STRUCTURAL LINKAGES BETWEEN AGRICULTURE AND THE REST OF THE ECONOMY: AN EVALUATION OF SECTORAL AND MACROECONOMIC MODELS

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Introduction

> "Agricultural economics earned its spurs and has made most of its contributions to science and knowledge with its work at the microlevel. If there has been one major failing over the years, it has been this failure to grasp fully the macroeconomics of agriculture."
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> Schuh, 1976, p. 810

The purpose of this paper is to evaluate models which directly or indirectly incorporate the agricultural sector as a part of a macromodel, or alternatively attempt to incorporate macroeconomic variables in agricultural sector models.

There has been an increasing concern about agriculture and non-agriculture interrelations which results largely from a greater awareness of the feedback mechanisms inherent in economic systems. Agricultural markets increasingly depend on policies in the rest of the economy and the overall performance of national economies in many instances is strongly influenced by the level of agriculture income which affects the market for non-farm products and by the amount of foreign exchange generated by exports of farm products. From a modeling perspective, inclusion of the agricultural sector into a macromodel permits the simultaneous determination of output and the rate of inflation for both sectors by taking into account macro-sectoral feedbacks. 1/

This paper reviews the literature which deals with linkages between macro and agricultural models, the structural specification of such models, estimation procedures and their use for policy analysis. Five categories of such models are identified, according to the analytical framework utilized: econometric models, programming models, hybrid econometric-programming models, general equilibrium models and simulation models. 2/ Within each subgroup, the main characteristics and limitations of each type of model are stressed, and potential areas of improvement are discussed.

1/ Just (1977) argues that the predictive power of econometric models may be improved by increasing the degree of endogeneity.

2/ Two excellent reviews of econometric and programming models of the agricultural sector can be found in King (1975) and Norton and Schieffer (1980), respectively. Huang et al. (1980) provide a useful comparison between econometric and programming models and methods.

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Econometric Models

Advances in computer technology and the increasing sophistication of statistical techniques have led to wider use of econometric models by such diverse institutions as research institutes, corporate firms, universities and government agencies. The purposes of such models can be grouped under three headings: First, econometric models enable the user to better understand the system being modeled (e.g., an entire economy); second, models permit the user to explore the consequences of alternative economic policies (i.e., policy analysis); and third, they enable one to forecast values for the endogenous variables.

Problems with formulation, estimation, prediction ability and validation of econometric models, however, have posed some limitations on the use of such models.

In general, macroeconometric models do not incorporate an agricultural sector that allows an investigation of the interactions between the macroeconomy and agriculture. Despite the fact that a number of agricultural sector models have been developed specifically for inclusion within a large macromodel, 3/ the interrelationships between the agricultural sector and the general economy are still far from being fully understood and specified in a satisfactory manner. This is also true for agricultural sector models which generally lack linkages to macroeconomic variables that can help to explain events in agriculture.

Gardner (1981) provides an example of such systematic connections between macroeconomic aggregates and sectoral variables. If, for instance, an exogenous event such as an accelerated growth in the money supply occurs, there will be a sequence of price and interest rate adjustments throughout the economy that will affect some sectors earlier than others. Given a certain time path of adjustment in agriculture and other sectors, if the transmission mechanism works in such a way that prices in competitive auction markets adjust more quickly than prices in imperfectly competitive markets, farm prices will rise faster than nonfarm prices.

One of the earliest attempts to put together in a single model the quantitative relations of various economic sectors was the study by Cromarty (1959), who incorporated a set of estimated relationships for the agricultural sector in an econometric model of the total economy. This made it possible to bring together the agricultural and non-agricultural sectors and hence to trace the effects of changes in the non-agricultural economy through the agricultural sector, as well as to estimate the contribution of the agriculture to the total economy. The model included 12 sectors within agriculture and its main purpose was to develop coefficients expressing the major relationships within agriculture and between agriculture and the rest of the economy. No attempt was made to develop specific areas of applicability such as policy analysis.

3/ See, for example, Cromarty (1959) and more recently Roop and Zeitner (1977), both discussed in this section.

Agriculture was disaggregated into a series of product categories with homogeneous demand and supply structures. A single supply relationship was specified and estimated for each product category whereas demand specification was dependent upon factors in addition to commercial demand. Hence, several demand relationships were eventually specified within each group. Simultaneous estimation of the parameters in the demand and supply relationships of related product categories was done in order to allow for their interaction.

