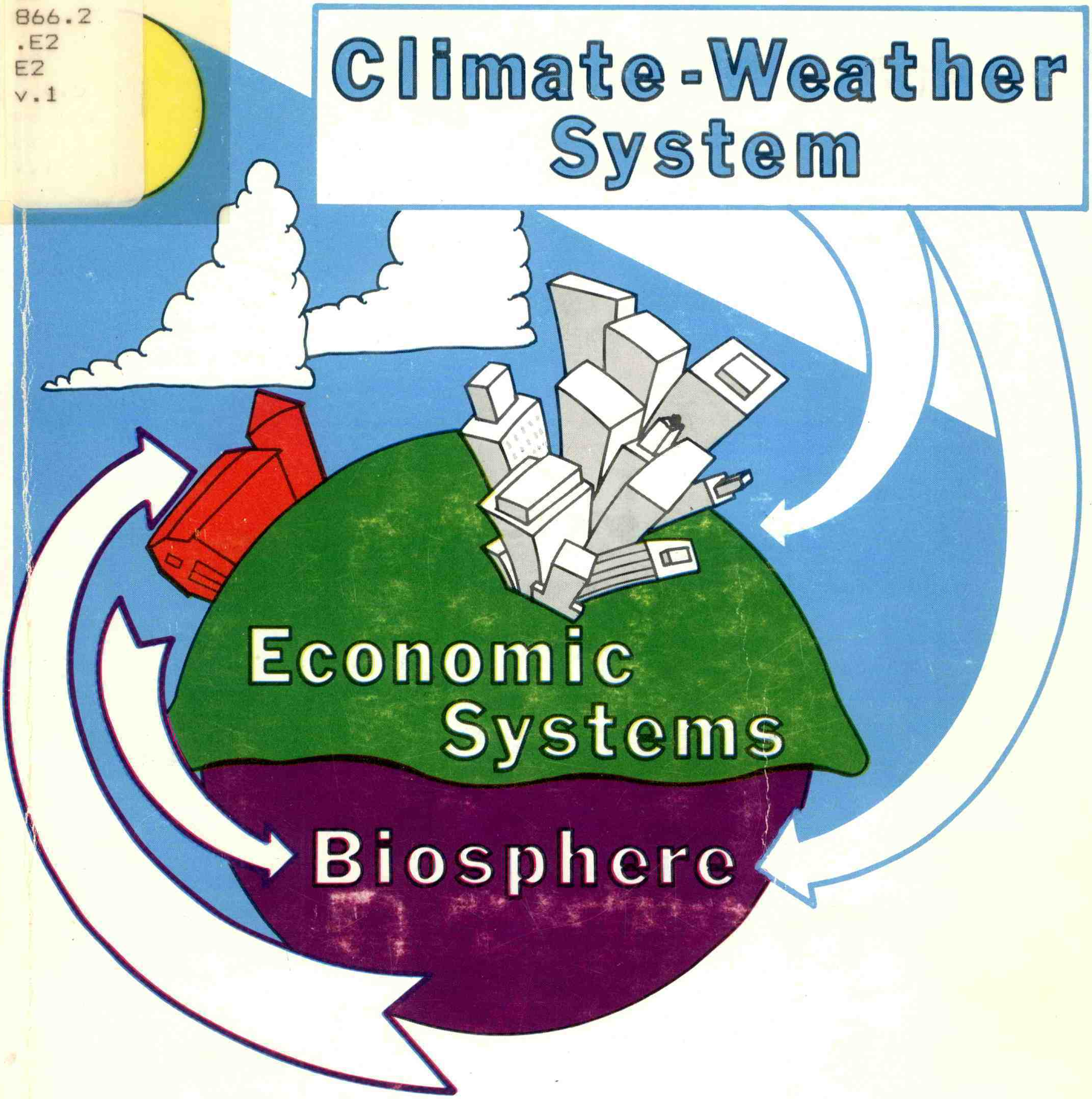

THE ECONOMIC IMPACT OF CLIMATE

VOLUME I

CONVENED BY
AMOS EDDY

MAY 1980

THE ECONOMIC IMPACT OF CLIMATE

Volume I

Proceedings of Two Workshops
on the Structure of
Economic Models

Convened by

Amos Eddy
Principal Investigator

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FOREWORD

This volume summarizes the first two of a series of six workshops to investigate the economic impact of climate. We would like to make use of current economic modeling practice in order to infer the optimal methodology to be employed in analyzing the effect of climate on the U.S. economy. This analysis subsequently would permit significant questions to be answered concerning the sensitivity and responsiveness of the economy to climate fluctuations. Water, food and energy supply and distribution are all functions of climate and play an important role in any econometric model. But how do we pose questions concerning the economic value of climate and climate information?

The first two workshops dealt mainly with the anatomy of two types of economic models: input-output and econometric. We discussed the potential for introducing weather and/or climate variables wherever we discerned such a possibility to exist.

The first chapter summarizes those possibilities for investigating climate-economic interactions which presented themselves to one of the professional climatologists in the group. That list will no doubt be supplemented and refined as the workshops proceed. The remaining chapters discuss some of the relevant nuts and bolts of economic modeling while bringing in possibilities for climate-economic interactions from the point of view of the economist.

Volume II contains examples of energy supply and demand.

Volume III treats water and agriculture in specific regional contexts.

Volume IV is a user-oriented non-technical summary.

WORKSHOP 1. September 28-29, 1979
Center for Environmental Assessment Services
Columbia, Missouri

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WORKSHOP 2. November 2-3, 1979
The Osage House
Lake of the Ozarks, Missouri

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I. INTRODUCTION

Amos Eddy

Man is a ubiquitous component of the biosphere, and his frenetic activity can cause perturbations in the earth ecosystem which are significant on space-time scales ranging from rather small (micro: with respect to himself as an individual) to rather large (macro: again with respect to his individual size and lifetime. We are interested in examining that particular subset of human activities which comprises the production and consumption of (his) "goods and services." This is described using an economic frame of reference, and money units to make the components of the system commensurable. This segment of human endeavor is subject to many influences; here we focus on those stimulations and constraints which are attributable to the climate.

In short: we wish to study the economic impact of climate.

The construction of any model to describe this system must first address the problem of scale. This is the problem of aggregation in space and time as well as with respect to economic sector. We face the classical dilemma: high resolution would enable us to study cause and effect but would lead to an unstable and very complex model (even if we could obtain all the data required), whereas high aggregation (low resolution) will give us a more stable model with sufficient data for validation but will mask much of the cause and effect detail in which we are interested.

There is one deadly trap to be avoided at all cost. If we average the climate (weather) and aggregate the economics separately <u>before</u> we combine them to produce our climate-economic impact model we will get a totally different result than that produced if we do our aggregation after we obtain the climate-economic interactive effects at a lower level of aggregation.

One can object that one should first decide on the questions to be asked before deciding on the model to be constructed. In many (if not most) cases this is correct and indeed a very important point. It is clearly out of place here. The questions to be asked and the type and scale of the model required to produce answers are indeed intimately linked in our case; however, this study is explicitly interested in finding out what kind of questions concerning economic-climatic relationships can be asked. Perhaps it would be more accurate to say that we are interested in ranking such questions with respect to the benefit/cost associated with obtaining answers to them.

There are many ways to undertake such an investigation. We have chosen to begin by considering a regional input-output (I-O) economic model as having enough structural detail to permit a fairly explicit relationship between climate/weather and man's economically related activities. If we consider the region to be at least the size of a state we can expect a certain amount of model stability and even have some hope of obtaining the required economic data. We can consider integrating (aggregating) to the national level through the use of the multiregional input-output modeling (MRIO) technique as opposed to the usual sectoral aggregation employed in constructing a national input-output model.

Suppose we consider the open static I-O model. It is static because the transactions described are valid at one point in time (when the survey was made, representing possibly one year of activity) and it is open because its final demands(exports, government services, household consumption and capital formation, for example) are determined exogenously to system (model). Inputs such as labor and imports are also exogenous. We shall consider later how econometric models, which are themselves subject to climatic influence, can be used to specify these exogenous variables. First, however, we shall look at some of the virtues and defects (with respect to our problem) in regional I-O models. They present a recipe for the buying and selling which goes on between industries in the regional economy. This recipe is in the form of technical coefficients which are reasonably stable for a given technology and a relatively low level of imports. When the imports become relatively so large a factor that the regional economic activity is not constrained seriously by changes in the endogenous economic activity, then we are dealing with trade coefficients (rather than technical coefficients) and it is the weather/climate impact outside the region which is producing the major economic impact within the region. In such cases we could be better off studying the effects of climate on the econometric models used to estimate imports.

It is often stated that the economic "health" of a region depends on its basic industries; i.e., those which sell their product principally outside of the region. Here we are looking at the exogenous export sector which is to be estimated using econometric models. Not only is this segment of final demand influenced by weather remote from the region but also the price, which is derived from supply/demand relationships and a vital factor in the I-O technical coefficient recipe, is influenced by climate both in and out of the region. Price is to be estimated using econometric models and macro economic supply and demand concepts.

So are there any virtues left to this I-O modeling device?

Certainly!

Weather/climate imposes a demand for utilities (say, heating) on a regional (airmass) scale and in time intervals of a few days. This can certainly not be aggregated safely beyond a season without losing the space-time location of the economic impact.

Climate affects the supply of food being produced within a region the size of a state, often on a subregional (crop reporting district (CRD) of climate division (CD)) scale. Critical time scales here are the very few weeks associated with planting, flowering and harvesting, to use examples in the grain producing economic sector. There are also "events" such as blizzards, droughts and floods to be considered. And we have "non-stationarities" in the form of non-linear interactions between weather and pests and diseases.

The I-O technique allows us to study the differences in impact on a regional economy of more wheat produced by irrigation, more wheat produced by weather modification, and more wheat produced as a result of natural rain occurring at exactly the best (for wheat) time in the best amount.

We can study the interactions between two sectors such as grain-producing and meat-producing where activitiy in one might be induced by climate-influenced demand from the other or stem from additional climate-influenced supply from the other.

The influence of governmental policy action in the production of energy-efficient housing (designed considering the local climate) will certainly require some detail in the construction and utility sectors on a regional basis in order to answer questions concerning the long term economic impact at the national level.

When we consider the economic impact of climate we are including not simply the passive response of our production and consumption to climatic variations, but also how we might use climate information both to stabilize the economic system and to optimize the benefit/cost ratio with respect to planning strategies and actions taken in individual sectors.

And what of climatic change?

A slight southward shift of the storm track and/or a slight overall drop in mean temperature could wreak havoc with nationally aggregated econometric models, but could be much more easily accommodated by the technologically structured regional I-O representations.

An annual multi-billion dollar economic effect would be associated with the return to dryland farming from current irrigation in the Kansas, Colorado, Oklahoma, Texas region; consequently, optimal irrigation strategies (which are a function of climate) are of vital importance in extending the lifetime of this diminishing natural resource.

We now turn to questions relevant to the impact of climate and climate information on econometric models (and hence by implication on the marginal distributions and prices determined by these econometric models which are vital to the I-O models).

Food production fluctuates significantly from year to year because of climatic influences. This fluctuation is with respect both to total amount and geographical (and economic) region. Runs of several years of weather which is bad on the global scale for producing food are to be expected from a climatological point of view. What stocks should the world have to reduce the impact of such potential disasters? Runs of weather which are bad for food production in one region (for instance a nation) but good in another region (a nation) are also to be expected climatologically. Since either overproduction or underproduction can cause instability within an economy, one would like to be able to anticipate such occurrences in order to provide for corrective measures. Abner Womack discusses in Chapter V of this proceedings the way in which a central agency such as the U.S. Department of Agriculture can use stockpiles of grain to add to current production in times of shortfall (keeping prices below a critical level) and to subtract from current production (increasing reserves) in times of bumper crops (keeping prices from dropping below a critical level). This economic stabilizing activity is certainly at least in part the result of climatic influences, and models concerned with it are of the econometric type. Womack also discusses the consequences of crops (such as soybeans) being overproduced in other countries (partly because of favorable weather) and affecting the price of soybeans in our own economy.

