labor of skill type λ employed in firms of size s in sector i in period t, and the parameters $\alpha_{is}, \beta_{is1}, \beta_{is2}, \ldots$ sum to unity, and n_{is} is the number of labor skill types employed by firms of size s in sector i.

Output in the two-farm sectors is modeled by two-level CES production functions of the form

$$X_{is}(t) = A_{is}(t)[\alpha_{is} \cdot L_{is}^{-\rho_i}(t) + (1 - \alpha_{is})K_{is}^{-\rho_i}(t)]^{-\gamma_{is}/\rho_{is}} \tag{8.2}$$

where

$$L_{is}(t) = k \prod_{\lambda=1}^{n_{is}} L_{is\lambda}^{\beta_{is\lambda}}(t) \tag{8.3}$$

and where $X_{is}(t)$ is the output of farms of size s in sector i in period t, $A_{is}(t)$ is the relevant productivity constant, α_{is} is the CES distribution parameter for farms of the (i, s) type, $L_{is}(t)$ is the aggregate labor input measure formed from seven labor skill categories, $K_{is}(t)$ is the sector's capital stock in period t, ρ_{is} is a parameter specific to farms of type (i, s) that is related to the elasticity of substitution between capital and the labor aggregate, γ_{is} is a parameter that is less than unity because of the absence of land from the agricultural production functions (more about this below), k is a parameter, $L_{is\lambda}(t)$ is the number of people in skill category λ who work in sector (i, s) in period t, n_{is} is the number of skill categories utilized on the (i, s) farm type, and the n_{is} exponents, $\beta_{is\lambda}$, sum to unity.

Outputs of the nine service sectors are determined by special assumptions. For the most part, output growth between periods is assumed to depend upon the level of the ratio of the service sector's current price to the average current price of commodities produced in the nonservice sectors. Labor demands are typically computed on the assumption of fixed labor–output ratios. Inter-industry purchases are incorporated into the model assuming fixed input–output coefficients.

This production structure has both a number of advantages and disadvantages. The relatively large number of sectors articulated and the formal consideration of firm sizes allows us to inquire about the pattern of production in great detail. This detail brings with it, however, certain problems. The assumption that most production functions were of the Cobb–Douglas variety was probably made to economize on data, but it precludes any non-Hicks neutral technological change. It is argued in Kelley, Williamson, and Cheetham (1972) that the factor-augmenting bias in rates of technical change may be an important factor in explaining the nature of the development process. Indeed, Williamson and Lindert (personal communication) show that understanding the factor-saving bias in technical change is a crucial element in understanding inequality trends over the course of U.S. economic development. To the extent that these arguments are correct, the omission of factor-augmenting technical change from the Adelman–Robinson model reduces its ability to analyze changes in the distribution of income properly. The lack of any technological change in nine service sectors may also cause problems.

Land is omitted from the agricultural production functions in a formal sense, but the parameters γ_{is} are assumed to be less than unity to reflect diminishing returns to agricultural labor and capital alone. In essence, the land input may be considered to be subsumed in the term $A_{is}(t)$ in the production functions.

8.2 DEMAND FOR LABOR, SUPPLY OF LABOR, AND DETERMINATION OF WAGE RATES

Given output prices, factor prices, capital stocks, technical conditions, market structure, and export constraints, firms in the Adelman–Robinson model generally demand that quantity of labor services that maximizes their profits. In most cases, the derived demand functions are straightforward and so need not be described here. There are several special circumstances, however, that are useful to discuss. In the nonagricultural sectors, the smallest firms are assumed to be self-employed unskilled individuals. Therefore, these firms have no derived demand for any other laborers. In agriculture, there are assumed to be two categories of workers, family workers who must stay on a given parcel of land during the year, and other laborers who are mobile within agricultural sectors. Also, farmers on different-sized farms face different constraints on how much nonfamily labor they can hire. Given this specification, the demand for nonfamily agricultural labor also arises from the process of farmers trying to maximize their incomes. There is no demand equation for farm family workers, and consequently no equilibrium wage rate for them is determined in the model. In the service sectors, labor demands are not derived from the assumption of profit maximization, but from a set of *ad hoc* rules described above.

Labor supply to the nonagricultural sectors takes two forms. The quantity of skilled labor is considered to be fixed during the year. The quantity of low-skilled labor available to the nonagricultural sectors is assumed to vary with the wage rate according to the following specification:

$$L^s(t) = L^{*s}(t)\left[1 + \phi_s\left(\frac{W^s(t)}{W^n(t)} - 1\right)\right] \qquad (8.4)$$

where $L^s(t)$ is the supply of nonagricultural labor of skill level s in year t, $L^{*s}(t)$ is the supply of nonagricultural labor of skill level s in year t under the assumption that the wage rate is $W^n(t)$, ϕ_s is an elasticity parameter specific to skill class s, $W^s(t)$ is the actual wage rate of laborers of skill class s in period t, and $W^n(t)$ is the "normal" wage rate of workers in that group in period t. The "normal" wage is defined in the model to be essentially a price index whose level is different for each skill group.

In equation (8.4) current labor supply and current wage rates are positively related. There are three possible interpretations of this association. It is possible that labor force participation rates are positively associated with real wage rates, that hours of work per individual are positively associated with wage rates, or that the rate of migration into these urban sectors from rural areas is positively related to the wage rate. Each of these three alternatives has quite different implications for the specifications in other portions of the model. The authors seem to lean toward the last interpretation, but, as we shall see below, that interpretation is difficult to square with their migration formulation.

Next, let us consider the determination of employment and wages in the nonagricultural sectors and in the agricultural sectors. In the nonagricultural nonservice sectors, wage rates are determined in a two-step procedure. First, the average wage rate for workers of a given skill level is assumed to be that wage rate that equates the aggregate demand and aggregate supply of workers of the given skill level. In the second step, the average wage is multiplied by a set of exogenous constants to compute the wage rate specific to a given industry and to a specific firm size. Further, wages in the service industries (except personal service) are also determined by multiplying the average wage by a set of exogenous constants. Thus, 78 wage rates (26 industries by 3 firm sizes) are determined from a single aggregate wage rate.