Annual observations for the period 1929-53 were used in estimating the model. Some categories, e.g., feed grains and livestock products were estimated simultaneously as a subsystem, whereas the other ones were considered independently for the purpose of estimation. The model was estimated by limited information simultaneous equation methods, except for the crop supply functions, where OLS was used. All equations in the model were linear in the variables.

Policy variables were an explicit component in the model proposed ten years later by Egbert (1969). The analysis aimed to identify both own-price effects and supply and demand shifters. The policy experiments performed with the model attempted to assess the magnitude of production-consumption gaps in agriculture. Several conditional projections were made for 1985 based on simple extrapolation of the exogenous variables and certain policy assumptions. The exogenous variables included some macroeconomic and non-agricultural variables such as non-food prices, income per-capita, population, exports and imports.

The model aggregates all agricultural commodities into one product. The overall structure of the model comprises behavioral specifications of domestic supply, domestic demand for consumption, domestic demand for stocks and a trade (market-clearing) identity for the supply-demand balance.

Data from 1947 through 1966 were used to estimate the structural parameters. To account for simultaneity among some variables, the three-stage least-squares method was used to estimate coefficients, and these were then compared with OLS estimates.

Three policy alternatives were tested. Under alternative I, it was assumed that acreage diversion and price supports would remain as in 1968 and that other exogenous variables would continue to increase at their long-run trend rates. The results obtained under these assumptions showed that if current programs were continued, additional land would have to be withdrawn from production in order to keep prices of farm commodities advancing at the same pace as other commodities, at least through the mid-seventies.

Alternative II assumed the elimination of production controls or diverted acreage programs. A dramatic fall in the index of prices received by farmers occurred when diverted land was brought into production in 1969, although the model predicted a dramatic rise toward the end of the period (1985). The wide variability in price under this alternative was attributed to the low price elasticities of demand for consumption and stocks implied by the model.

Alternative III explored the possibility of channeling excess production into exports, since under alternatives I and II demand was assumed to remain static. Under this alternative, exports become endogenous and average farm prices are assumed to increase at the same rate as the "prices paid" index. With the assumed steady increase in price, production, consumption and stocks were projected to increase at a steady pace. The volume of exports, on the other hand, followed an irregular pattern but ultimately increased by about 70 percent in the 1970s. This was considered by the author to be an unlikely event unless "food for peace" programs were greatly expanded.

The export-import component of the above model raises the question of the openness of national economies and hence of the sensitivity of the agricultural sector to changes in international events. One of the most important macroeconomic variables linking agriculture with international markets is the exchange rate. In fact, the export-import component of today's agriculture is such a large fraction of the total output that fluctuations in the exchange rate are likely to have a significant impact on agricultural production, income and prices. Schuh (1974) evaluated the role of exchange rates in U.S. agriculture in the context of induced technological change. He argued that the overvaluation of the dollar aggravated the adjustment problem of U.S. agriculture and resulted in shifting an important share of the benefits of technical change to the consumer; he also argued that the devaluation of the dollar in the beginning of the 70s constituted an important structural change for U.S. agriculture.

The interaction between exchange rates and the agricultural sector has been formally quantified by Chambers and Just (1981) using a quarterly econometric model of the wheat, corn and soybean markets. The model comprises twelve behavioral equations and three identities which explain disappearance, inventories, exports and production for the three commodities. A separate block for each commodity was specified but because of the likelihood of cross-block correlation of disturbances, the model was estimated as a single system by three-stage least-squares based on data for the period 1969-I through 1977-II.

The dynamic effects of exchange rate fluctuation on U.S. commodity markets were examined through the use of dynamic and long-run multipliers. The results indicated that the devaluations of the early 1970s had extremely important effects on agricultural exports and prices as well as on domestic disappearance and inventory accumulation. The short-run effects were more dramatic than the long-run effects. The results also suggested that monetary factors in general, such as money supply controls, can have significant indirect effects on agriculture operating through changes in the exchange rate.