As we move toward solar and wind energy supply we will have yet another "climatic expectation" problem which will have to consider normals, variability, autocorrelations, cross-correlations and trends in the time series of climate variables. Some of this supply will be endogenous to each I-O economic region, but some will show up as a demand for imports in times of weather-inflicted shortfalls. How often and to what extent will this type of interregional transport (import-export) be expected to occur.

It should be clear by now that the climatologist should supply a climatology of the world with the space-time resolution and with those descriptor parameters most appropriate for the upgrading of various economic models. In order for him to perform this relatively straightforward task he will have to be told by the economist exactly what space-time resolution and descriptor parameters are needed. Given the above communication and analysis our problem will be solved...until, of course, technology changes or someone makes an unanticipated choice - both of which are occurring every day.

Although we do not deal with these at this point in our project, there are all the usual problems of model validation and sensitivity analysis, of inadequate data samples, and of error or noise analysis. This type of problem we plan to face as squarely as we can at the time of our sixth workshop - next June.

II. ECONOMIC MODELS AND THE IDENTIFICATION OF CLIMATIC EFFECTS ON ECONOMIC PROCESSES

Stan Johnson

Introduction

It is well known that the climate and/or weather has important impacts on economic processes. These impacts enter the economic process through the influence of physical or technical relationships on which economic activities depend as well as through their direct impact on economic agents. Numerous studies are available documenting climatic effects on basic physical processes. Also, there is evidence that the climate influences attitudes and forecasts of economic decision makers or agents whose behavior governs economic processes.

The purpose of this discussion is to take the simple observation that the climate affects physical processes on which economic activities depend and economic agents one step further. In particular, the discussion will review the potential for various types of economic models to incorporate relationships which quantify these effects and assess their more general influence on the functioning of various economic systems. There are two reasons why this exercise is important. First, from a scientific viewpoint it is advantageous to improve the basic understanding of economic processes. If the incorporation of climatic variables and climatic effects can improve the understanding of these processes, then the predictive content of economic models and their value for policy analysis can be improved. Second, substantial resources are not devoted to the generation of information on the climate and/or weather. These expenditures and their allocation is itself an important economic policy problem. If society is to make good decisions regarding the expenditure of funds to generate information on the climate, then it is important to know the value of such information for the functioning of economic processes and the improved decision making of economic agents.

The discussion first reviews concepts of systems and models as applied in economic analysis. A general understanding of these concepts must be developed before particular economic models are reviewed regarding the incorporation of climatic effects on economic processes and, relatedly, the evaluation of information on the climate. By identifying the key features of systems as perceived in an economic context and modeling exercises, it will be possible to provide an improved perspective on the potential for incorporating climatic effects in existing economic models.

Once the general discussion of systems and models is completed, four specific types of economic modeling exercises are reviewed. These are organized with respect to model purpose and include macroeconometric, commodity, economic base and/or regional, and input-output models. After a review of these models, the potentials for linkages between them is investigated. The term developed in this connection is "bridging." It refers to the idea that models developed for different purposes may be linked together for the accomplishment of more integrated economic analysis.

Finally, alternative strategies for the incorporation of climatic effects in economic models are reviewed. The objective of this final discussion is to provide, within the framework generated by the review of different models, an appraisal for the current status of economic research involving climatic effects and to identify promising areas for potential gains in developing economic models that more adequately reflect the climatic environment within which the economic and physical activities occur.

Systems and Models

Concepts of economic systems are determined by particular theories or paradigms. In general, there are two types of systems, those which refer to the activities of individual economic agents and those which reflect the activities of collections of economic agents. The primary economic agents are individuals and firms. Collections of activities of these agents can be viewed in terms of economies and markets which can be further delineated on the basis of geographic considerations, types of goods, time, and other factors. In general, the economist focuses on a particular economic activity of interest for forecasting of policy analysis. An appropriate theory for that activity is then synthesized from the existing literature. Thus, the perspective from which the system is viewed and in fact its definition is governed by the interest of the researcher and the understanding of a particular process.

Models of these systems are themselves systems. They are, however, abstractions designed for a specific purpose. Models can, for example, be descriptive, behavioral, forecasting, or of a decision nature. In judging a model and its appropriateness for particular economic analyses, the purpose for which the model is developed must be specified. The performance of models and their use in understanding systems is thus ultimately judged based on the purpose for which they were formulated. Hence, very different models of identical economic systems can be formulated and utilized with the differences determined by their ultimate use. Given the fact that people develop models for relating to systems from different perspectives, very different types of models of a particular system can be appropriate.

Economic models all incorporate prior information on both the functioning of agents and the physical or technical relationships. The decision as to which propositions regarding the functioning of the system are to be tested, and the ones to be maintained and untestable as a part of the model construction process, refers to the art of model building. This decision is in general governed by the use for which the model is intended.

Economic models typically feature or attempt to represent interactions occurring within systems. The theory regarding the interactions is usually incorporated in what is called a structural representation of the system. This structural representation is intended to make it possible to incorporate simple hypotheses about the functioning of economic agents, their relationships to each other, and the physical processes on which the systems depend. Reduced forms of the systems are representations in which factors that are taken as exogenous, predetermined or environmental can be traced for their effect on the endogenous or internally determined variables. These reduced form representations reflect the a priori information which has governed the specification of the model and information introduced in the form of parameter estimates. Thus, in the specification and specialization of model structures to particular systems, the structure is typically the proper frame of reference, while for forecasting and policy analysis the reduced form representation is the appropriate characterization. In each of the four model types to be discussed, it will be apparent that these two representations play important roles in allowing the researcher to incorporate available information in the model and, relatedly, permitting a characterization of the model that is useful for accomplishing the ultimate purposes of the research exercise.

Macroeconometric Models

There are many types of macroeconometric models. As suggested by the previous discussion, these models are formulated for both forecasting and policy analysis. In addition, these are utilized to test hypotheses regarding the appropriateness of structural representations. These types of models are in wide use at highly aggregated levels in the U.S. economy. The one selected for illustration is of a simple textbook Keynesian type and could be used for forecasting gross national product, consumption, and investment, or for attempting to understand the impact of changes in government fiscal policy on the levels of these endogenous variables.

The macroeconometric models frequently begin with an accounting identity. The identity in this case indicates that Y or gross national product is equal to consumption, C, plus investment, I, plus government expenditures, G. That is,

$$(1)\quad Y = C + I + G$$

The model is assumed to be linear, and includes three internally determined variables, Y, C, and I. Thus, two additional equations are necessary to identify the endogenous variables. Typically, these equations are introduced in a behavioral format. For example, consumption is typically related to consumption in the previous period, representing a persistence type of hypothesis and income, Y; i.e.,

(2) $C = f(C_{-1}, Y)$.

In a similar fashion, investment might be introduced as a behavioral function of income and the interest rate, i,

(3) $I = g(Y, i)$.

The three equations represent the structural specification for the macroeconometric system. If the behavioral equations (2) and (3) were linear, then it would be possible to solve for the endogenous variables of the system or the internally determined variables (Y, C, and I) as functions of the predetermined or exogenous variables C_{-1}, i and G. The expression would be of the form

(4) $(Y, C, I)' = \pi (C_{-1}, I, G)'$.

This expression is called the reduced form of the system and can be used to forecast values of Y, C and I on the basis of the predetermined variables. Various estimation processes would be used to determine (4) and correspondingly the parameters of the behavioral equations (2) and (3).

Clearly, the system could be extended by "endogenizing" additional variables. The most likely one in this case would be the interest rate, i. In many macroeconometric models, the interest rate is endogenized by specifying a money demand function and a money supply function along with a market clearing condition. As this is a textbook exercise in basic macro modeling, we will not follow-out the implications. It suffices to say that macro models can be specified in the manner indicated above, estimated by an appropriate means based on data or subjective information held by the researcher regarding the economy and utilized in policy or forecasting contexts.

How can climatic variables be introduced in such models? Clearly, in the example model, climatic effects are not easily identified. To introduce climatic effects, one would have to understand how such variables influence the basic behavioral relationships of the model. In rationalizing such relationships, it might be necessary to disaggregate these variables so that the climatic effects could be more clearly traced. For example, one could disaggregate the investment function into investment, say, in the construction industry, I_1, and other investment, I_2. If information were available linking investment in the construction industry to climatic variables, perhaps represented by an index W, then the investment equation could be specified in two parts. First, as indicated, an identity would be introduced. This identity would be of the form

$$(5) \quad I = I_1 + I_2 \ .$$

Then behavioral equations for I_1 and I_2 would be specified. For I_2 the specification would be the same as equation (3) above, i.e.,

$$(6) \quad I_2 = g(Y, i) \ .$$

For I_1 it would perhaps be

$$(7) \quad I_1 = h(Y, I, W) \ .$$

By solving for the reduced form based on an estimation of (7), and the other equations, it would be possible to trace the impact of this weather index on all of the internally determined variables within the system.

The above comments are intended to show that it is a simple matter to introduce climatic effects into macroeconometric models given a sufficient level of disaggregation and an appropriate rationalization for the introduction of the associated variables into the behavioral equations. The exercise should illustrate how simple behavioral relationships pursued by researchers interested in studying the effects of the climate on particular economic activities can be incorporated in larger economic constructs and analyzed for their effects within economic systems. What the exercise also indicates is that to make the results of these exercises informative, valid and careful empirical work needs to be done in establishing the behavioral relationships that include climatic effects.

In terms of the objectives of this discussion, the climatic variables so introduced could be viewed from two perspectives. Firstly, the model could be simulated or otherwise manipulated based on a specification not including the climatic effects. The performance of the model could then be compared to a version including the climatic effect. Based on this comparison, it would be possible to infer the value - through the improvement in model performance - of knowing the climatic variables or alternatively knowing the behavioral relationship that included the climatic variables. From a more general perspective, by placing a weight on the ability to forecast the endogenous variables correctly and/or the effects of the control variables for the economic agents in question, in this case the control variable would likely be G, the value of the weather information could be assessed. The point emphasized is that assessing the value of the weather information goes back to the purpose for developing the model and accordingly the perspective from which the economic system is viewed.

Commodity Models

Commodity models are also specified at aggregate levels and typically focus on a particular market or collection of markets that function in an integrated manner. For the present, the discussion will be limited to a single market. The supply demand framework utilized in characterizing markets is appropriate as well for macroeconometric models. Although somewhat more veiled in the specification, macro models ultimately have a demand and supply orientation.

Specifications for the demand components of commodity models are usually motivated by consumer demand theory. The demand specification is rationalized on an individual level. The appropriateness of the individually motivated specification at the market level is justified by viewing the market in terms of representative consumers. Demand functions typically state that the quantity demanded, Q_d, is a function of own price, P, the price of substitute commodities, S, and income, I. Specifically, the function is of the form

$$(8) \quad Q_d = f(P, S, I) \quad .$$

The supply of the commodity, particularly for agricultural commodities, frequently includes a number of equations which can be compressed in a partial reduced form. That is, the equations can be substituted into each other to form one supply equation. For current purposes the supply function in this partial reduced form context is specified directly. It is important to recognize however, that the supply of many commodities studied in economic models is determined on the basis of underlying physical processes. These physical processes are necessary as components of the models and in the present context since it is at this point that weather effects are probably most appropriately included.

The supply functions are of the form Q_s, the quantity supplied a function of the market price P, costs or prices of factors of production C, and to illustrate the climate effect W, an appropriately defined weather index. Specifically, the supply function is

$$(9) \quad Q_s = g(P, C, W) \quad .$$

Of course, the rationalization for the inclusion of the weather index W would have to depend on careful research regarding the impact of the climate on the physical processes which underlie supply response. These economic models also include an identity which simply states that the market clears or the quantity supplied is equal to the quantity demanded. That is,

$$(10) \quad Q_d = Q_s = Q \quad .$$

The above model is structural. The reduced form of this system is used for both policy analysis and forecasting. The reduced form of the system which includes endogenous variables Q, the quantity transacted in the market, and P, the price at which the quantity is transacted, is

$$(11) \quad (Q, P)' = \pi\,(I, S, C, W)' \quad .$$

Thus, through this reduced form the values of the endogenous variables in the system can be examined for their relationship to the predetermined or exogenous variables, I, S, C, and W. Again, the reduced form structure can be used for forecasting or policy analysis, for forecast questions can be asked related to scenarios of the exogenous variables and the resulting values of the endogenous variables. For policy, one might pose questions that would for example relate to the impact of a change in costs perhaps in turn induced by some government policy on the supply and correspondingly the market equilibrium quantity and price.