This specification seems to be seriously flawed, particularly in the context of a model that focuses upon changes in the distribution of income. On a purely technical level, that formulation seems to violate a very basic aggregation constraint: the sum of all the labor demands of the firms at the wage rates facing them should equal the aggregate demand for labor and in equilibrium the aggregate supply of labor. However, the aggregate demand for labor by firms facing the wage rates after the multiplicative adjustment described above is not, in general, equal to the aggregate demand for labor by the same firms when they all face the average wage rate. Thus, *ex post*, the aggregate supply and demand for various grades of labor are not in equilibrium. Any attempt to force them into equilibrium by modifying the firms' demands would violate the postulate of profit maximization.

On a substantive level, it seems that assuming that 78 wage rates are determined as fixed multiples of each aggregate wage rate builds into the model a substantial amount of stability in the size distribution of income. It would surely be of some interest if the robustness of the model's conclusions concerning the distribution of income could be tested in a framework in which there is more flexibility in the relative wages of individuals with the same skill levels.

In each agricultural sector, wage rates are determined so that the demand for nonfamily labor (consistent with the hiring constraints mentioned above) is equal to the exogenously determined number of nonfamily workers in that sector. No equilibrium wage is determined for family laborers.

8.3 THE TRANSLATION OF FACTOR INCOME INTO HOUSEHOLD INCOME

The Adelman–Robinson model distinguishes 15 groups of income recipients: engineers, technicians, skilled workers, apprentices, unskilled workers, white-collar workers, government workers, self-employed workers in manufacturing, self-employed workers in service occupations, capitalists, agricultural laborers, and owners of farms of four different sizes. The income distribution in each recipient group is assumed to be lognormal. The log means and roughly half the log variances are computed from the income data described above. The other log variances are determined outside the model and are assumed to be constant.

Before we continue, it should be recalled that within recipient groups for which the log variance is computed, the entire variation in income is produced by applying an exogenous set of multipliers to the average income for members of that recipient group. The number of people at each income level will vary, of course, but a substantial portion of the determinants of the log variances are built into the model in the form of the fixed multipliers.

Given survey data on the occupational distribution of workers in households where the head is in one of the fifteen recipient groups, data on the average number of workers in households in each recipient group, and the assumption that those figures remain constant over the simulation period, it is possible to compute, in a straightforward manner, the mean incomes of households where the head is in each of the recipient groups, and the numbers of households in each group. Each of these distributions is assumed to be lognormal, with the calculated mean and log variances determined in the previous step.

It is worth pausing here to digest the meaning of this last assumption. Since roughly half the log variances in the occupational income distributions are assumed to be fixed, roughly half the log variances of the household income distributions are assumed to be fixed. The other log variances are determined in good measure by the fixed multipliers discussed above. Household income distributions are combined to form the aggregate income distribution by weighting them by the proportion of households in each of the 15 categories. As we shall see below, the Adelman–Robinson model is specified so as to make substantial changes in these weights difficult to achieve. It appears, then, that the specification of the model is biased toward the conclusion that the aggregate income distribution is quite stable. It should come as no surprise, therefore, to learn that this is indeed one of the main conclusions the authors draw from their simulations.

8.4 CONSUMPTION, SAVINGS, AND INCREASES IN MONEY BALANCES

In any year, savings are computed on the assumption that average savings rates for each recipient group are constant. These average savings rates vary across recipient groups in a given year and vary over time within groups. Still in each year, the amount saved is independent of all the intragroup distributions of income and depends only on the distribution of mean income levels between groups. A preferable treatment of savings would be the use of the extended linear expenditure system (see Lluch *et al.* 1977), which makes the current savings rate depend on relative commodity prices. In addition to savings, taxes are subtracted from the mean income in each recipient group to obtain disposable income. Taxes paid by members of a recipient group do depend on the distribution of income within the group, but whether the relation between income distribution and taxation is a quantitatively significant one remains to be seen.

After the subtraction of savings and taxes from the mean income in each recipient group, consumers are assumed to allocate their remaining income to the purchase of one of the commodities or services in the model or to new money balances. The amount of disposable income spent on new money balances may be written as

$$\Delta M_h(t) = \xi_h \Delta M(t) \tag{8.5}$$

where $\Delta M_h(t)$ is the change in the holding of money balances by members of recipient group h in year t, ξ_h is a constant specific to recipient group h, and $\Delta M(t)$ is the aggregate change in money holdings for the economy as a whole in year t. The aggregate change, in turn, may be expressed as

$$\Delta M(t) = kY(t) - M(t-1) \tag{8.6}$$

where k is the average velocity of money (assumed to depend upon the inflation rate, nominal interest rates, and a time trend), $Y(t)$ is nominal GNP in year t and $M(t-1)$ is the money supply in year $t-1$.

There are two features of this approach that are especially puzzling. First, savings and increases in money holdings are determined independently. Savings are manifested neither in the purchase of durable goods nor in increases in money holdings. What form savings take is unclear. Second, changes in a group's cash balances are independent of changes in the group's income level and of the level of its cash balances. Thus, if one group's income and savings decreased, it still might increase its monetary holdings. A better specification would be one that derived each group's cash balances from information on the group's economic condition and then aggregated across groups and firms to determine aggregate money holdings.

Income available for commodity consumption, then, is obtained by subtracting from the recipient group's mean income, its mean savings, taxes, and increases in its money stocks. Consumption expenditures on goods are then determined for each recipient group from a formulation that assumes that price and income elasticities are invariant during the year. The implied system of demand equations unfortunately does not meet the "adding-up" criterion, so an *ad hoc* proportional adjustment is needed to ensure that expenditures sum to the income available for such expenditures. The income and price elasticities are readjusted every year in stage III of the model. Commodity consumption patterns, then, clearly depend on the mean of the within-group income distribution but are affected by other aspects of the distribution only to the extent that those aspects affect the group's level of taxation. A specification of the commodity composition of consumption that paid more attention to intragroup income distributions surely would have been more appropriate for this model.

8.5 INVESTMENT, GOVERNMENT EXPENDITURES, AND FOREIGN TRADE

The allocation of investment funds to sectors is done in stage I of the model and is discussed briefly below. Nominal investment is translated into the demands for the outputs of the various sectors using the current prices of those outputs and a fixed coefficients capital matrix that specifies the commodity composition of one unit of investment in each sector.

Real government expenditures in each year are specified exogenously.