The foregoing models trace the influence of aggregate variables on agriculture; however, they still lack feedback mechanisms required to trace the impact of agricultural variables on the general economy. These impacts can be of considerable influence. For example, almost two thirds of the average prediction error of econometric inflation forecasts during the 1970s could be traced to changes in exogenous prices, among which farm and food prices are key components (Popkin, 1975).

The paper by Lamm (1980) explicitly incorporates such feedback mechanisms in a study designed to determine the nature of the relationships between agriculture and the overall economy. The analysis was based on a small macroeconometric model of the U.S. economy which incorporated a dual representation of production systems, labor markets and capital markets for both agricultural and manufacturing-service sectors of the economy. Moreover, it was assumed that rational price expectations played an important role in determining behavior in both sectors. Dual production functions, labor supply functions and investment supply functions were specified for each sector, comprising a total of 6 relations for each sector, 3 of which were identities.

In addition to the dual sectoral specification, economy-wide components are included in the model through four stochastic relations and five identities. The four stochastic relations explain money demand, consumption, unemployment and labor force participation. The five identities provide definitions of real balances, effective interest rates, the difference between actual and expected prices, employment and the labor-force participation ratio.

The linkages between the sectors and the overall economy are specified through three identities which state that total investment is the sum of agricultural and manufacturing-service investments and that the sum of real and nominal income for the agricultural and manufacturing service sectors equals aggregate real and nominal income, respectively.

Expectations functions for both sectors were obtained separately. Once expected prices were obtained, the behavioral equations of the model were estimated by three-stage least squares based on data for the period 1932-76.

Dynamic multiplier analysis highlighted three characteristics of the agricultural sector. First, agricultural prices and income were not very sensitive to changes in wage rates, expectations and control variables. In fact, the magnitudes of all price multipliers for the agricultural sector were much less than the corresponding price multiplier for the manufacturing-service sector. Second, changes in exogenous variables of the agricultural sector (e.g. wage rates, price expectations) had relatively little impact on national economic aggregates such as output, unemployment rate, consumption and income. On the other hand, changes in exogenous variables of the manufacturing-service sector had a much greater impact. This result is supported by Gardner (1981) who examined the importance of several macroeconomic variables 4/ in explaining events in U.S. agriculture and concluded that agriculture is a small sector of the economy and hence the logical dominance of causality is from the general economy to agriculture. The third result obtained

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4/ These included: recession, inflation, productivity, non-farm wage, government programs, exchange rate, exports and output. Dependent variables were real net farm income, real prices paid by farmers, real farm wage rate, real farmland price.

by Lamm was that the total effect of increased nominal government expenditures on real agricultural income and real manufacturing-service income was negative, which is inconsistent with the Keynesian argument that an increase in government expenditures would decrease the unemployment rate and increase income.

The results obtained by Lamm are very much conditional on the specification and coefficients of his model. In fact, one of the major limitations of the model used is that the agricultural sector is an "aggregate." As Chen (1977) points out, there is a gap between the complexities of farm commodity markets and the simplified nature of the agricultural sector specification in macromodels. He calls attention to the need for an integrated view of the agricultural economy in which the market behavior of individual commodities is specified. As such, he presented a quarterly model - the Wharton Agricultural Model - which contains four interrelated blocks of equations: the intercommodity block, the annual crop production block, the income-expenditure block and the micro-macro linkage block. The intercommodity block contained simultaneously determined quarterly equations of supply, demand, inventory and price relations for seventeen commodities or commodity groups. The micro-macro linkage block provided a set of bridge equations to treat the agricultural sector in similar form and specification as other production sectors of the economy. It focused on aggregate demand components, output origination, wage, labor and employment, sector prices and final demand prices, farm income and personal income components. This block makes it possible to specify a feedback mechanism between the agricultural sector and a macromodel and hence enables the user to assess the agricultural implications of macroforecasts as well as macroeffects of agricultural forecasts.

The complete model is represented by a simultaneous equation system of 249 equations, 101 of which are stochastic, the others being definitions and identities. The OLS method was used to estimate the model parameters based on data for the period 1945-74 for annual equations and 1959-I through 1974-IV for quarterly equations. Chen argued that the direct application of OLS to structural equation estimation yielded acceptable results despite potential biases.