This commodity model demonstrates the possibility for introducing weather effects. The validity of models including such effects and their usefulness is governed by the validity of the functions which incorporate the weather variables. For commodity models, these functions can be technical or behavioral. In general, in agricultural models which are developed on a commodity basis, the weather effects are included in the technical relationships. For example, the yield of a particular crop is specified as a function of climatic variables. Again, the evaluation of the weather information for the model can proceed in two ways. First, models can be formulated with and without the climatic variables. Then the two structures can be compared for their ability to reproduce the important variables in the system. As before, the value of the weather information for the modeling process can be examined in an economic context by reference to the model purpose. The model was formulated for investigating the performance of a particular system. By specifying a criterion function for the performance of the system, the improved functioning of the model can be valued. This would then be the empiric value of climatic information. Also in the context of commodity models, ideas of economic surplus obtained by integrating the area between the supply and demand functions can be used as an internal measure of the value of weather information. The technicalities of this approach to valuing weather information will not be developed. For an exposition of the use of such methods in a supply and demand context function, see Currie et al (1971).

Economic Base and Regional Models

There are wide ranging possibilities for modeling regional economies. The major difficulty with these models relates to the fact that the regions being modeled are typically not completely economic in nature. Specifically, many regional models have been constructed for politically defined geographic areas. These political boundaries, although impacting on economic activity through, for example, tax rates and other infrastructure factors, are not natural economic boundaries in terms of the intended purpose of the modeling exercise. Thus, a major difficulty with these models relates to the delineation of economic factors which are determined within and externally to the region. This is the origin of so-called economic base models. These models separate economic activities into those externally and internally determined. The particular activities selected are of course a function of the purpose for which the model is constructed. Generally, the delineation of activities externally and internally determined is at first along industry lines.

A simple example of such a model would be one in which E, employment in the base industry, is represented as a function of output levels in the base industry X, and regional personal income, I; i.e.,

$$(12) \quad E = f(X, I) \quad .$$

Income would in turn be determined by employment in the non-based industry, say Y. Specifically,

$$(13) \quad I = g(Y) \quad .$$

Employment in the local or non-based industry would be specified as a function of the level of economic activity in the base industries, with perhaps population factors taken as exogenous. In particular,

(14) $Y = h(X, P)$

where P is an appropriate measure of population.

As in the case of the previous two models, the reduced form for this system of equations could be specified. Climatic activities could be introduced by further disaggregating the employment in either the base or the local industries. With appropriately justified expressions relating employment in the industries to climatic indices, the effects of climate could be traced through the reduced form for this system to the endogenous variables. Thus climatic conditions could be related to regional income as generated from a specific non-base industry or the regional income as a whole. Also, climatic variables could be related to employment in the various industries.

The value of weather information in this context would again be obtained following processes indicated in the sections on macroeconometric and commodity models. Specifically, the usefulness of the weather input for understanding the level of economic activity, or more importantly the forecasting performance of the model, could be examined by specifying the model first including and then excluding weather variables. The two versions of the model could be compared for their reliability in terms of a representation of the underlying economic system. The value of the weather information could be assessed as well by referring to the purpose for which the model was generated. Economic impacts of various climatic events could be assessed. This would again imply the development of an objective function which could be specified over the endogenously determined variables. Information must be evaluated within a well-specified context. This context is typically given by the purpose for which the model was specified. However, it will also be likely to require a more formal statement of the purpose. With such a formal statement of the modeling purpose and an assessment of the underlying character of the economic system, the value of weather information can be assessed.

Input-Output

Input-output models have been developed for understanding interindustry relationships within regions and/or economies. Values of industry inputs and outputs are assembled in a transactions table. This array is then utilized for purposes of generating a coefficient matrix to relate levels of economic activity within industries to predetermined or exogenously specified levels of final demand. Mechanically, the coefficient matrix can be represented as A, the vector of industry outputs as X, and the vector of final demands as Y. The input-output expression utilized in this simple context is of the form

$$(15) \quad AX + Y = X \ .$$

That is, interindustry demands plus the final output equal the outputs of the various industries.

Solving equation (15) for the level of activity in the various industries produces

$$(16) \quad X = (A - I)^{-1} Y \ .$$

Expression (16) is the reduced form of the economic system represented in (15). It can be used to trace the effects of various changes in final demand to the levels of industrial activity for the industries specified in the vector X.

The incorporation of climatic information in such input-output constructs is a simple matter. For example, suppose that the final demands were somehow conditioned by a particular weather event. Then an equation of the form

$$(17) \quad Y = f(W)$$

could be specified, where W is an appropriate weather index. Using the reduced form expression (16), effects of the weather variables could then be traced to levels of industrial activity.

Given extensive papers on input-output modeling in this compendium, not much detail is given regarding their advantages and limitations. The features emphasized relate to the fact that there is a structural and reduced form version of the model, and the model is designed for a representation of a particular type of economic activity. That is, input-output models are developed for a specific modeling purpose, the understanding of inter-industry relationships within an economic region or economy. There are a number of limitations of such models. These relate to the specification of final demands, the importance of prices in determining the interindustry flows, and the A matrix as a monetarily defined approximation of the underlying production function.

Weather effects can be traced through, for example, from equation (17) into equation (16) to discover how the system is better modeled with the inclusion of this information. The value of weather information can be assessed as well by placing some value on the forecasts of industry activity. Clearly, there is great room in this type of model, as with the previous three models, for the development and definition of behavioral relationships that relate climatic activity to economic and technical factors. These factors can then be directly incorporated in more general economic constructs as a basis for assessing their improved performance and valuing the climatic information.

Merging Models

The idea of merging or bridging models developed for different purposes is commonplace in econometrics. If the reason for the merging of the models were known prior to their development, it could be more systematic. The reason is that the models would be formulated on a general basis and then specialized for the particular sub-tasks. The process is in fact usually reversed. That is, models constructed for differing purposes are spliced together to achieve more general or diversified ends.

Options for bridging the model types reviewed should be fairly clear. First, the Keynesian models or the macroeconometric models have great detail regarding final demand. Also, they are developed at highly aggregated levels. The final demand vectors generated from these models could be introduced in the input-output models. It is possible, for example, to specify the macroeconometric models in sufficient detail that the demand vectors apply directly into the input-output models. Usually, however, assumptions are made to decompose the output vectors from the macroeconometric models for inclusion in the input-output frameworks. As the macroeconometric models are limited from the viewpoint of production function specification, the merging of the input-output models and macroeconometric models has the effect of improving the "supply side" content of the combined model.

Similar observations are appropriate regarding the economic base or regional models and input-output models. In fact, input-output models are more frequently used for regional economic analysis. In these cases, it is customary to attempt to generate the final demand vector on the basis of factors external to the economy and internal to the economy. In this sense, the input-output model can be transformed into the type of economic base construct. Relationships of the final demand vectors to the internal and external factors are typically ad hoc, specified using simple relationships based on past experience incorporating information related to the industries studied. Thus it is a simple matter to endogenize the final output vector sufficiently within the input-output model such that a merging can occur.

The final type of merging relates to commodity models. Commodity models can be combined with regional econometric models and macroeconometric models. The usual procedure is to make the bridge between these models in terms of income and/or price indices. In the case of macroeconometric models the feedback from the commodity models to the macroeconometric model is through the consumer price index. Large scale experiments involving these linkages are currently underway, conducted by major model venders and the government agencies. This is especially true for agricultural sector models.

Commodity models can also be merged with the input-output models. This is done by identifying the commodity models with particular industries. If the commodity models can be formulated on an industry basis, then the input-output models can be used to provide greater supply side disaggregation, opening the possibility for studying substitution relationships as related to the supply response and input utilization. To summarize, the delineations of the models should be recognized as essentially arbitrary. Thus the process of combining them is simple, involving simple redefinitions to expand areas of conformability in terms of internally determined variables. Problems that occur in combining the models are more related to specialization in their construction than to the fact that on a conceptual basis there are difficulties for their integration. In short, there are no conceptual problems with integration of the models since model types are defined related more to the emphasis or the purpose than to particular characteristics of the systems being studied. Merging and model integration is more a pragmatic than a theoretical concern.

Inputing Weather Relationships

The obvious approach for productively introducing climatic effects into economic models has been anticipated in the earlier comments. It is also suggested by the areas in which success has been achieved in this regard. The most apparent of these is agricultural modeling. In this case, climatic effects on yields were studied and relationships developed incorporating available physiological information to form weather yield functions. This physiological information was used largely to motivate the specification of the climatic variables for introduction into the yield function. As a general matter, the method by which the physiological information was incorporated in this context should be helpful as a model for the study of other weather related economic activites.

Generally then the avenues for introducing climatic information into economic models is suggested by Figure 1. That is, various weather variables are measured. These weather variables are used together with appropriate physical information to estimate technical or behavioral relationships for eventual inclusion in economic models. If the economic models do not afford an appropriate place for the introduction of this information, then sufficient

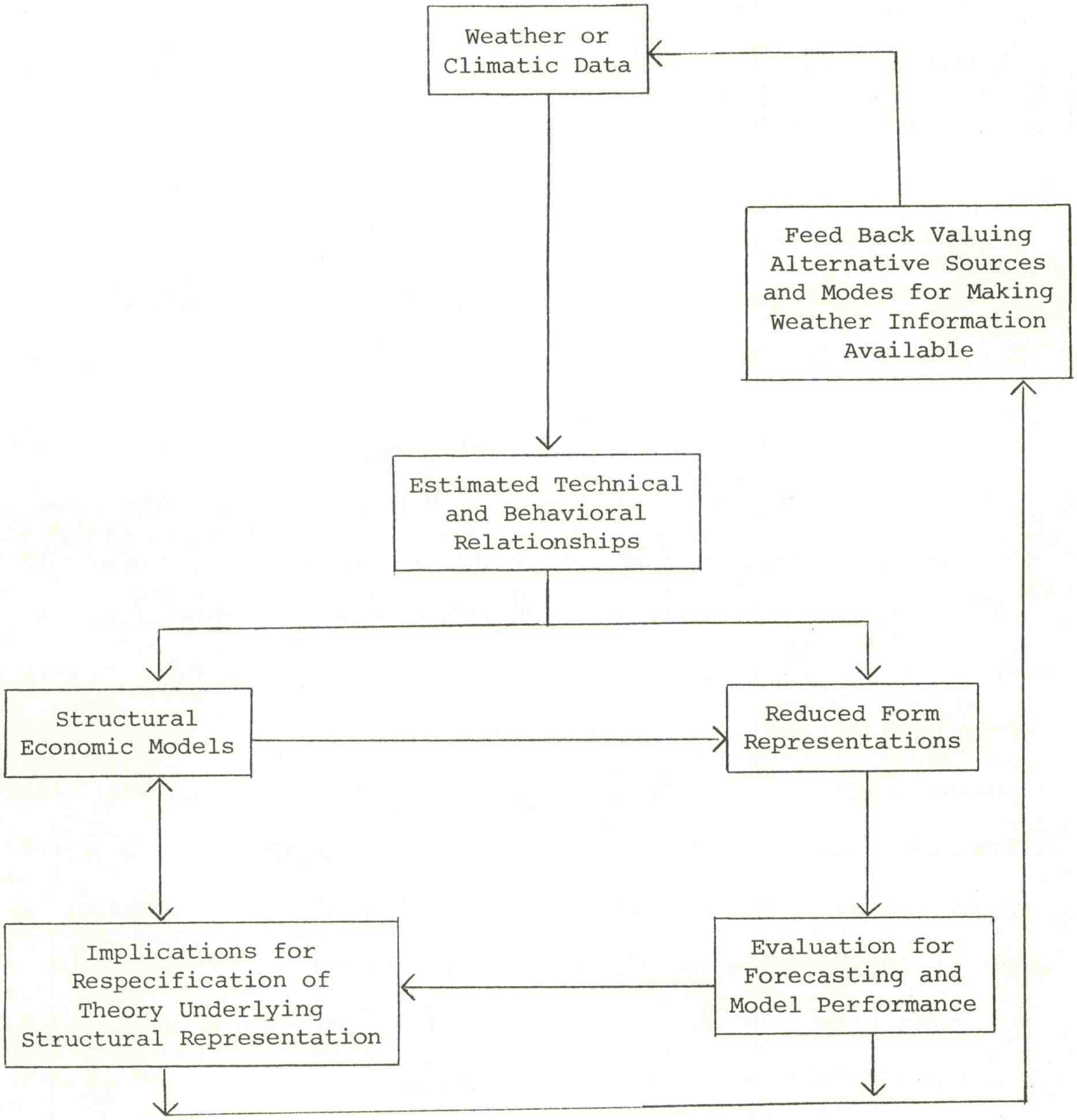

Figure 1. Introduction of Climatic Relationships in Economic Models.

respecification must occur so that the endogenous variables from the simple weather relationships can be directly introduced.