Nominal expenditures on each sector are determined by multiplying the real expenditure level by an appropriate price index and then by a set of exogenously determined budget shares. The Adelman–Robinson model distinguishes five kinds of internationally traded goods: noncompetitive imports, competitive imports whose prices are domestically determined, exports whose prices are domestically determined, competitive imports whose prices are determined in the world market, and exports whose prices are determined in the world market. The specifications also take into account governmental export-promoting activities.

8.6 THE DYNAMIC EQUATIONS

Output prices, output quantities, factor prices, the price level, and the distribution of income are all determined in stage II of the model conditional on some initial conditions. These initial conditions are of two sorts. The first is essentially an updating of parameter values and changes in various stocks. These form stage III of the model. Stage I of the model describes the workings of the financial sector of the economy. The nominal levels of investment expenditures in each sector of the economy are determined there. In this section, we discuss the stage III equations. The financial sector specification will be briefly discussed in the following section.

In stage III of the Adelman–Robinson model, the productivity constants in the production functions are updated on the assumption of exogenously fixed rates of technological progress. The time profile of the interest rate for funds in the organized money market is exogenous and is updated in stage III. The exchange rate is modified in this portion of the model to take into account the last period's rate of inflation. Exports, imports, and tax rates vary over time in a predetermined manner.

In terms of the emphasis on income distribution in the Adelman–Robinson model, an important element in stage III is the representation of migration, both between rural and urban areas and between various occupational groups in the urban area. Unfortunately, this aspect of the model is discussed so briefly that it is difficult to ascertain exactly what the authors did. The natural growth rates of both the urban and the rural areas of Korea are determined exogenously. Since the urban growth rate is assumed to be somewhat higher than the rural growth rate, the model, as the authors realize, incorporates a certain amount of implicit rural–urban migration that is completely independent of their migration specification. Not only are rural and urban natural growth rates assumed to be fixed, but the natural growth rates of the various skill categories also appear to be exogenous. Rural migrants are assumed to come from agricultural laborers and owners of the two smallest sizes of farms. They are assumed to enter three urban labor groups: skilled workers, apprentices, and unskilled workers. No migrants are allowed to become self-employed urban workers. Further, we are not told in what proportions the rural migrants are allocated to each of those three urban labor groups. Once migrants arrive in the urban area and are assigned a sector, it appears that they remain in that sector for the remainder of the simulation period. This observation is modified to a minor extent, both for the migrants and for the other members of an occupational category, by the labor supply specification in equation (8.4).

The driving force behind migration is assumed to be the differential between the average incomes of people in the sending and receiving sectors of the economy. No mention is made of cost of living differentials or of any Harris–Todaro type considerations, nor is there any mention of where in the occupational income distributions the migrants come from or where they settle. The latter is particularly unfortunate for a model that focuses on questions pertaining to the distribution of income.

It can be seen that rural-urban migration is not a well-articulated phenomenon in the Adelman–Robinson model. This is also true of movement between urban occupations. The numbers of engineers, technicians, government workers, and self-employed urban workers all grow at exogenously given rates. Limited endogeneity is allowed only for skilled workers, apprentices, and unskilled workers.

Clearly, the migration specification here can be substantially improved by following the formulation in the Kelley–Williamson model discussed in Chapter 9.

8.7 THE FINANCIAL MARKET

Of all the models reviewed here, the Adelman–Robinson model provides the most detailed description of the financial side of the economy. What follows is a brief discussion of a quite detailed specification. The function of the financial market in the model is to allocate investment funds, in nominal terms, between sectors and firms. For the most part, investment demands are based on expectations of future output levels, output prices and factor prices. First, let us consider how these expectations are formed and then move on to consider how these expectations affect the allocation of investable funds.

Expectations concerning the rate of sectoral output growth are assumed to be identical across sectors and to depend on past growth rates. Each firm's expected share of its market is assumed to depend on its relative profitability in the previous period. The expected rate of output price change is assumed to be identical across sectors and is assumed to be an exogenous constant over the simulation period. Thus, expected rates of price change are not influenced by the observed rates in the recent past. Expected wage rates for the following year are assumed in the model to be the wage rates paid in the past year. Even if wages are rising steadily over time, firms will still maintain the expectation of stationary wage rates for each year into the future. The price of capital goods is assumed to grow at the same exogenous rate as prices in general.

Given these expectations, firms are assumed to demand two types of capital: working capital and fixed capital. The demand for working capital, in turn, is assumed to have two components: working capital that is required for the firm to have any positive level of output, and working capital above that minimum requirement. The demand for the first sort of working capital is proportional to the expected value of output and is independent of variations in the interest rate. The demand for the second sort of working capital depends both on the expected value of output and on the interest rate.

The demand for fixed capital on the part of manufacturing firms is the solution to the problem of maximizing profits given fixed output levels, output prices, factor prices and its initial capital stock. Certain government interventions are allowed here to encourage firms to increase their capital spending.

Service and agricultural sectors are treated differently. Service sectors are assumed to have a desired rate of growth of their capital stocks, which is allowed to vary with sector and firm size. Their demands for investment funds for fixed capital depend only on the expected price of capital goods and on the desired increase in their capital stocks. Investment in the agricultural sectors is assumed to be exogenously determined, and thus the discussion above does not apply to them.

The supply of funds for investment has five sources in the Adelman–Robinson model: retained earnings, household savings, foreign capital inflow, government savings, and the financial sector itself. Interest rates in the formal portion of the financial market are assumed to be set exogenously by the gôvernment and may differ by sector and by firm size. Firms are allowed to borrow as much as they please in the formal sector subject to a creditworthiness constraint. If they wish to borrow more than that, they can turn to the informal portion of the market, where they can borrow money at a higher interest rate. Equilibrium is reached when the interest rate in the informal sector of the financial market clears the market for investable funds.

8.8 THE ADELMAN–ROBINSON MODEL: SOME CONCLUDING THOUGHTS

The Adelman–Robinson model is truly a pioneering piece of research. It breaks new ground in a number of areas, but particularly in the field of income distribution analysis. It is unfortunate, therefore, that some of the specifications in that segment of the model are questionable. There is no doubt, however, that this work will have a substantial influence on future efforts in this field and that model builders will now be more sensitive to questions concerning the distribution of income than they have been hitherto.