As pointed out previously, a number of agricultural sector models have been developed for inclusion within a larger macromodel. Such an experiment was performed by Roop and Zeitner (1977), who developed an agricultural sector model that was self-contained in a sense of being a satellite model, but was also integrated into a large macromodel. Many of the agricultural model's exogenous variables were endogenous to the macromodel. Because of a large percentage error in the net farm income variable during the model validation period, the model was not used to develop policy implications. However, results from simulating the large macroeconomic model with the embedded agricultural model suggested that a macroeconomic model may be substantially altered by a change in the specification of a sectoral component.

Econometric models have been widely used for purposes of both forecasting and understanding structural relations. However, such models have often failed to produce sensible or reasonable results. Cromarty and Myers (1975) have summarized the limitations of large simultaneous equations systems. 5/ Among these are the difficulty in adjusting coefficients to reflect structural changes, rigidities imposed by internal consistency, the management of a complex information system and the inability to predict exogenous variables.

In addition to the inherent limitations of econometric models, agricultural sector model builders face the additional problem of the complexity of the interrelations among agricultural subsectors. To be useful, an agricultural model should incorporate a great degree of commodity detail and specify linkages between commodities. This would necessarily increase the number of endogenous variables. As Egbert (1969) pointed out, the ultimate econometric model would consist of only endogenous, lagged endogenous and policy variables.

Another important consideration in modeling applications is the periodicity of the analysis. A quarterly model is favored over an annual one because decision-making in agriculture is influenced by short-run agricultural developments. An analysis of quarterly data could contribute greatly to forecasting efficiency and policy precision (Chen, 1977).

Finally, it should be noted that although complex structural models may "explain" the meaningful economic relations in a satisfactory manner, they may not provide a mechanism for incorporating such factors as major policy changes, currency fluctuations, shifts in world demand, etc., which are all extremely important for forecasting purposes. That is, a model may explain well but may not forecast well. Moreover, good forecasting models are designed to incorporate new information as it becomes available. As such, they are a composite of techniques plus subjective judgement and intuition. On the other hand, a "true" understanding of the interactions within agriculture and between agriculture and the general economy would necessarily rely on a highly complex and preferably disaggregated model, capable of capturing the relevant sectoral-macro linkages.

Programming Models

Policy-makers are usually faced with the necessity of solving two problems. One is to forecast how economic agents (e.g., farmers) would react to various hypothetical policy actions. This is usually referred to as the "positive problem." The other is to select the most appropriate combination of policy instruments, given the policy goals and constraints and the conditional forecasts of outcomes. This is the so-called "normative problem" (Norton and Schieffer, 1980).

5/ This paper contains an excellent critical evaluation of econometric models and their relevance and limitations for practical commodity decision-making.

Traditionally, econometric methods have been used to solve the forecasting problem, but more recently mathematical programming methods have been employed as well. This is because econometric response functions have at least three disadvantages. First, because the parameter estimates are valid only over the historically-experienced range of variation, they may not be applicable for the analysis of proposed policy changes which involve significant departures from historical trends. Second, econometric models cannot include inequality constraints such as seasonal land constraints. Third, econometric models typically do not provide much complementary information on the movements of other variables of interest. This last disadvantage is especially important if policy makers are interested in movements of relevant macroeconomic variables that have linkages to the agricultural sector. For example, in the case of a crop supply response model, policy makers may wish to base their crop pricing decisions not only on the conditional forecasts of output responses, but also on projected movements of macro-variables such as seasonal employment and exports earnings, as well as on sectoral variables such as farm income and land values.

Activity analysis (or programming) models usually can satisfy these three criticisms. By being mostly cross-section based, however, they remain less satisfactory than econometric methods with respect to fidelity to historical data and availability of objective measures of reliability for their forecasts.

Norton and Schieffer (1980) have pointed out in their review of agricultural programming models that a "policy objective function" may be attached to the constraint set of the positive problem, thereby creating a normative model. They argued, however, that such a model will not represent completely either the policy (normative) problem or the descriptive (positive) problem. This is because it does not contain representations of specific policy instruments whose use might lead to the outcome suggested by the model, and therefore there is no indication of whether, in fact, the outcome is feasible, given political limits on policy actions and farmers' own preferences.