Once the simple weather related relationships are introduced, there are two representations of interest. The first is the structural model. The structural model or the equation of the structural model would be identical with the simplistic weather relationship. The second and more complex method for studying these relationships relates to the implication for reduced forms. In this case, the interaction of the climate through the economic relationship can be traced to the system modeled. These reduced form models can be useful in economically evaluating the weather information and in indicating how the inclusion of the weather relationships improves the model performance.

From the viewpoint of an optimal strategy for progressively integrating climatic effects into econometric models, a portfolio of approaches would seem appropriate. In particular, in areas where some success has been achieved, further refinement can be attempted, e.g., in agricultural models. In addition to these areas, there are instances where progress has been made in introducing climatic variables in an *ad hoc* way. This progress suggests that climatic variables and their impact on economic or technical relationships represents an important decision input to the agents in the industry. One example is the utilities industry, where climatic factors are widely used to normalize demands for electric power and natural gas. What the developers of these models can learn from the experience in agricultural contexts is that substantial gains can be made by introducing technical information in this model specification. For electric power or natural gas consumption, this technical information is likely to be in terms of end-use models, widely applied in engineering.

Finally, considerable exploratory work needs to be undertaken in widening the use of climatic variables in economic models. The necessity for this is fairly obvious and represents a useful opportunity for those interested in studying the interactions between the climate and the economy. More and more regional or localized economic models are being developed. As these models are developed, it is apparent that usual approaches to seasonality are inappropriate for characterizing weather effects. In particular, specific functions incorporating these variables must be introduced if the models are to reproduce the internally determined variables with acceptable degrees of reliability.

Possibilities of this expansion to construction, transportation, and recreation industries seem clear. The strategy should be to develop the basic exploratory or other relationships between the climatic variables with the assumption that existing economic models can be appropriately altered to accommodate these relationships. As has been indicated in the discussion of the four model types, it is a simple matter to alter the specifications of existing economic models so that these behavioral or technical relationships can be accommodated.

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III. OBSERVATIONS ON THE USE OF ECONOMIC MODELS TO ASSESS THE EFFECTS OF CLIMATE

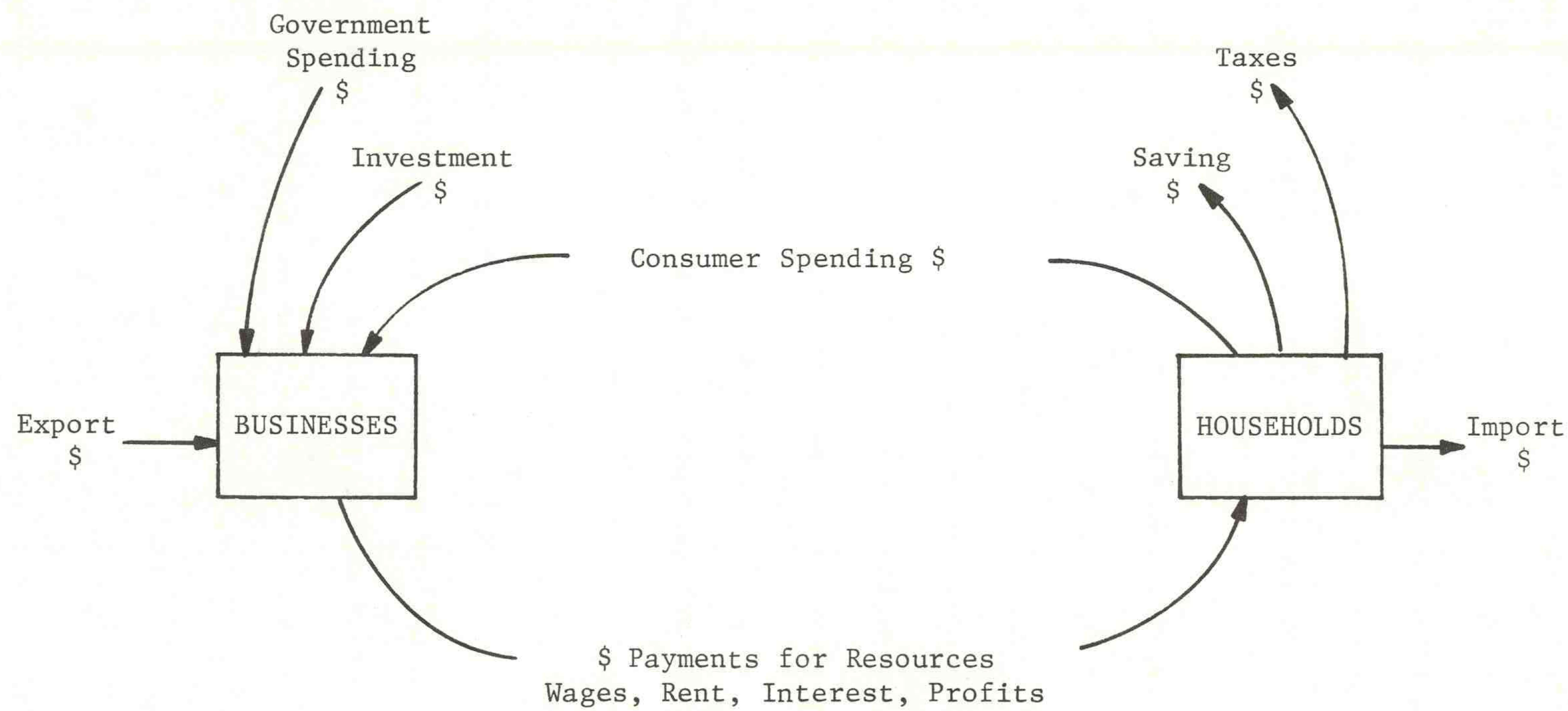
Jim Morgan

Three points will be addressed in my talk this afternoon. First, a few general comments about econometric models versus input-output (I-O) models will be made. Then regional econometric models will be dealt with specifically because there are some characteristics of regional models which differ from the national model discussed this morning which are important to note in evaluating whether it will be worthwhile to use the models that are available on the regional level. Finally, the questions of when it might be appropriate to use econometric models to assess climatic impacts, when it might be appropriate to use I-O models for this type of assessment, and when some combination of the two methods might be appropriate will be discussed.

Econometric Models Versus Input-Output Models

To begin, refer to the very simplistic model of the circular flow of economic activity in a region or nation in Figure 1. In this model all economic activities are divided into either business activities or household activities. Households are assumed to do all of the consuming in the economy while all production is performed by businesses. The flows coming into business at the top of the figure represent, in a highly aggregated form, all of the sources of demand for goods and services in an economy. These include consumer demand, investment demand, and government demand coming from inside the nation or region, and export

Figure 1. The Circular Flow of Economic Activity



demand from outside which causes a demand for goods produced in the nation or region.

The bottom portion of Figure 1 depicts total supply in the economy. Businesses purchase land, labor, and capital from households, and these resources are used to produce the goods and services that were demanded at the top of the diagram. Households in turn use the money received from business either for consumption, saving, to pay taxes, or to buy imported goods.

These flows are highly interrelated; businesses will need to produce goods only if there is a demand for those goods. Thus the resources which businesses purchase and the payments to households depend upon the demand for goods and services in the economy. Similarly, the amount that households will spend for consumption depends upon the amount households have received as payments for resources they have supplied to businesses. Thus there is an interdependence between total supply and total demand in an economy, and any model of aggregate economic activity must involve a representation of the components of total demand and total supply and the interrelationship between them.

The simple circular flow model described above is a familiar one. Its significance in evaluating regional I-O models and econometric models is that it should suggest that the two types of models are not totally unrelated. It will not be possible to model an economy with either I-O analysis or an econometric model without both of these types of flows. How goods get produced, the factors that are supplied and the production process that takes place will have to be explained. Once the goods are produced, the factor payments provide the household with money with which it can buy products and have viable demands. Both I-O analysis and econometric models provide models of both the economy's demand and supply flows. Usually I-O models concentrate on the production process. The production process and the interrelationships among various industries in the production process are described in great detail by the coefficients of the I-O model. The demand side of the circular flow is represented by the final demand sectors of the I-O table. The assumption is that from some source we are going to come up with a forecast of those final demands to introduce into the model. Some components of demand may be made endogenous to the I-O model by expanding its dimensions. Typically, econometric models reverse this emphasis. They deal with the demand portion of the circular flow and include fairly simplistic, highly aggregated production functions which are often in implicit form. The emphasis is on what causes people to buy products, the source of the demand for what is being produced. These components of total demand are modeled in great detail.

It makes little sense to argue about which type of model is "better"; they simply represent alternative approaches emphasizing different elements of the economy. Which model is more appropriate depends in large part upon the particular application. If you are dealing with climatological data which impacts predominantly on the production process, there is appeal for using I-O analysis. If, on the other hand, you are dealing with climatological data which impacts on demand, e.g., what kind of house is going to be demanded by households, then use of the type of model that emphasizes this relationship, the econometric model, would be logical.

It is important to understand that we are talking about the way in which these types of models have traditionally been oriented. There are ways in which I-O models can be modified to handle the demand side of the economy more completely. Similarly, econometric models can be formulated to include detailed characterizations of the production process. However, you will find that in dealing with most existing models, particularly at the regional level, the I-O models are strong in their modeling of production relationships and rather weak in their modeling of demand, while econometric models will be stronger in their modeling of demand relationships and rather weak in their analysis of production processes.

An Overview of Regional Econometric Models

The output data used in econometric models is organized differently than the output data one would typically use for I-O analysis. Since the econometric model primarily describes the sources of demand, the tendency is for econometric modelers to disaggregate output into categories like durable goods and nondurable goods and services or goods that respond to the same sources of demand. An I-O model, on the other hand, would disaggregate output into industry groups which have similar production processes and uses of inputs.

National econometric models are typically built around the aggregate expenditures GNP accounts (consumption, investment, government spending, and net exports where each of these major components is divided into several subcomponents). Regional econometric models have not in most cases used this system of accounts because accurate aggregate expenditures accounts are not available at the regional level.

Regional models have typically divided output into two types, basic and nonbasic. That is, total regional output is equal to total basic output plus total nonbasic output. Basic output is produced in response to exogenous demands, products produced in the region that are going to be exported out of the region, or gross exports. Nonbasic output is everything produced in the region in response to local demand. Nonbasic output is equal to total spending in the region (all types, consumption, investment, and government spending) minus imports.

This method of dividing regional output into basic and nonbasic components is taken from economic base analysis, and regional models have borrowed rather heavily from the economic base concept. Economic base theory claims that basic industries are the key to a region's growth. Inevitably a region is going to import many items, and the reason for the region being there and growing and prospering is the fact that it can produce something that it can export. The income generated by exports provides the money for needed imports and the spending to support nonbasic industries in the region. In economic base theory the growth of nonbasic industries is assumed to automatically follow growth in basic industries.

Although economic base models have been frequently and rightly criticized for placing too much emphasis on the role of basic industries in regional growth and thereby excluding other factors influencing growth, most regional models have placed special emphasis on exports - indicating that basic output is at least a major determinant if not the sole determinant of the rate of regional economic growth. This is true of both I-O models and econometric models. A frequent method of making long run forecasts with an I-O model is to expand the dimensions of the transactions matrix so that all of the local sources of final demand can be made endogenous. A set of forecasts of the export (basic) components of final demand is obtained in some way, and when these forecasts are introduced into the expanded I-O model a forecast of total output and output in each local (nonbasic) final demand category can be generated from the assumed levels of basic activity.