9 THE KELLEY–WILLIAMSON REPRESENTATIVE DEVELOPING COUNTRY MODEL

The Kelley–Williamson (1980) model of a representative developing country (hereafter referred to as the RDC model to avoid confusion with the Kelley, Williamson, and Cheetham model) is an extension of the Kelley, Williamson, and Cheetham model described in Chapter 7. Like the KWC model and the Adelman–Robinson model, the RDC model is neoclassical in spirit, in that both output and factor prices are endogenous and simultaneously determined. The focus of the model is on the pattern of development of a representative small developing country. It has purposely been kept relatively simple in order to aid our understanding of the results that it will produce. Although the model contains several new features, its most innovative feature is its inclusion of goods that are not tradable between the urban and rural portions of the country. The existence of such goods implies that there could be cost-of-living differences between the urban and rural areas and, through this mechanism, has important implications for the pace of economic growth, migration, and the distribution of income. Let us now turn to the specification of the model.

9.1 THE PRODUCTION RELATIONS

The RDC model distinguishes eight sectors. Two sectors, manufacturing and agriculture, produce goods that are traded both internally and internationally. Their prices are determined in the world market and by the trade policy of the country. Skill-intensive services are assumed to be produced in the urban portion of the country and to be tradable within the country, but not externally. The outputs of the remaining sectors are assumed to be consumed locally. Three types of output produced in urban areas are completely nontradable: high-cost housing, low-cost housing, and labor-intensive services. Two types of output in the rural areas are completely nontradable: low-cost housing and labor-intensive services.

The production functions for manufacturing and skill-intensive services are of the two-level CES variety. They take the form

$$Q_i(t) = A_i(t)\{\xi_i \Phi_i(t)^{(\sigma_i-1)/\sigma_i} + (1-\xi_i)[z(t)\cdot L_i(t)]^{(\sigma_i-1)/\sigma_i}\}^{\sigma_i/(\sigma_i-1)} \quad (9.1)$$

$$\Phi_i(t) = \{\xi_i'[x(t)K_i(t)]^{(\sigma_i'-1)/\sigma_i'} + (1-\xi_i')[y(t)S_i(t)]^{(\sigma_i'-1)/\sigma_i'}\}^{\sigma_i'/(\sigma_i'-1)} \quad (9.2)$$

$$Z_i(t) = a_{iz}\cdot Q_i(t) \quad (9.3)$$

$$Q_{ij}(t) = a_{ij}\cdot Q_i(t) \qquad j = 1,2 \quad (9.4)$$

where the subscript i refers to either the manufacturing or the skill-intensive service sector; the subscript j refers to the other two remaining tradable-goods-producing sectors; $Q_i(t)$ is value-added in sector i in the period t; $A_i(t)$, $z(t)$, $x(t)$, and $y(t)$ are productivity constants; ξ_i, ξ_i', σ_i, and σ_i' are parameters of the two CES functions; $\Phi_i(t)$ is the aggregate capital variable in sector i in period t (as specified in equation 9.2); $L_i(t)$ is the quantity of unskilled labor employed in sector i in period t; $K_i(t)$ is the quantity of physical capital employed in sector i in period t; $S_i(t)$ is the quantity of skilled labor employed in sector i in period t; $Z_i(t)$ is the quantity of intermediate inputs purchased from abroad used in sector i in period t; a_{iz} is a fixed parameter; $Q_{ij}(t)$ is the quantity of intermediate inputs purchased from domestic sector j for use in sector i in period t; and the a_{ij} comprise two fixed parameters for each sector i.

This two-level CES specification for value-added has a number of virtues. First, it can be used to investigate both the effects of biased factor-augmenting technological change and unbalanced technological progress across the various sectors of the economy. The literature has suggested the importance of both aspects of technological development and therefore it is certainly appropriate to incorporate a specification that can deal with both of them. The two-level CES formulation is consistent with the development literature in that it allows for complementarity between skilled labor and capital. It is certainly a strength of this formulation that it receives support from other work in the field.

It is somewhat unfortunate, however, that this sophisticated specification for value-added is combined with the simplest possible assumptions regarding intermediate inputs purchased domestically and intermediate inputs purchased from abroad. The constant-coefficients hypotheses manifested in equations (9.3) and (9.4) certainly simplify the model, but at a considerable cost in terms of plausibility. If the RDC model were like the Adelman–Robinson model in having a time horizon of only 9 years, then the fixed-coefficients assumptions could be acceptable. It is implausible to believe, however, that, over a 20- or 30-year simulation span, these input–output coefficients would remain unaltered. Further, this representation presumes that there can never be any input-saving technological change nor any substitution between domestically produced intermediate inputs and imported intermediate inputs. Over time, as technological progress occurs in value-added, but not in the use of intermediate goods, the cost of the latter will become an ever larger fraction of all gross output prices. Perhaps an example will help clarify one of my objections. In the face of rising oil prices, Brazil has decided to build a nuclear power plant to generate electricity and to produce gasohol as a fuel for automobiles. Neither of these substitutions is allowed given the current formulation of the production equations.

Value-added in the agricultural sectors is represented by a Cobb–Douglas production function, and there are again two fixed-coefficient intermediate inputs equations. The production relations are

$$Q_A(t) = A_A(t)\,[x(t)K_A(t)]^{\alpha}\,[z(t)L_A(t)]^{\beta}R(t)^{1-\alpha-\beta} \tag{9.5}$$

$$Z_A(t) = a_{AZ}Q_A(t) \tag{9.6}$$

$$Q_{Aj}(t) = a_{Aj}(t) \qquad j = 1, 2 \tag{9.7}$$

where $Q_A(t)$ is agricultural value-added in period t; $A_A(t)$, $x(t)$, and $z(t)$ are productivity constants relevant for argiculture in period t; $K_A(t)$ is the quantity of physical capital used in agriculture in period t; $L_A(t)$ is the quantity of unskilled labor used in agriculture in period t; $R(t)$ is the quantity of land used in agriculture in period t; α and β are parameters; $Z_A(t)$ is the quantity of intermediate inputs purchased from abroad and used by agriculture in period t; a_{AZ} is a parameter; $Q_{Aj}(t)$ is the quantity of intermediate inputs purchased from domestic industry j for use in agriculture in period t; and j refers to either of the two other tradable-goods-producing sectors in the model.