At the farm level, the programming framework of cost minimization or profit maximization under a fixed-price regime seems appropriate and in fact has mostly been used for such purposes. A complete representation of sector-wide behavior, however, must take into account price endogeneity and hence price-endogenous optimization models have been used to simulate aggregate farmer and consumer behavior. The basic optimizing market equilibrium formulation of such models embodies the assumptions that producers are profit maximizers and that consumers' behavior is adequately described by a set of demand functions in the space of price and quantities. Producers' supply functions are represented implicitly via specifications of their technological alternatives, the constraint set and the objective function.

In a broader sense, a descriptive sector model comprises five structural elements (Norton and Schieffer, 1980): First, the technology set representing the production alternatives; second, the resource limitations; third, the economic environment including the consumer demand specification and the specific market conditions; fourth, the preferences of producers; and fifth, the policy environment (subsidies, taxes).

An economy-wide model should incorporate, in addition to the usual specification of sectoral models, several other components. These include macrovariables such as employment and output, and intersectoral and sectoral-national linkages. The latter are of considerable importance in adding "reality" to the optimization exercise and may provide valuable insights into the appraisal of the results. These macro linkages could be incorporated as additional constraints and/or exogenous variables. For example, the input coefficients (e.g., capital, labor) for a certain production process may very well be a function of macroeconomic variables such as prevailing interest and wage rates, which are in a way determined outside the model (exogenous), but still impose limitations on the choice and level of activities.

Despite its importance for policy analysis, there is not much literature on the linkages between agricultural optimizing models and economy-wide models. Duloy and Norton (1973) provide a good example of a linkage between sector and national models for the case of Mexico. A sectoral model was solved under varying assumptions about factor prices (e.g., capital, labor, foreign exchange) in order to provide a set of alternative agricultural technology vectors for inclusion in an economy-wide programming model. The assumptions regarding factor prices were derived from a prior set of solutions of the economy-wide model. Their analysis demonstrates that inclusion of new information from the sector model on factor substitution possibilities altered significantly the results obtained from the economy-wide model. For sector studies, however, sensitivity analysis on a few parameters was more relevant than the interaction of the sectoral with the economy-wide model.

This brings up an important technical aspect of programming models, which has to do with their use for policy analysis. Programming models are often used for finding an optimal policy (which cannot be done with econometric models) or for evaluating alternative policies. Regarding the latter, a policy maker can vary the values of the parameters reflecting resource endowments and the values of the technological coefficients - both contained in the constraints of the model - to investigate the impact of a policy related to commodity demand, resource supply and changes in production technology. The user can also adjust the parameter values of the objective function to estimate the effect of a price (or per-unit return) change of a certain variable (e.g., quantity of corn) on net farm income and on the crop mix. 6/ In addition, the policy maker can delete or include a constraint to investigate the consequences of a change in the structure of production or regulation. Past sectoral applications of linear programming models fall into two major categories: estimation and policy impact study. Estimation has focused on projections of future production-distribution with respect to technological change and population growth, production capacities under resource limitations, estimation of land values and crop prices based on a spatial equilibrium framework. Policy analysis has focused on impact studies such as resource and environmental restrictions, land retirement programs supply control, rural income and employment generation and institutional constraints (Huang et al., 1980).

6/ These are called post-optimality (sensitivity) analyses.

Linear programming has been used mostly to deal with problems related to the potential interactions of agriculture, resources and the environment. The macroeconomic component - or linkage - of such models has been almost non-existent, being limited to inclusion of national production balance constraints and specified final demands. Explicit incorporation of exogenous macroeconomic variables is seldom observed in these models.

A model constructed by Sherbiny and Zaki (1974) incorporates agronomic and institutional characteristics of Egyptian agriculture into a multi-regional linear programming framework. The objective was to estimate the magnitude of the possible gains associated with crop reallocation along lines of comparative advantages and within the context of the agronomic and institutional constraints in Egyptian agriculture. Unlike the previous model, however, no explicit linkage with the general economy was included. Institutional characteristics are perhaps the most "general" variable considered, even though these were treated only implicitly through the crop constraints.

Programming models have an attribute which can be quite useful for policy analysis; namely, the capability of determining a conditional equilibrium toward which the market system tends, conditional upon specified policy instrument values. Several different equilibria of this type may be determined based on alternative possible policy actions. Since each policy package usually has multiple impacts, it is helpful to compare the patterns of such impacts, even in qualitative form. Such models are best suited for analysis of marginal policy changes, which are usually more acceptable on political grounds.