Regional econometric models almost without exception place special emphasis on basic industries. As noted earlier, aggregate expenditures product accounts at the regional level are usually not available. The types of output data commonly available at the regional level are a set of estimates of income originating (approximately equal to value added) by industry. That is output in the region is equal to the sum of the outputs of the complete set of different industries in the region. We have estimates of the output of the construction industry, the output of the manufacturing industry, or, if we have more detailed information, the output of the automobile industry in the region, and so forth. What is frequently done in econometric models, where we would like to concentrate on this concept of basic activities and nonbasic activities, is to characterize certain industries as those producing predominantly for exports. For instance, in Missouri the auto industry would be considered a basic industry because it produces predominantly for export. Other industries predominantly oriented toward local consumption or local investment are characterized as nonbasic industries. Essentially we end up dividing the industries in the regional economy into a subset which produces predominantly basic output and a subset which produces predominantly nonbasic or local output.

A regional econometric model would be built largely around the industries that are basic because it can be assumed that those sectors tend to predominate the fluctuations in the regional economy. A flow diagram and a set of equations showing how the level of output might be forecast in a typical regional econometric model are presented in Figure 2. In this prototype regional model, a set of P basic industries has been created. Equation 2.1 is the form of equation used to forecast output in the ith basic industry, using largely a set of exogenous national variables to forecast output from the basic industries. Normally some national econometric model would be used as the driving mechanism here. The national model would provide forecasts of how much the total demand for the product will be nationally and the demand for that product in the state or region is a function of the total demand nationwide. If one of these basic industries were affected by climate, that factor could be introduced in the output equation. Output would not only be a function of demand at the national level, but also of some climate factor. Both national demand and climate are variables that are exogenous, whose values are determined outside the regional econometric model. The fact that these variables are exogenous is indicated by the bar above them in equation 2.1.

The equations forecasting output in nonbasic industries, 2.2, have not been described, but will be later in the discussion.

The employment in each industry is simply a function of the output level in that industry. To produce something you have to hire workers, so output in basic and nonbasic industries determines the employment level

Figure 2. Demand Equations of a Typical Regional Econometric Model

2.1 $B_i = f_i(\overline{UO}_i, \overline{C}_i, \overline{P}_i, W_i)$

2.2 $L_j = f_j(PI, \overline{C}_j, \overline{P}_j, W_j, POP)$

2.3 $O = \sum_{i=1}^{P} O_i + \sum_{j=P+1}^{N} O_j$

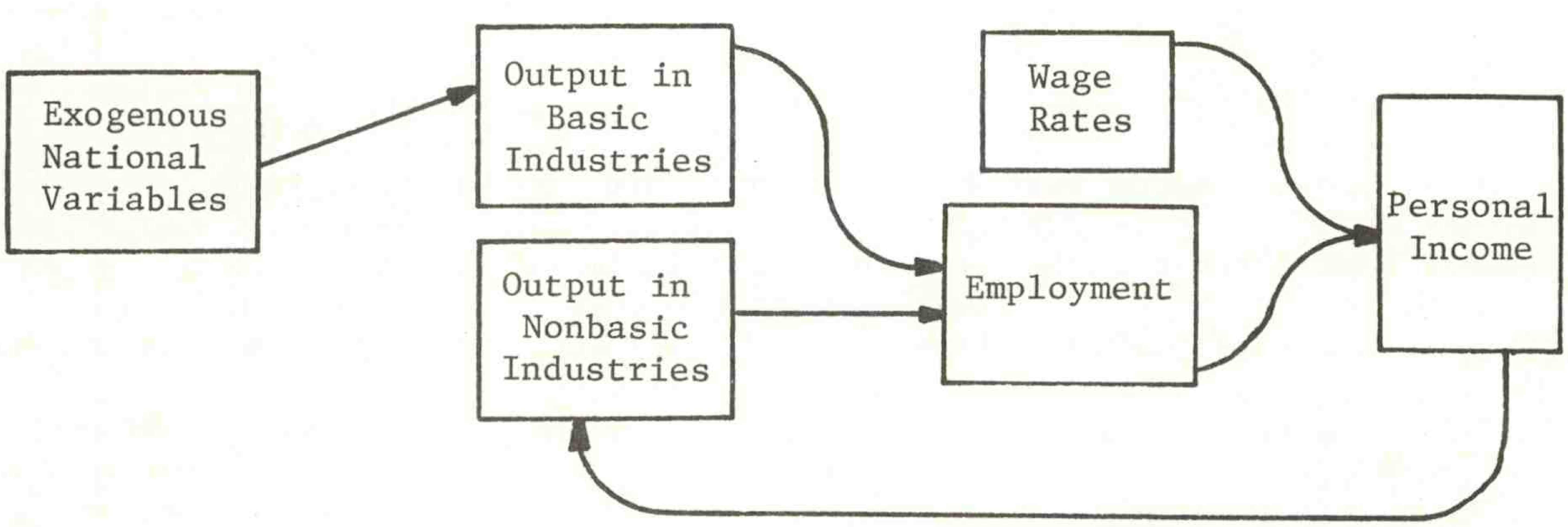
2.4 $E_i = f_k(O_i)$, $E_j = f_l(O_j)$

2.5 $PI = \sum_{i=1}^{P} E_i \cdot W_i + \sum_{j=P+1}^{N} E_j \cdot W_j$

Where

O = Total output of the region.
B_i= Output of the ith basic industry.
L_j= Output of the jth nonbasic or local industry.
E_i= Employment in the ith industry.
$\underline{PI}$= Personal Income for the region
$\overline{UO}_i$=U.S. output or other variables representing U.S. demand in the ith industry. (Exogenous)
$\overline{C}_i$= Climatological variables affecting the ith industry. (Exogenous)
$\overline{P}_i$= Relative prive of products produced by the ith industry. (Exogenous)
W_i= Relative wage of workers in the ith industry in the region.
POP=Total population of the region.

Demand Linkages of a Typical Regional Econometric Model



as shown in equation 2.4 This equation, incidentally, represents an inverse production function in which employment is a function of the output level.

Once a forecast of employment in each industry has been made, personal income, equation 2.5, can be forecast by simply multiplying the employment level in each industry by that industry's average wage rate and summing across all industries. This does not ignore all of the nonwage components of personal income. The level of the nonwage components of personal income is highly related to the level of wage income.

Personal income is the main factor determining the level of output in nonbasic industries, equation 2.2. From the diagram of Figure 2, we have a complete circular flow similar to that discussed previously. If there is more output in the economy, and therefore more people have been employed to produce this output, people will have more income and will then be able to buy more of the products produced by those sectors which provide services for the local economy. If there is less personal income there is not as much money to buy the output produced by nonbasic industry. For instance, the construction sector might be viewed as a sort of local investment (nonbasic) industry. If personal income in the region increases, all other things remaining the same, there will be a greater demand for housing. Again, climatological variables could be introduced directly into the output equation of any nonbasic industry.

The demand linkages just described are the most important driving force in virtually all regional models but there is another set of relationships which is of considerable importance and present in some detail in most regional models. These relationships may be loosely referred to as the labor supply linkages and they are outlined in flow chart and equation form in Figure 3.

The amount of detail in these linkages varies greatly from regional model to model. It is often assumed that a forecast of population can be obtained from some exogenous source, as in the case of our prototype. If you know the level of population, laborforce can be forecast straightforwardly, equation 3.1. Laborforce and the level of total employment together serve to determine the level of unemployment. The laborforce is the supply of labor, the employment level the demand for labor, and when supply is greater than demand there is unemployment. Thus in equation 3.2 unemployment is determined as the residual of laborforce minus employment. The unemployment level might feed back to affect the size of the laborforce if many people are unemployed, become discouraged workers and drop out of the laborforce. Therefore, unemployment as well as population is included in the laborforce equation.

The level of wage rates in various industries in the region is likely to be affected by the unemployment level. When unemployment is high this is likely to depress wages in the region. In addition, wage rates nationally have a strong influence on regional wage rates. Thus wage rates, equation 3.3, are a negative function of the regional unemployment level and a positive function of the U.S. wage rate for the industry. The wage rates are expected to feed back and influence the output levels in basic industries (equation 2.1). The theory is that, with other things the same, high wages in the region relative to wages nationwide will tend to reduce the region's competitiveness and cause its market share in those

Figure 3. Labor Supply Equations of a Typical Regional Econometric Model

3.1 $LF = f_m(\overline{POP}, UN)$

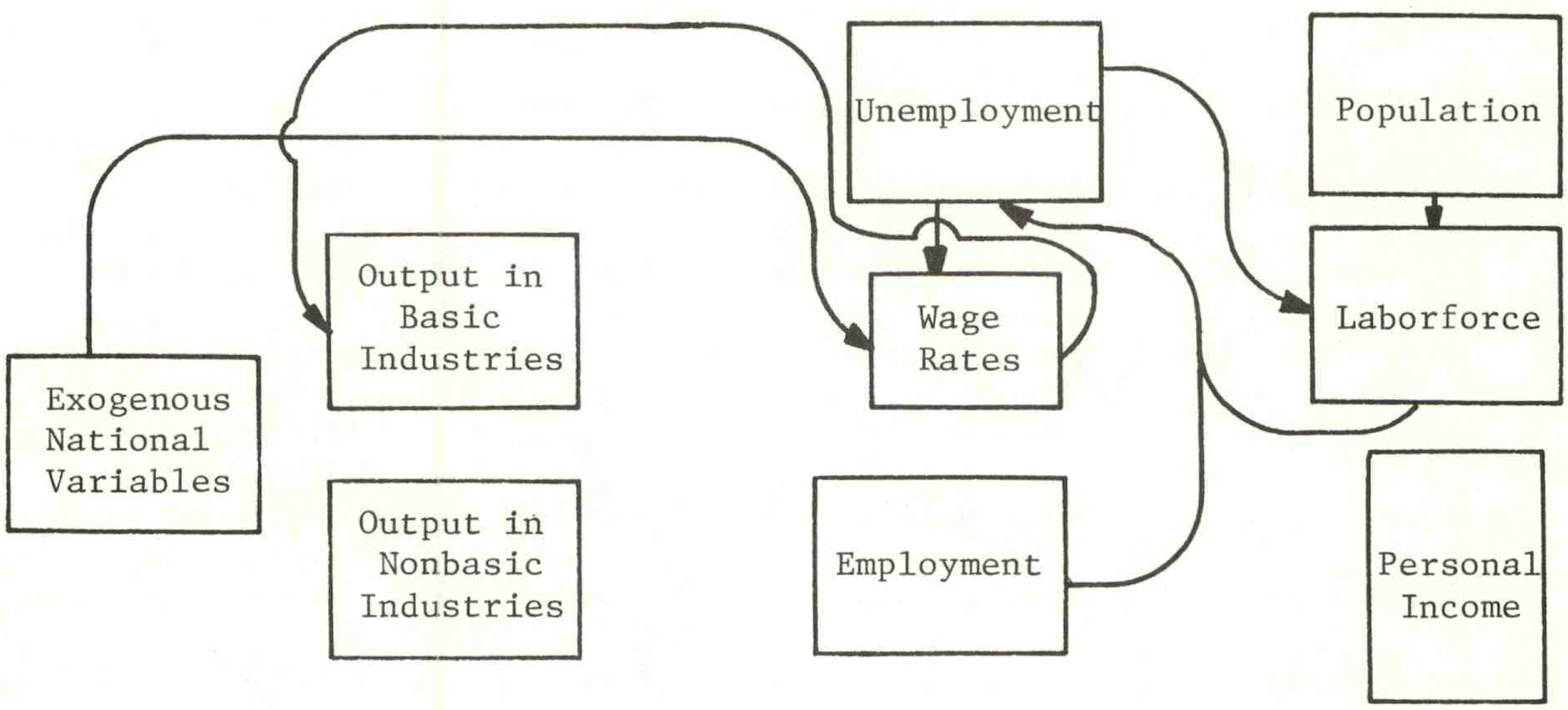
3.2 $UN = LF - EMP$

3.3 $W_i = f_n(UW_i, UN)$

Where

$\overline{POP}$ = Total population of the region.
LF = Total laborforce of the region.
UN = Total unemployment in the region.
W_i = Wage rate in the ith industry in the region.
UW_i = Wage rate in the ith industry nationwide.