There are several aspects of this specification that require comment here. First, it is not clear that the elasticity of substitution between unskilled labor and capital should be unity. My preference is not to impose that restriction on an *a priori* basis, but rather to treat agriculture and manufacturing more symmetrically. Second, the Cobb–Douglas production function for agricultural value-added implies that no skilled labor is ever used in agriculture. This assumption is very restrictive. Certainly commercial agricultural sectors in some developing countries employ quite skilled workers. Further, it is not impossible to conceive of a governmental policy aimed at increasing the skills of farmers. For this reason, it seems appropriate to allow skilled labor to enter the agricultural production function. Third, the assumption of fixed coefficients in the use of intermediate inputs separately for domestically and foreign produced goods is clearly inappropriate. Fertilizer use per unit of value-added certainly may increase over time. Also, it is possible that eventually some intermediate inputs that are currently purchased from abroad may be produced domestically. Finally, as the authors state, it would certainly be useful to disaggregate the agricultural sector, at least, into a commercial and noncommercial sector.

The output equations for the two labor-intensive service sectors are given by

$$Q_k(t) = \phi_k [z(t) \cdot L_k(t)] \tag{9.8}$$

where k refers to either of the two labor-intensive service sectors; $Q_k(t)$ is the output of sector k in year t; ϕ_k is a sector-specific constant; $z(t)$ is the productivity multiplier in period t; and $L_k(t)$ is the number of unskilled workers employed in sector k in year t.

The assumptions in this specification that capital is irrelevant to output and that there are constant returns to scale to labor alone seem to need justification. This is especially true since this sector produces low-cost housing and small-scale retail services where the values of inventories may be large relative to the values of output. Further, although it is true that the activities of members of the labor-intensive service activities may be privately profitable, it is not always clear that these activities are socially productive. Petty theft is common in urban slums, but should the "value-added" in this endeavor be added to aggregate output?

The production functions in the three housing sectors are straightforward. They are

$$Q_l(t) = \frac{H_l(t)}{\sigma_l} \tag{9.9}$$

where l refers to any of the three housing sectors, $Q_l(t)$ is the service flow from housing of type l in year t, $H_l(t)$ is the physical stock of housing of type l in year t, and σ_l is a sector-specific parameter.

9.2 STATIC LABOR DEMAND, LABOR SUPPLY, AND WAGE DETERMINATION

At any moment in time the supplies of unskilled labor in both urban and rural areas are assumed to be fixed, as is the supply of skilled labor in the urban areas. The demand for labor is obtained from the production relations on the assumptions of cost-minimizing behavior and perfectly competitive product markets. It is also assumed that the wage rates of the skilled workers in the two urban modern sectors are equalized, that the wage rates of rural unskilled workers are equal in the agricultural and service sectors, and that the wage rates of unskilled workers in the manufacturing and labor-intensive service sectors are equalized, but that these wage rates are not equal to the wage rates of unskilled workers in the traditional service sector. Instead, it is assumed that the wages of unskilled laborers in the urban modern sectors are always a fixed proportion above those of similar laborers in the urban labor-intensive service sector. Given these assumptions, three wage rates are computed that clear the three labor markets.

It is useful to return for a moment to the assumption that there is a fixed proportional wage differential between unskilled workers in the urban modern sectors and those in the urban traditional sector. It certainly appears in many developing countries that such a wage differential does indeed exist. It may be important, however, to understand the origin of the differential and whether it is likely to be constant over time. For example, in the Edmonston *et al.* (1976) model for Colombia, the wage of unskilled workers in the urban modern sector was determined by a minimum wage law and the wage of unskilled workers in the urban traditional sector was set essentially by market forces. Thus, the wage gap there is endogenous to some extent, depending, in part, on the size of past migration flows and, in part, on the demand for the output of the urban traditional sector.

9.3 SAVINGS AND THE COMMODITY COMPOSITION OF CONSUMPTION DEMAND

One important improvement in the RDC model over the KWC model is the use of the Lluch, Powell, and Williams (1977) extended linear expenditure system. The advantage of this approach is that savings flows are determined simultaneously with the commodity composition of consumption. In this framework, relative price changes, changes in disposable income, and changes in tax rates affect savings as well as the commodity composition of consumption.

Although the extended linear expenditure system is a very useful device for specifying demand structures, there are two caveats that are worth mentioning here. First, in the ELES system, in the long run as income increases, all income elasticities of demand asymptotically approach unity. This is certainly not realistic, and care must be taken when the simulation period is long that the implied income and price elasticities remain plausible. The second point is related to the first one. It is not clear that the "subsistence" quantities in the ELES system are independent of the level of income. Before this system is actually applied, it would be important to demonstrate the constancy of those "subsistence" quantities.

9.4 AGGREGATE SAVINGS AND THE COMPOSITION OF INVESTMENT DEMAND

Aggregate savings in the RDC model arises from three sources: the reinvestment of profits, household savings, and government savings. The entire flow of savings in a given period is assumed to be invested during the same period. Investment can take the form of increasing any of the three housing stocks in the model or increasing any of the three capital stocks. The financial arrangements surrounding increases in the stocks of housing and increases in the capital stocks, however, are quite different. Housing is assumed to be financed only out of the savings of those household groups that purchase the housing services. Further, demands for investable funds for housing are assumed to take priority over investment demands for the purpose of augmenting capital stocks.

The equation determining the demand for housing investment is

$$I_h(t) = \min \{S_h(t), a_h [D_h(t) - D_h(t-1)] + \delta_h H_h(t-1)\} \quad (9.10)$$

where the subscript h refers both to housing of type h and to groups who demand housing of type h, $I_h(t)$ is the investment (in physical units) in housing of type h in year t, $S_h(t)$ is the current value of savings in year (t) by those groups who demand housing of type h, a_h is a sector-specific parameter, $D_h(t)$ is the demand (apparently measured in physical units) for housing of type h in period t, δ_h is a sector-specific depreciation parameter, and $H_h(t-1)$ is the stock of housing of type h in period $t-1$.