Hybrid Econometric-Programming Models

A hybrid econometric-programming specification is perhaps a remedy for the shortcomings of both models. Huang et al. (1980) proposed such a model, where an LP model was used to validate the projections made by an econometric model, and to adjust these projections when the values were outside the feasible region defined by the LP model. In addition, the LP model provided structural and other policy variables to enhance the analytic capability of the econometric component.

A common use of hybrid models is to estimate future production potentials and resource use possibilities under policies never realized in the past. The econometric component of the model can be used to estimate the market impacts if these future potentials were realized. Huang et al., point out that considerable effort is required to use hybrid models for policy analysis where interest is in prediction. To be useful, both econometric and programming components need to reflect the consequences of implementing alternative policies. In addition, if accurate forecasts are to be made, regression coefficients of the econometric component and the technical coefficients of the programming component need to be updated.

General Equilibrium Models

General equilibrium models are perhaps the most recent innovation in macroeconomic planning. Such models explore the effects of changes in policy variables on a set of potential targets such as those concerned with agricultural production and distribution, in an economy-wide context. Typically, equilibrium values or projections for major macroeconomic variables are obtained in a quantitative framework, which in general tends to capture the linkages between the national economy and both the agricultural sector and the world economy.

Computable General Equilibrium (CGE) models are usually used when time-series data for estimation of econometric models are non-existent or non-reliable. As pointed out by Mansur and Whalley (1981):

> "Most of these (CGE) models involve dimensionalities which are quite outside those which econometricians are used to and estimation of all model parameters using a stochastic specification and time series data is usually ruled out as infeasible." (p. 1)

In practice, parameter estimation of CGE models is much less rigorous than one might expect. Rather than system or subsystem estimation, calibration is the usual procedure in the specification of a numerical CGE. Calibration means the ability of the model to reproduce base year data as a model solution; that is, the model is "calibrated" to a base year observation (which, by the way, uses cross-sectional data). Calibration is augmented by literature search (and eventually econometric estimation) for key model parameters, whose values are required before calibration proceeds. If a single value for certain parameters is non-existent, some kind of "sensitivity analysis" may be performed with alternative values. Hence, the model would provide "ranges" of policy impacts, according to the various parameter specifications.

Policy analysis with CGE's usually proceeds as follows.[7/] An initial observable equilibrium in the economy is assumed, from which a consistent "equilibrium" data set is constructed. Since the economy is "in equilibrium" (by assumption), all behavior is consistent with the equilibrium prices in that consumers maximize utility, producers maximize profits and all market demands equal market supplies. Policy evaluation proceeds by comparing an "initial" equilibrium under existing policies to a new equilibrium under new policies. This would provide an indication as to how the structure of the economy might be affected by policy changes. Since prices are endogenously determined, policy modifications are expected to change relative prices in the economy. Price endogenous equilibrium would then involve separate specification of systems of equations representing the demand and production side of the economy.

In a CGE framework, Adelman and Robinson (1978) examined the distributional consequences of various policy experiments in the context of the Korean economy. The policy packages were classified as rural, urban and combined rural-urban strategies. These policies included land reform,

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7/ This is based on Mansur and Whalley (1981).

consumption subsidy, education and demographic change, public works and a "policy-mix," among others. Indicators of the overall distributional effectiveness of the programs were computed. These included the income of the bottom decile, percent of households in poverty and the Gini coefficient.

DeMelo (1979) explored the relationship between agricultural policies and development by means of a dynamically recursive CGE model applied to Sri Lanka. The agricultural policies investigated included elimination of the food subsidy, elimination of the export tax, land reform and technical change in agriculture. The goals considered were the levels and growth rates of GNP and employment, the distribution of income and the real income level of the poorest group.

Macroeconomic effects of distributional policies were addressed, also in a CGE framework, by Taylor et al. (1980) for the case of Brazil. Almost thirty model simulations for the 1959-71 period were performed to explore how the distribution of income responded to a variety of policy or institutional changes. Government policy variables included changes in real expenditure levels, tax rates and exchange rates. Institutional changes were reflected in experiments with shifts in the skill mix of the labor force, redistribution of profits and movements in the wage structure. In addition, the impact of exports on employment and income distribution were also examined.