Labor Supply Linkages of a Typical Regional Econometric Model



basic industries to decline. The wage rate equations also interact with the demand linkages of the model through their effect upon personal income. Lower wage rates mean less personal income which affects nonbasic output and so on.

Although most regional econometric models are driven primarily by equations to forecast output in basic industries, the previous discussion indicates that this type of model is capable of allowing for other sources of growth. In fact other diverse factors influencing the rate of growth could and have been included in some regional models. For instance, population could be made endogenous to the model under the assumption that the migration of people is influenced by economic opportunity. Under this assumption the rate of population growth in a region would be a positive function of wage rates or per capita income or a negative function of the unemployment level relative to the United States. Also it is reasonable to include prices in the output equations of the model. The quantity of goods demanded in both basic and nonbasic industries should be negatively affected by increases in the real price of the goods in question. Prices can be assumed to be determined exogenously at the national level, as in equations 2.1 and 2.2 of the prototype model, or they can be made endogenous by allowing prices in the region to be influenced by the unemployment rate. A very healthy, thriving economy where there is little unemployment would be expected to experience price increases that are somewhat more rapid than those experienced by the rest of the country, and this in turn should eventually tend to depress the region's ability to sell goods for export.

This description has certainly not been exhaustive of all of the types of relationships that have been or could be included in regional econometric models, but it has, I hope, given a feel for the way in which they are structured. The data required to forecast a model like the prototype model are relatively easy to obtain. The output data are not directly available, but these output by industry data can be generated rather easily with a mechanical technique known as the Kendrick-Jaycox method (Kendrick and Jaycox, 1965), using personal income data available from the Bureau of Economic Analysis. Employment and unemployment data are available in fairly good detail from state departments of economic security or employment security. Portions of the wage and personal income data may require some manipulation, but essentially comes from unemployment insurance files available from the state employment offices and the Bureau of Economic Analysis.

The most appropriate method of incorporating climatological data into one of these regional models would be to simply incorporate the climatological variables directly into the equation for whatever variables are felt to be climate influenced and reestimate those equations. Effects of these climate factors could be measured by simply comparing the results of alternative simulations with differing climate assumptions.

Before leaving the discussion of regional econometric models, let me make just a few comments about where regional modeling techniques seem to be heading. A lot of the emphasis in recent models has been on increasing the level of detail in which some key export industries are modeled. For instance there is a regional econometric model for the area around Tucson, Arizona (Taylor, 1976), which uses a set of eleven equations to forecast copper output. This level of detail was used because copper is the largest and most volatile basic industry in the Tucson area. The idea is once again that export industries are very important in the dynamics of a region's economy, and if you can do a good job of forecasting developments in a region's major export industries you will have pretty adequately characterized the region's economy. It may also be suggested that in many cases the export industries will also be key energy using industries and those that are more likely to be adversely affected by climatic fluctuations. Among the nonbasic industries the one most likely to be affected by climate would be construction. Construction is also a sector to which regional econometric models are beginning to devote more attention, and if regional econometric models are going to progress in their accuracy they must devote a lot of attention to this sector because it is the most volatile nonbasic industry. There are an increasing number of models which utilize this key industry approach. They may be aggregated and simplistic in their view of many of the nonbasic sectors, but they focus in with a great deal of energy, time and effort spent in trying to forecast output in these key industries as accurately as possible.

Others of this type are the models the Missouri Public Service Commission will be building in the next two years. These regional models will be used ultimately to forecast electric power demand for each of the major privately owned electric utilities of the state. The focus, as I understand it, is going to be on the key industries that are intensive power users. In a lot of other areas there may not be a tremendous amount of detail. For certain types of climatological research it would seem to be very appropriate to plug into that type of model which emphasizes industries which are intensive energy users.

There are several references from the Bibliography of Regional Econometric Models that I think would have particular merit for anyone who would like to do additional reading in the area. First, the Tayloe Murphy Institute at the University of Virginia has been putting out a periodic bibliography of state and regional models which includes information on the use and maintenance of each model (Knapp, Jerome, and Windsor, 1978). Checking that list should give a good idea of whether there is any model available and in use in the state or region with which you are concerned. The article by Adams, Brooking, and Glickman (1975) is very readable, outlining a model that perhaps represents the mainstream of the way regional econometric models have been built in the past. The article by Ballard (1978) is a good source for looking at the possibilities of using a multi-regional model. Klein's article, "The Specification of Regional Econometric Models" (1969) is a good source for a perspective on the origin of the whole idea of building regional models. The modeling philosophy proposed in his article has been frequently cited and at least occasionally used by a lot of builders of regional models since that time. Ratajczak's article (1973-74) is good for giving a perspective on some of the problems caused by data limitations and the modifications in modeling techniques that may be used to overcome them.

Using Climatological Data with I-O and Econometric Models

There is no correct answer to the question "Should I use an I-O model or an econometric model as a vehicle for forecasting economic impacts of climate?" However, I do think there are some considerations which can serve as useful guidelines in evaluating the use of alternative models.

First, unless you are willing to construct an I-O or econometric model from scratch, availability of a relatively current model that is being maintained on a computer available for use is a very important factor. Regardless of the type of model used, many types of assessment of climatological impact would require extensive simulation and therefore necessitate access to the full model in computerized form. In many cases you will find that there are no alternative models.

Second, one should be guided by the specific application required. As we noted earlier, I-O models tend to provide their greatest detail in their description of the production process while econometric models place more emphasis on demand relationships. Therefore, the I-O model would seem an appropriate vehicle for evaluating the impact of climate on the production process in a particular industry. On the other hand an econometric model might be more appropriate if we are evaluating a climatic occurrence whose direct impact is on demand, for instance a colder than normal winter would affect the demand for electricity.

Third, attention must be paid to specific weaknesses of the two modeling techniques. The assumption of the input-output model that the technical coefficients are constant is a very unrealistic one when there are sharp changes in relative prices. The I-O model can be modified to allow for the effects of price changes, but an econometric model is able to accommodate price changes more readily and in fact will typically be constructed to automatically include and evaluate the effects of price changes on the economy. This is a factor which should be considered when evaluating climate influences in areas such as energy use where prices have been changing and climatic changes themselves could conceivably change prices.

Regional econometric models cannot provide as detailed a set of coefficients as can be derived from I-O models because they estimate coefficients from statistical correlations using historic data. It is probably unrealistic to assume that the industry by industry effects of a particular climatic event could be estimated at the same level of detail with an econometric model as with an I-O model.

Finally, there may be some cases in which it may be possible and appropriate to link a regional econometric model and a regional I-O model together. Recall that in forecasting with an I-O model you have to start with forecasts of final demand levels, and based on these the interaction of industries in the regional economy is estimated by the coefficients of the I-O model. One means of obtaining these final demand estimates is to simply take them from an econometric model. The I-O model could then be used to provide estimates of output in each industry based on these estimates of final demand from the econometric model. This type of hybrid model has been tried with considerable success at the national level but is only in the exploratory stage at the state and regional level. One problem in connecting I-O and econometric models at the state level is that regional econometric models usually do not contain estimates of final demand by category such as local household consumption. These models normally provide estimates only of total value added by industry. This should not be an insurmountable obstacle to the construction of a hybrid model, however.

The decision of whether to use an input-output model or a regional econometric model or whether to go through the rather extensive effort required to construct a hybrid of the two is one which should probably be approached on a case by case basis.

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IV. ECONOMETRIC MODELING: STATE-OF-THE-ART FOR THE U.S. AGRICULTURAL INDUSTRY

Abner Womack

The purpose of this paper is to describe in general terms the basic structure of econometric models that have been and currently are being developed to quantify the U.S. agricultural industry. This work follows a long tradition that began with the first simultaneous investigations of the grains and livestock industries in the early 1950's.[1] Prior to this period most analysis was conducted via single equations with primary focus on variables likely to have the greatest influence on prices. Economists tend to refer to these equation specifications as direct estimation of the "reduced form system." While these equations were useful in outlook and policy analysis, they were severely constrained to micro components of the industry. For example, equations to depict coarse grain prices were found to be strongly correlated to own production, high protein prices, livestock prices and livestock numbers. In order to derive a price estimate all variables on the right side of the equation were treated as independent or given. Recognition that livestock prices and quantities were dependent on grain prices and vice versa led to models that attempted to estimate simultaneously grain prices, livestock quantities and livestock prices.[2]

A large body of literature has developed over time that examines properties of estimators in simultaneous systems and likewise a large number of modeling activities have evolved that are aimed at quantifying either specific industries or integrated sectors of the U.S. feedgrain-livestock economy.[3]

In order to review the current state-of-the-art, the following general areas will be discussed: 1) flow charts that depict the major components of the industry with corresponding linkages, 2) a brief statement of equation specifications as derived from economic theory, 3) graphical examples of interactions in the soybean, wheat and corn industries, and 4) measures of weather-related impacts on the U.S. economy.

Flow Charts

The simultaneous linkage of the U.S. agricultural industry is depicted by Figure 1. Each block represents a major industry and most model development is initiated in this pattern. Arrows indicate direct linkages between major sectors - the feedgrains model generates corn, oat, sorghum, and barley prices; it in turn utilizes soybean, wheat, soybean meal, and livestock prices and livestock numbers. The livestock sector is linked via retail prices and input prices originating in the crops sector.

Figure 2 depicts the basic nature of the feedgrains industry. Most models address the supply and utilization identity. The left portion or set of blocks represents major supply components - the right side major demand components. Variables indicated in brackets are shift or explanatory variables. For example, planted acreage, lower left-hand block, is functionally related to government policy variables, substitute prices and lagged market price as indicated by the broken line from farm price.