This approach, which separates investment in housing from investment in other capital, has two very important advantages over the competitive specifications discussed above. First, it captures an important aspect of the capital market in developing countries. Second, because of the connections between housing investment, migration, and the age structure of the population, this approach allows the investigation of the relationship between demographic and economic phenomena on a much more realistic level than do other models. The specification in equation (9.10) also has two problems. First, savings are measured in monetary units, while the second term in the brackets is measured in physical units. Thus, the equation asks for the minimum of two noncommensurate figures. The equation would be correct if the savings flow were deflated by the current cost of construction of housing of type h. Second, equation (9.10) may cause some undesirable intertemporal effects. An example should help clarify this. For simplicity, assume there is no depreciation and that a_h is equal to unity. Now assume that the demand for housing in period 1 substantially exceeds that for period 0, or, in words, that $D_h(1) - D_h(0)$ is positive and large, and that savings in that year is zero (any small number would do equally well here). In year 1, then, there is no investment in housing of type h. In year 2, let savings skyrocket so that it is no longer constraining and let $D_h(2) = D_h(1)$. The result is, plainly, that there is no investment in housing in year 2 either, even though $D_h(2)$ is substantially above $D_h(0)$ and savings is more than adequate to finance the desired housing. Clearly, some modification of equation (9.10) is in order.

Once housing demands are subtracted from the flow of savings, what remains is assumed to be invested in the three capital stocks. In the RDC model, those funds are allocated according to the following equations:

Minimize

$$|\tilde{r}_A^*(t) - \tilde{r}_M^*(t)(1-\tau_M)| + |\tilde{r}_A^*(t) - \tilde{r}_S^*(t)(1-\tau_S)| + |\tilde{r}_M^*(t)(1-\tau_M) - \tilde{r}_S^*(t)(1-\tau_S)| \quad (9.11)$$

where

$$\tilde{r}_i^*(t) = \tilde{r}_i(t)(1-\delta_i) + \left[\frac{\partial \tilde{r}_i(t)}{\partial K_i(t)}\right] \cdot I_i(t) \qquad i = \text{A (agriculture), M (manufacturing), S (skill-intensive services)} \quad (9.12)$$

and where $\tilde{r}_i(t)$ is the rate of return to an efficiency unit of capital in sector i in period t, τ_i is the tax rate for sector i, δ_i is the depreciation rate relevant for capital in sector i, $K_i(t)$ is the capital stock in sector i in period t, and $I_i(t)$ is the amount of investment (in physical units) in sector i in period t.

This specification embodies the notions that this segment of the capital market in the developing country is operating rather efficiently and that there is no relationship between the sector in which savings is generated and the sector in which it is invested. As the authors realize, this is certainly debatable.

There are two minor points worth mentioning about equation (9.12). First, $I_i(t)$ in equation (9.12) should be investment net of depreciation instead of gross investment. Second, net investment should be multiplied by a factor $(1 - \delta_i)$ to make both terms in the equation comparable. Finally, relative sector size is not taken into account in equation (9.11). It is possible to re-specify the equation so that it is more important for the marginal rates of return for two larger sectors to be closer together than for those of a larger and a smaller sector.

9.5 FOREIGN TRADE, TAXATION, AND GOVERNMENT SPENDING

The specifications of foreign trade, taxation, and government spending in the RDC model are reasonably straightforward. There is no need to discuss all of them in detail. Instead, we shall cover here only the few cases where some possible questions arise concerning the specification.

The first point that requires mention in this context is the assumption in the model that the balance of payments is always in equilibrium. For the countries for which the RDC model is to be applicable, this assumption may not be a good one. Another formulation that allows at least transitory disequilibria may be fruitfully used here. The second point is the assumption that there are no economically relevant differences between governmentally produced services and privately produced services. This postulate certainly requires some justification. In many developing countries, governmentally controlled enterprises are often constrained to pay nonmarket clearing wages. If this phenomenon is sufficiently widespread, it may be worthwhile altering that specification.

In the portion of the model dealing with government revenues, it is assumed that tariff revenue is a constant fraction of total tax revenue. This formulation is used because the commodity composition of imports and exports cannot be determined within the structure of the model. Still, as a second best choice, this specification is not a very good one. It certainly eliminates from the model one of its interesting policy variables. Perhaps one way to improve this portion of the model is to include a separate equation for the imports of manufactured goods. This equation and the others in the model would imply a level of exports and thus allow the tariff rate to remain a policy variable.

One final point, which is relevant not only in this model but in the others reviewed here as well, is that government consumption is assumed to be an end in itself. There is never any consideration of the individuals who consume the publicly provided good. For example, in the migration decision no account is taken of the fact that governmentally provided services may be substantially greater in the urban areas than in the rural areas.

9.6 THE DYNAMIC SPECIFICATION

There are two aspects of the dynamic specification that are particularly interesting and novel: the notion of endogenous training and the migration rate specification. Let us deal with each of these briefly.

While population and labor force growth are taken to be exogenous to the model, the growth of the number of skilled laborers is taken to be endogenous. Firms are allowed to train skilled laborers when it is advantageous for them to do so. The equation used in the RDC model for the annual increase in the number of skilled workers is

$$\Delta S(t) = \epsilon_0 [(1 + n)L^*(t - 1) + nS(t - 1)]^{\epsilon_1} [G(t - 1)]^{\epsilon_2} [\text{percent wage premium}]^{\epsilon_3} \quad (9.13)$$

where $\Delta S(t)$ is the change in the stock of skilled laborers from period $t - 1$ to period t; $\epsilon_0, \epsilon_1, \epsilon_2, \epsilon_3$ are parameters; n is the exogenous rate of growth of the population; $L^*(t - 1)$ is the number of unskilled laborers in the two urban modern sectors in period $t - 1$; $S(t - 1)$ is the number of skilled workers in the economy in period $t - 1$; $G(t - 1)$ is governmental expenditures on noncapital items in period $t - 1$; and "percent wage premium" is a complex expression for the ratio of the wages of skilled to those of unskilled workers.

This particular specification, however, seems as if it could be improved. One possibility would be to allow new skilled labor to come from two distinct sources: public education programs and private training programs. The number of skilled laborers resulting from public education programs should be explicitly linked to governmental expenditures on education programs, not to governmental expenditures on all noncapital items. The number of skilled laborers resulting from private training should be related to the effects on profits of increasing the stock of skilled laborers. That effect depends not only on the wage premium but on other features of the production function as well.