The question of food policy planning is addressed in the paper by McCarthy and Taylor (1980), where probable impacts of food policy changes in a poor country (Pakistan) were assessed through a general equilibrium macroeconomic model. Several possible food policy interventions were analyzed, and much of the macro-adjustments occurred through price-induced changes in real income flows. The policies examined included (among others) the removal of the subsidy on wheat, an increase in wages by 10 percent, redistribution of land, and an increase in fertilizer subsidy by 50 percent.

The results generated by the model refer to the impact of the policies above described in almost every sector of the economy. With reference to the agricultural sector, the model can be used to assess the impact of agricultural policies (e.g., land reform) on the rest of the economy or the impact of general economic policies (e.g., increase in government expenditures) on agriculture. Given the limitations and scope of this paper, the latter one will be stressed.

Rural expenditures, rural (low-income) consumption of wheat, rice, sugar and imports as well as prices of rural capital (land, manufactures) constitute the principal agriculturally related endogenous variables of the model. The model was used to compare effects of a comprehensive land reform with an increase in government purchase of urban manufactures. The comprehensive land reform program proved to be the most effective policy to improve the welfare of the lowest 40 percent of the rural income strata and to increase consumption of wheat, rice and sugar.

In general, consistency-type general equilibrium models are snapshots of a particular set of relationships describing the economy under study. Because they are highly disaggregated (and hence data-intensive), they capture most of the structural interrelationships among economic sectors and groups within the economy under study, as well as those between sectors and the macroeconomy.

Even though the basic analytical framework of these models allows for explicit linkages among and within sectors, the data availability can become a serious constraint to their practical usefulness. Moreover, additional complications such as non-linearities may increase dramatically the complexity of analytical solutions.

Simulation Models

Simulation models may be used to quantify and formalize many aspects of the consistency-type equilibrium models, especially with respect to the inclusion of sectoral relationships and consideration of the time component in the analysis. In addition, computer simulations with models of economic systems are often performed when there is no analytical solution for the system or when such a solution is too complex. Changes in the system over time may be simulated by changing the policy (control) variables and in this way economic strategies can be evaluated over a closed planning horizon.

The paper by Byerlee and Halter (1974) describes a simulation model built in an input-output framework and applied to Nigeria. The model takes account of interactions between the agricultural and non-agricultural sectors. These include the backward and forward linkages of agriculture, the induced consumption and investment effects resulting from changes in agricultural inputs and the impact on food supply and demand of changes in migration out of agriculture. The agricultural-nonagricultural interrelationships are considered in such a way that variables of a sector analysis (e.g., agricultural income, exports and employment) can be made consistent with other sectors of the economy and with the overall macroeconomic variables.

The model's usefulness for specific policy analysis lies in its ability to incorporate a sector analysis into a broader macroeconomic framework. This requires an explicit specification of the agricultural sector; variables derived from the sectoral analysis are then passed to the macromodel. These variables such as the level of agricultural exports can be related to specific agricultural policy instruments (e.g., export pricing) in a sectoral analysis; however, they are treated as "exogenous" at the macro-level. The macromodel provides estimates of population, urban food demands and migration for use in the sectoral models. Variables are transferred iteratively through both upward and downward linkages between the sector models and the macromodel to ensure consistency.

The Nigerian model was used to examine the consequences of two broad agricultural strategies: export crop promotion and food crop promotion. The simulation period was ten years; all policy runs were compared with a base run which assumed continuation of the existing agricultural policies. Simulation runs suggested that both the export promotion and food promotion strategies would lead to an increase in agricultural value added. But because of the change in the terms of trade against agriculture associated with the food promotion strategy, the effects of such a policy on nonagricultural value added and macroeconomic variables were relatively small.

Discussion

Interest in specifying linkages between agriculture and the overall economy was stimulated by the explosion of agricultural prices in the 1970s. Most macroeconomic models failed to predict the inflationary impact on the rest of the economy of this explosion, mainly because so little attention had been given to the agricultural sector (Lamm, 1980).