FIGURE 1

FORECAST SUPPORT GROUP (ANNUAL MODELS)
PRICE LINKAGE MECHANISM

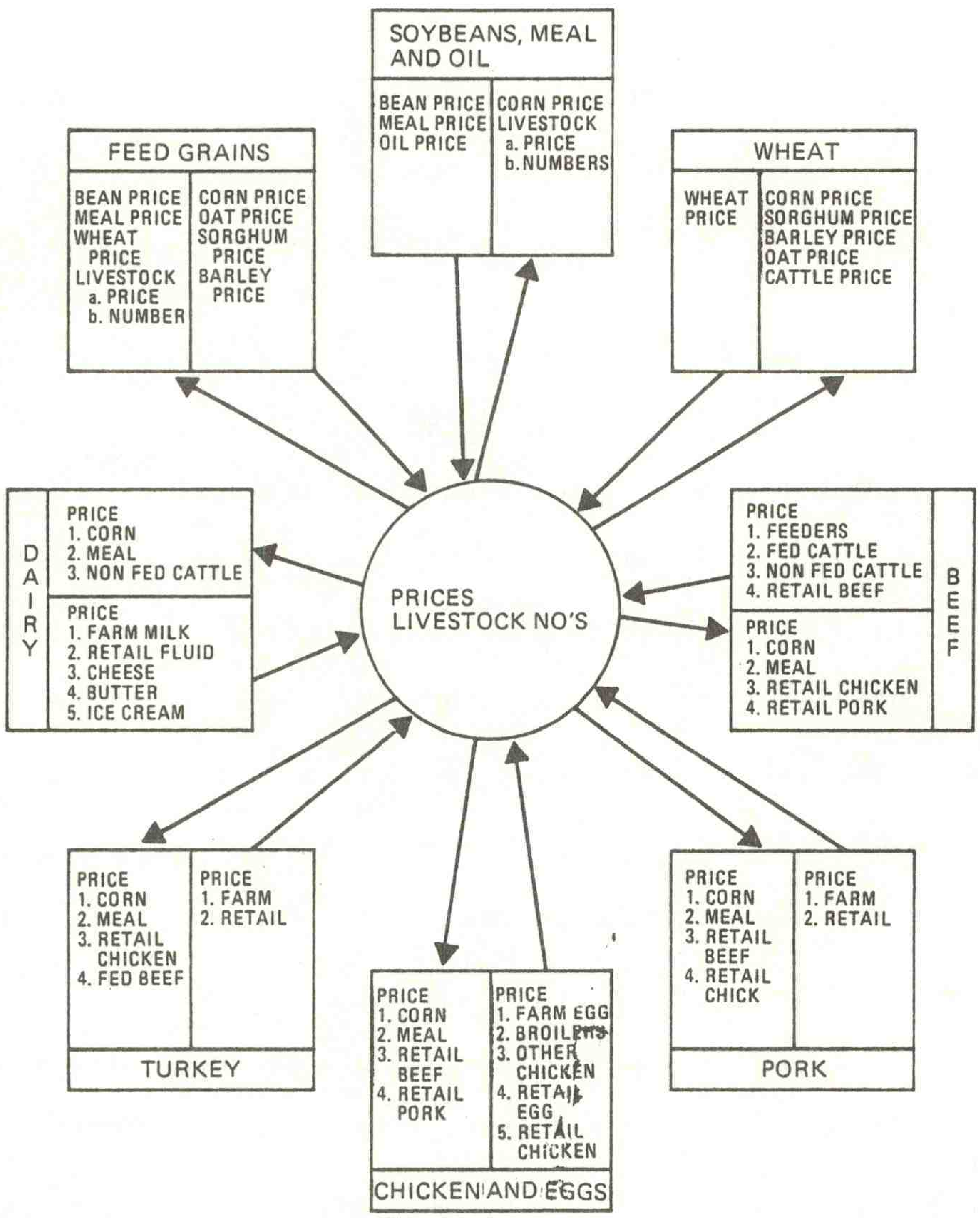
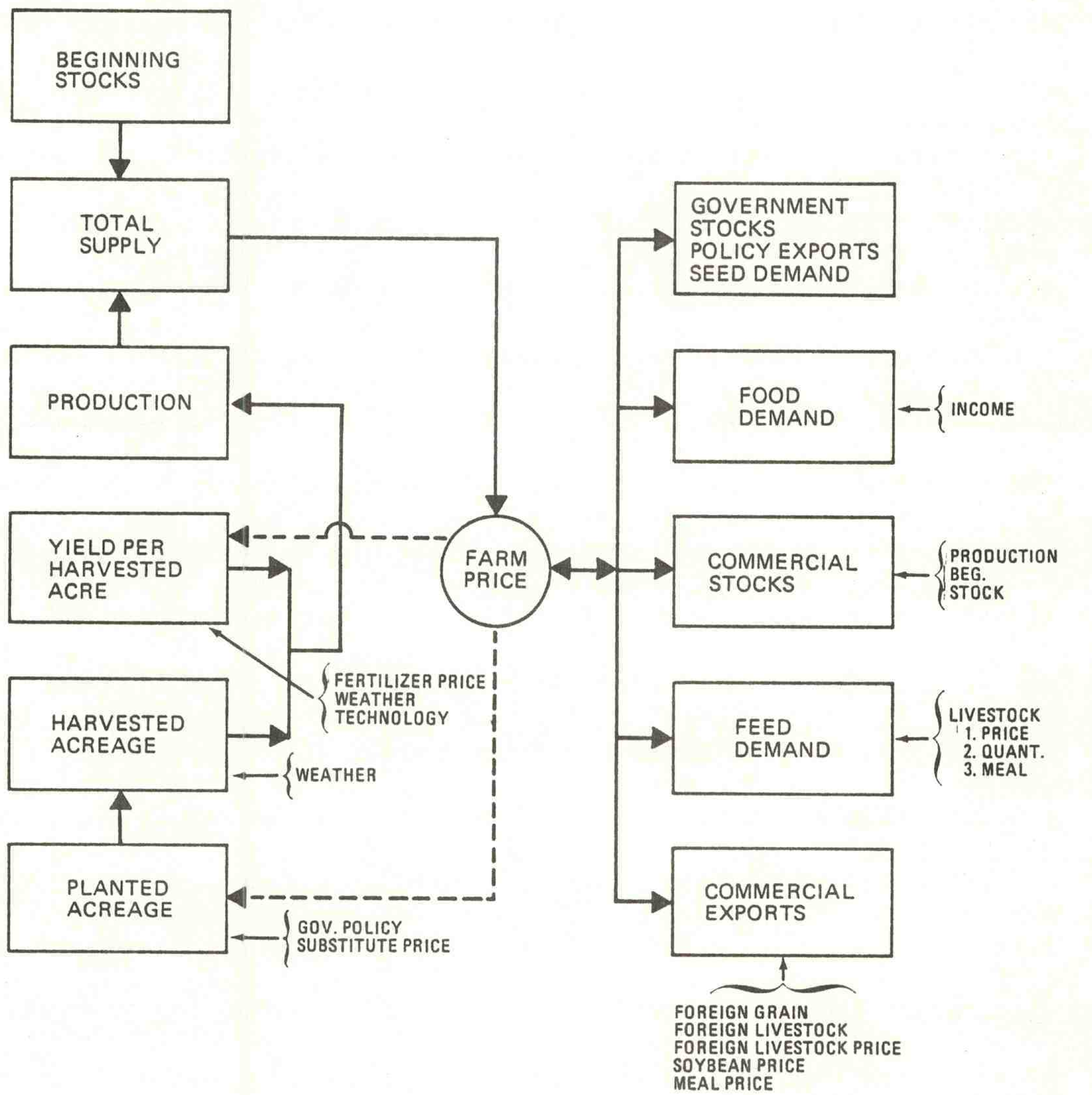


FIGURE 2

FEED GRAINS (ANNUAL MODEL)
CORN, SORGHUM, OATS AND BARLEY



ENDOGENOUS VARIABLES

			PLANTED ACRES	HARVESTED ACRES	YIELD
1. CORN PRICE	7. OATS FED	13. OAT FOOD	18. CORN	21. CORN	25. CORN
2. SORGHUM PRICE	8. BARLEY FED	14. CORN FOOD	19. SORGHUM	22. SORGHUM	26. SORGHUM
3. OAT PRICE	9. CORN STOCKS	15. BARLEY FOOD	20. OATS	23. OATS	27. OATS
4. BARLEY PRICE	10. SORGHUM STOCKS	16. CORN EXPORTS	21. BARLEY	24. BARLEY	28. BARLEY
5. CORN FED	11. OAT STOCKS	17. SORGHUM EXPORTS			
6. SORGHUM FED	12. BARLEY STOCKS				

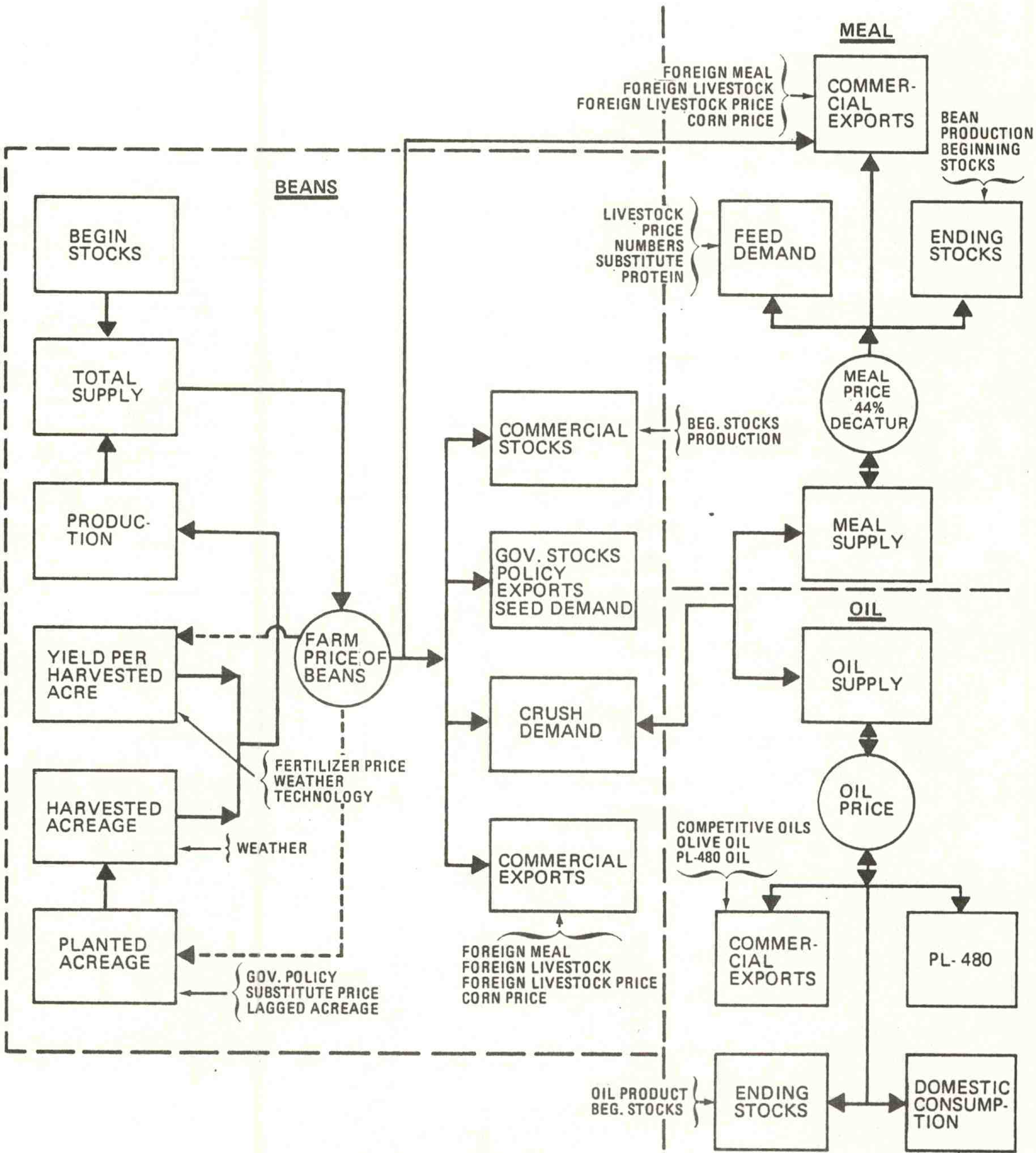
Feed demand is functionally related to livestock prices and quantities, own price and soybean meal price. Exports are explained by an excess demand formulation which quantifies the U.S. market to the international arena via foreign grain production, livestock numbers, livestock prices, dollar exchange rate and U.S. prices of soybeans and soybean meal.

Figures 3 and 4 represent the soybean and wheat sectors - the same interpretation as given in the feed sector is implied. Note, however, that the soybean industry is somewhat more complex in that two additional sectors are derived from soybean crush which produces meal and oil. Simultaneous linkage of this model is discussed in greater detail later.

The livestock industry is represented by Figures 5 through 9. Each industry has a similar structure, hence this discussion is limited to the specification of the pork sector. Three blocks reflect two markets in this industry. Farm supply (left block) intersects wholesale demand (process market, middle block) producing the farm price of hogs and sows. Process or wholesale markets convert animals from live weight to slaughter pounds, thus creating a supply into the final market (block three) and a corresponding retail price. Production incentives in the farm sector are based on expected future prices or profitability. These expectations are often proxied by a series of price lags as indicated by variables explaining the size of the pig crop, sows slaughtered and total hog supply. These lagged prices normally have larger weights on most recent observations, and the length of the lag generally conforms to the biological nature of production. Models estimated in this formulation will reflect the cyclical nature of the livestock industry. The current situation with relatively large pork supplies, low prices and

FIGURE 3

SOYBEAN-MEAL AND OIL (ANNUAL MODEL)