The migration portion of the RDC model is the strongest of any of the models reviewed here. Any future work in this area should undoubtedly begin with the insightful treatment of migration in the RDC model. The RDC formulation of the migration problem gets its strength from plausibly combining a number of empirically important features. Primary among these is the explicit recognition that there can be a substantial cost of living difference between the urban and the rural areas. In addition, the formulation takes into account the wage spectrum faced by new migrants and the probabilities that they will be able to obtain each of these wages. Rural–urban migration is assumed to continue in any given year until the real wage in agriculture is equal to the real expected urban wage rate.

The authors discuss the elaboration of their migration specification to include the effects of changes in the age structure of the population by utilizing the recent contribution of Rogers, Raquillet, and Castro (1978). This would undoubtedly make an already good thing even better.

9.7 THE RDC MODEL: SOME FINAL THOUGHTS

The RDC model takes what was a very good simulation specification and improves upon it. The current model is truly excellent. For a policy maker interested in economic–demographic interactions, the next step would be to begin with the RDC framework and build in more demographic structure. For example, the effect of governmental programs on education and health should be explicitly considered, as should the age structure of the population. Further, policy makers may well wish to follow the lead of Adelman and Robinson and consider the relationship between the functional distribution of income and the size distribution of household income. Whatever they wish to add, however, they can be confident that they will be off to a good start when their model is based on the RDC framework.

10 CONCLUDING COMMENTS

Five well-known second-generation economic–demographic simulation models are reviewed in this paper. None of them, in their current versions, can offer serious guidance to agricultural-policy makers. The reasons for this negative conclusion vary from case to case. In most instances, the models are of limited usefulness because agricultural policy was not the main concern of the model builders. Typically in such situations, agricultural production was not ignored, but rather its specification was simplified to the point where significant policy options were completely omitted. Those models in which the agricultural sector is sufficiently articulated to allow meaningful policy alternatives suffer from technical problems of such severity as to render what guidance they do give of questionable validity.

These economic–demographic simulation models are not totally without value for policy makers, however. In their present form, they are useful as pedogogical aids in teaching government officials about the kinds of long-run consequences their decisions could entail. Further, they provide an important step toward formalizing processes and structures the descriptions of which have hitherto been mainly discursive and the analyses of which have previously been mostly qualitative. Thus, past efforts at building economic–demographic simulation models, although they cannot be rated as successful for agricultural planning purposes, provide a useful foundation for future quantitative work.

Two third-generation simulation models are also reviewed here. Neither of them has a significant demographic component and neither can offer serious guidance to agricultural policy makers. They are useful in the context of this review for two reasons. First, they provide some improved representations of important aspects of the development process. Second, they give us a glimpse of the directions in which economic–demographic simulation models will probably be evolving in the future. For example, one evolutionary path is one being trod by Kelley and Williamson. Their latest model is of more general applicability than their earlier one. Instead of becoming involved in the intricacies of policy trade-offs in a given country, they have specified a model that is broadly applicable to a number of developing countries. The resulting model helps us to understand phenomena that are common to the development process in many countries, but the policy implications that result from the model are necessarily general ones.

Another evolutionary path is the one that Adelman and Robinson have begun to travel. This is the path toward detailed short-run models that have specific policy instruments built into them. These models need not have the breadth that the current models have, and they certainly have greater depth in the areas of particular interest. A third possible route of development of economic–demographic simulation models would combine the best features of both these two. At present there are no economic–demographic simulation models in which the trade-offs between long-run and short-run goals can be seriously studied. Such a model would certainly be useful to policy makers, who are more often judged on their ability to handle short-run crises than on their ability to solve long-term problems. Thus, now that the technology of model building is well known and widely diffused, we are likely to see a much greater variety of economic–demographic simulation models than we have seen in the past.

The history of economic–demographic simulation models has taught us a number of important lessons. Perhaps chief among them is the lesson that there is no such thing as a perfectly general model. Even with models of thousands of equations, researchers have been forced to make simplifying assumptions. Thus, the question of sorting out what is relevant and what is irrelevant to a particular problem is still important. What we have learned, then, is a lesson in modesty. There is no model for all seasons. But I must hasten to add that the blossoms in the springtime are often quite beautiful.

NOTES

1. Given a production function that is homogenous to degree one, output per worker can be written as a monotonically increasing function of capital per worker. Increasing the rate of growth of employment relative to the rate of growth of the capital stock decreases the amount of capital per worker compared to what it otherwise would have been and therefore decreases output per worker. Given a constant aggregate employment rate, the statement in the text follows immediately.

2. These models are

The FAO Model as implemented in "A Systems Simulation Approach to Integrated Population and Economic Planning with Special Emphasis on Agricultural Development and Employment: An Experimental Study of Pakistan," Food and Agriculture Organization, PA 4/1 INT/73/PO2 Working Paper Series No. 11, Rome, March 1976.

The Bachue-Philippines model as implemented in "Economic-Demographic Modelling For Development Planning: Bachue-Philippines," by G. B. Rodgers, M. J. D. Hopkins and R. Wery, International Labour Organization, Population and Employment Working Paper No. 45, Geneva, December, 1976.

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3. These are large-scale industry, small-scale industry, capital goods industry, construction, small-scale (traditional) services, large-scale (modern) services, and government services.

4. The 1.25 figure is obtained by adding the increment in exports (assumed to be one unit) to the product of $\alpha_i(t)$ and the increment in $Z_i(t)$ (assumed to be 1.5 units).

5. The equation determining $\alpha_i(t)$ is

$$\alpha_i(t) = 1 - [1 - \alpha_i(t-1)]\,(1 - S)$$

where S is an exogenously determined policy variable.