The importance of incorporating agriculture into macroeconomic models or explicitly specifying linkages depends, of course, on the relative size of the agricultural sector. The direction of causality also needs to be considered. In some cases, agricultural and macroeconomic variables interact and thus are simultaneously determined. In other cases, especially where agriculture is a small part of the total economy, the dominant causality is from the general economy to agriculture. Where this situation prevails, it is not necessary to provide formal linkages if one is concerned only with the effects of macroeconomic variables on agriculture. Gardner (1981) argues that in the case of the United States, the dominant causality is from the general economy to agriculture. Lamm (1980) reaches a similar conclusion. His analysis suggests that changes in the rest of the economy have large effects on agriculture, while the converse is not ordinarily the case. But not everyone agrees with this conclusion. Roop and Zeitner (1977), for example, argue that changes in the agricultural sector can have a substantial impact on the results of the larger macromodel.

In practice, the interface between the agricultural sector and the general economy includes at least three classes of relationships (Just, 1977): first, the interaction of general price and income levels, agricultural marketing costs, and agricultural prices; second, the interaction between agricultural input markets which are influenced by other economic sectors, with the supply of agricultural products; and third, the interaction between international trade in agricultural and trade balances, exchange rates and non-farm export demand. Traditionally, agricultural sector models have emphasized mainly the first class of relationships and to a limited extent the second. The third class of relationships has been practically ignored. The paper by Roop and Zeitner (1977) includes the second class of relationships but not the third. Chen (1977) incorporates all three classes of relationships. Both input and output linkages to the agricultural sector are provided and also exchange rates influence export demands for agricultural crops. Thus, much of the interface between agriculture and the rest of the economy is captured.

But there are other significant omissions. Most models omit the relationship between income and capital accumulation or borrowing requirements. Penson and Hughes (1979) point out that the lack of equations explaining the financial side of farms makes most sectoral models ill-equipped to address questions regarding the direct and indirect effects of alternative national economic policies on the farm business sector.

The complexity of economic systems constitutes an enormous limitation for sectoral and/or macroeconomic modeling efforts. The agricultural sector, for example, is composed of many subsectors - vegetables, livestock, grain, fruits - which are all "independent" but interrelated to each other. Moreover, changes in key variables for individual subsectors such as output, prices and stocks are difficult to "explain" given the inherent complexity of agriculture. As such, the simplifying assumptions needed in any modeling effort may distort the true pattern of these relationships and/or make the probability of a correct prediction very small. This situation is likely to occur in models that represent agriculture as a single-output aggregated sector comprising all its subsector components, such as the model developed by Lamm (1980). Alternatively, a more disaggregated model may increase dramatically its complexity and analytical solution in order to provide detailed and subsector-specific insights.

The degree of complexity of agricultural models has been pointed out by King (1975). In fact, it is not an easy task to specify and estimate models which will be consistent with economic theory, capture the relevant interactions within agriculture and its interfaces with the nonagricultural sectors including the financial, internal and external markets, and produce sensible or useful results. Subotnik (1980) has discussed these complexities as well as the problems associated with specifying macroeconomic linkages. Schuh (1976) has emphasized, however, that increased complexity in terms of modeling is not necessarily a disadvantage, for it increases the degrees of freedom open to policy makers because there are more variables which can be manipulated. Moreover, due to the increased number of variables that can adjust, a given shock to the system is diffused on a much wider basis. Clearly there are many unsolved problems in attempting to link agricultural and macroeconomic models. Kost (1981) points out the difficulties and also suggests a way in which integration of macro and micro models might be achieved. He states:

> "Macroeconomic models have been built with macroeconomic methods, whereas agricultural commodity models have been built with microeconomic methods. Macroeconomics starts from aggregate economic behavior and attempts to model this aggregate behavior directly. Microeconomics starts from the individual (...) and market phenomena are explained by an aggregation of individual behavior. In one case, aggregate agricultural sector behavior is arrived at through aggregation. In the other case, it is arrived at through a disaggregation process. As they start from different views, these two processes may not reach the same, or even compatible, positions. (...) Conceivably, the proper approach to develop feedback loops between agriculture and the rest of the economy may be best achieved indirectly. Instead of directly linking macroeconomic models to commodity models, it would be preferable to link the models indirectly - that is, from macroeconomic to macroeconomic agriculture to commodity models. This may prove the most fruitful approach to modeling this agriculture/nonagriculture interface." (p. 7)

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