6. In the Bachue model, current income has no effect on current consumption. The latter is determined by the past values of income. This point is discussed in more detail in section 3.2.
7. There is one exception to the statements that inputs do not affect outputs and that technical progress is irrelevant to output growth. This is in the case of traditional agriculture. It is assumed in Bachue that labor productivity in traditional agriculture increases at a predetermined but endogenous rate in each year. This assumption is maintained in all the versions of the model discussed below.
8. The maximum possible rate of growth of labor productivity in traditional agriculture is assumed to depend positively on the ratio of the prices of agricultural to nonagricultural goods.
9. Rodgers *et al.* (1976), pp. IV-17 and IV-18.
10. The determination of the $\theta_{id}(t)$ is discussed below.
11. Estimated income instead of actual income is used in this equation because no simultaneity is allowed in the Bachue model. Income is estimated using the assumption that income growth between year $t-1$ and year t at each decile level is identical to the growth that actually occurred between year $t-2$ and year $t-1$.
12. The function of the $Z^*(t)$ is described below.
13. This assumption is made on page IV.24. It is not clear, however, whether it is maintained for all time periods or just for 1965. In the text, we assumed the former.
14. The questions of the trade-off between growth and inequality can at least be addressed in the two variants of the model that allow some aggregate supply-side forces to operate. But those versions of the model are still not well suited to answer such questions. For example, it is still the case in those formulations that the income distribution has a small effect on savings, and that savings and investment have no direct links. Indeed, investment and the income distribution have practically no relation to one another. This aspect of the model requires modification if those trade-offs are to be seriously studied.
15. This statement is derived from equation 2 on page V.73 after applying the definition of a harmonic mean.
16. The equations used in determining the labor force are discussed in section 3.2 above, while those determining the number of households are discussed in section 3.4 below.
17. The $M_i(t)$ are determined from current income ratios relative to a lagged function of their historical values.
18. The correct equation is

$$W_{ri}(t) = \frac{V_{ri}(t)}{E_{ri}(t)} \cdot \frac{v_i(t)}{v_i(0)}$$

The $v_i(0)$ cannot all be set to unity without altering the input–output coefficients.
19. The number of households in each of the two areas is discussed below in section 3.4.
20. Coale, A. 1971. Age patterns of marriage. Population Studies 25(2):193–214.
21. Coale, A., and P. Demeny. 1966, Regional Model Life Tables and Stable Populations. Princeton, New Jersey: Princeton University Press.
22. Recall that in Tempo II sectoral outputs in period t are independent of any events in period t.
23. This scheme is more simplifed than the specification in Tempo II, which distinguishes students by sex.
24. This equation is derived from the equation in the footnote to page 19. I have taken

the liberty of changing the reference period for the proportion of users from period t to period $t - 1$.

25. Given the assumption of a Cobb–Douglas production function for the output of modern sector and that unskilled workers are, on the average, paid their marginal contribution to output, w is the constant appearing in equation (4.2) above.

26. The parameters 0.4 and 0.6 in equation (5.1) are the values assigned by Simon in the baseline simulations and are subject to variation in different runs. In the discussion of the Simon model that follows all the numerical parameters are of this character.

27. Either the classic problem of adding apples and oranges is ignored or the implicit assumption is made that relative prices forever remain fixed at unity.

28. It is not assumed in the FAO model that the government directly controls the allocation of investment funds. Instead, it is assumed that the government has complete indirect control over such allocations through the use of policy instruments not included in the model.

29. It is assumed for the sake of analysis here that the incremental quantities of intermediate inputs are held at zero. As was demonstrated above, the optimum amounts of these inputs are either zero or infinite. In the latter case, further efforts at maximizing output have no impact. When the incremental quantities of intermediate inputs are zero, the strategies for maximizing net and gross output are identical.

30. There are two statements made here, one concerning investment and the other concerning land conversion. Since the demonstrations of these two are essentially the same except for terminology, we shall concentrate here on sketching out the proof of only the first statement. Between any current year t and terminal year T there exists an investment strategy that will maximize agricultural output in the final year. Suppose that we take as given this optimal strategy for years $t + 1$ to T and with regard to expenditures on land conversion in year t. This can be done because it has been assumed that investment in agriculture in each year is exogenous. In this situation, the allocation of investment expenditures in period t that maximizes agricultural output in the terminal period clearly is part of the optimal strategy. In the FAO model, such a strategy involves investment in at most one form of agriculture. To see this, define $\Lambda(j, T)$ to be the amount of land in agriculture of type j in the terminal year T and define $\Delta Y(j, t, T)$ to be the increment in yield in agriculture of type j in year T due to a 1-dollar investment in that type of agriculture in current year t. Since both $\Lambda(j, T)$ and $\Delta Y(j, t, T)$ are fixed constants independent of the allocation of investment funds in period t, output in the terminal period is maximized simply by finding the single value of the index j that maximizes the product of $\Lambda(j, t)$ and $\Delta Y(j, t, T)$. If that product, by coincidence, is identical for more than one type of farming, then any distribution of investment funds between those sectors is optimal.

31. In the construction industry, the nonagricultural sector with the highest marginal product of capital, investment of 1 million dollars will bring a return in perpetuity of 911 thousand dollars per year, for a rate of return on such an investment of 91 percent per annum. Investment in the construction industry, however, is subject to special constraints, which are discussed in detail below.

32. This is based on the incremental yield coefficients in rainfed agriculture for 1965–1976. After 1976, the coefficient for small farms is assumed to fall, but the coefficient for large farms remains at its previous level.

33. Constant returns to scale are assumed here. Therefore, to determine the derived demand for construction arising from any amount of investment it is only necessary to multiply the derived demand per dollar by the number of dollars invested in the sector.

34. It is useful to recall in this context that the price of the output of the construction industry is not allowed to vary.

35. Investment in construction requires a certain amount of construction. If the sectors that lost most of the investment funds did not require much construction, then, the total amount of construction required in period $t-1$ could rise because of the reallocation of investment funds. This problem does not arise if, as in the Pakistani case, investment in the construction industry generates the least amount of construction per dollar.

36. The concept of the unemployment rate in the large-scale modern sectors is not a very clear one. This problem is discussed in more detail below, where we shall also present the FAO definition of the unemployment rate in those sectors.

37. The general fertility rate is the ratio of births to the number of women in the reproductive ages.

38. The relation between ρ_I and σ_I, the elasticity of substitution between capital and labor, is $\rho_I = 1/(1-\sigma_I)$.

39. There is neither a government nor a foreign trade sector in the KWC model.

40. The KWC model does not allow for unemployment. If unemployment were added to the model, then the wage rates adjusted for unemployment rates would have to be equalized.

41. The KWC model also includes a similar treatment of the possibility of urban-to-rural migration.

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