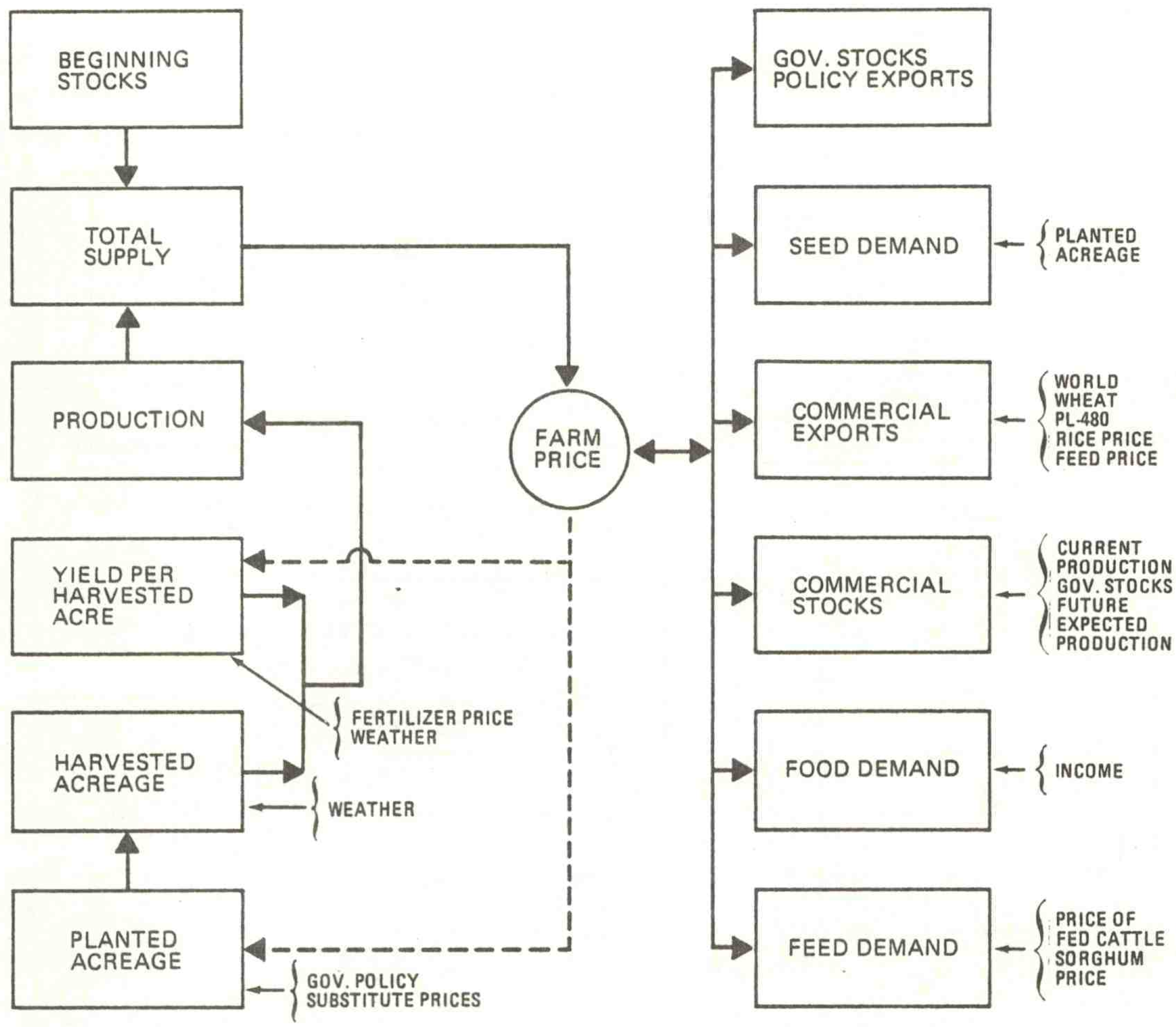


ENDOGENOUS VARIABLES

29. MEAL FED
30. MEAL EXPORTS
31. OIL DEMAND
32. OIL PRICE
33. OIL EXPORTS
34. BEANS CRUSHED
35. BEAN PRICE
36. PLANTED ACREAGE
37. HARVESTED ACREAGE
38. BEAN PRODUCTION
39. BEAN STOCKS
40. FEED & SEED BEANS
41. MEAL PRODUCTION
42. OIL PRODUCTION
43. MEAL PRICE
44. OIL STOCKS
45. REGIONAL ACREAGE
46. SOYBEAN MARGIN

FIGURE 4

WHEAT SECTOR (ANNUAL MODEL)

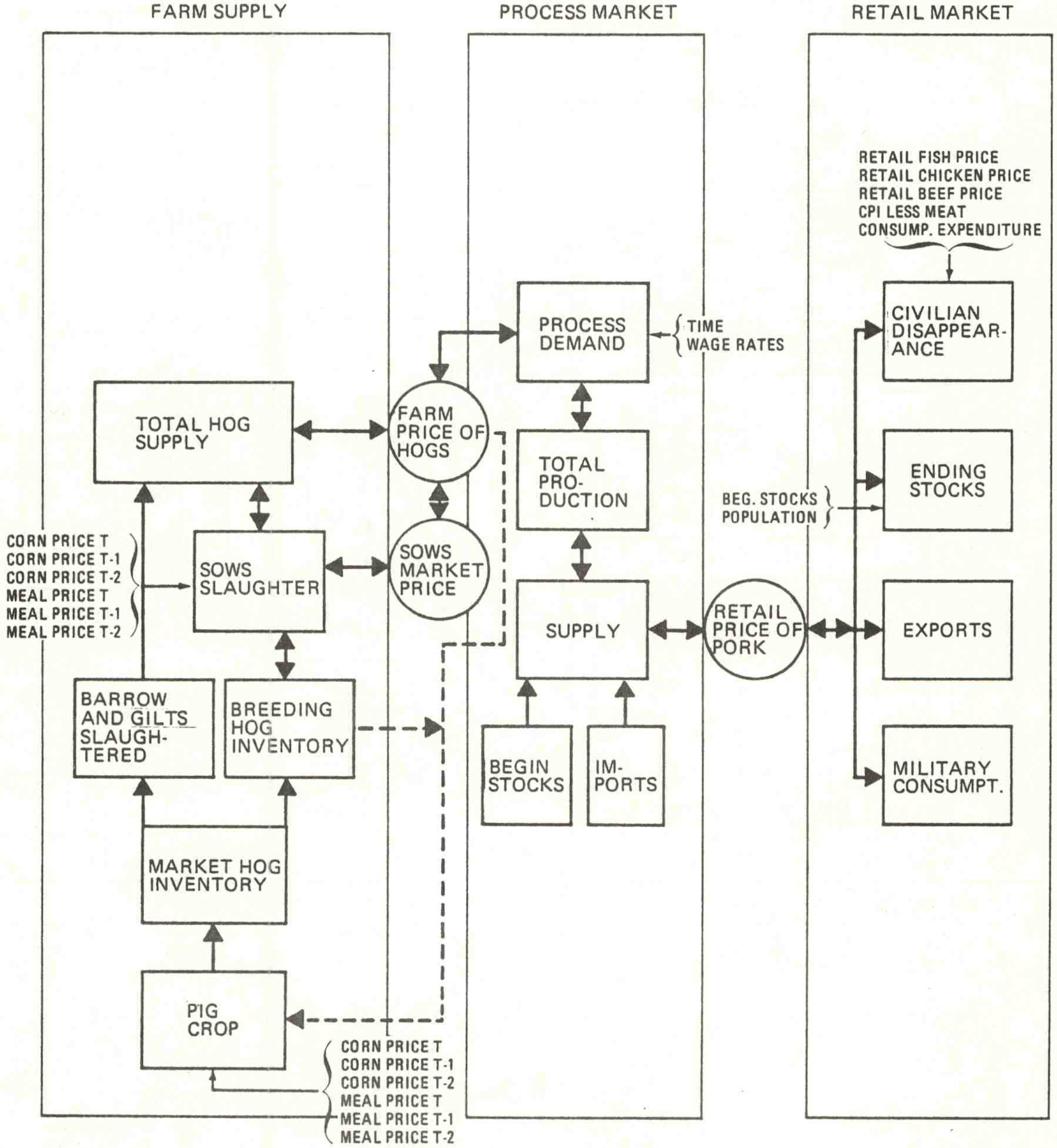


ENDOGENOUS VARIABLES

47. WHEAT FOOD
48. WHEAT FED
49. WHEAT SEED
50. COMMER EXPORTS
51. COMMER STOCKS
52. WINTER WHEAT ACRES
53. SPRING WHEAT ACRES
54. WHEAT PRODUCTION
55. WHEAT FARM PRICE

FIGURE 5

PORK SECTOR (ANNUAL MODEL)

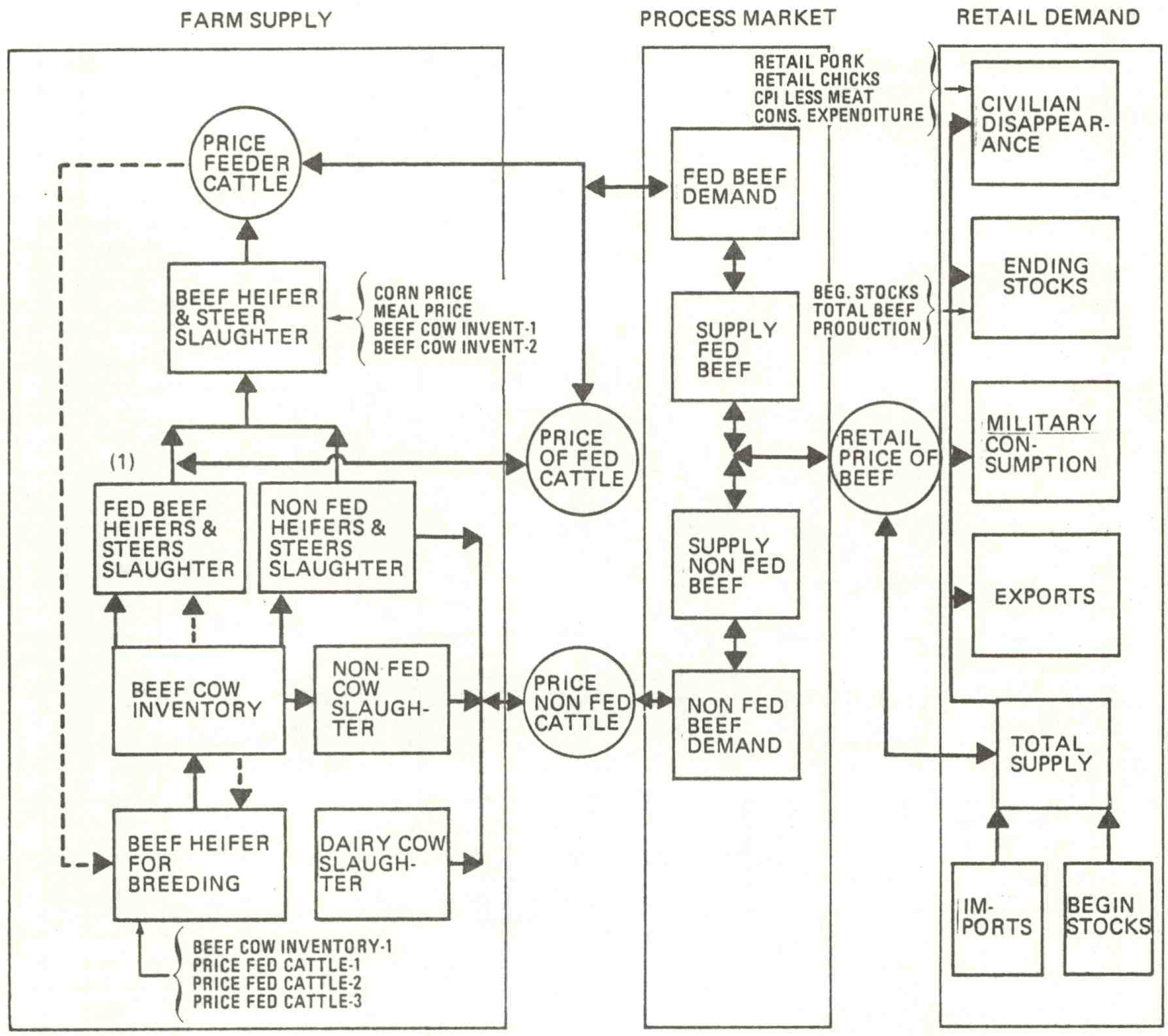


ENDOGENOUS VARIABLES

56. RETAIL PORK PRICE
57. SOWS MARKET PRICE
58. SOWS SLAUGHTERED
59. PIGS FOR BREEDING
60. PIG CROP
61. BARROWS AND GILTS SLAUGHTERED
62. PORK PRODUCTION
63. ENDING STOCKS
64. BARROW & GUILT PRICE
65. BREEDING HOG INVENTORY
66. TOTAL PIG SLAUGHTERED
67. MARKET HOGS
68. PORK SUPPLY
69. CIVILIAN DISAPPEARANCE

FIGURE 6

BEEF SECTOR (ANNUAL MODEL)



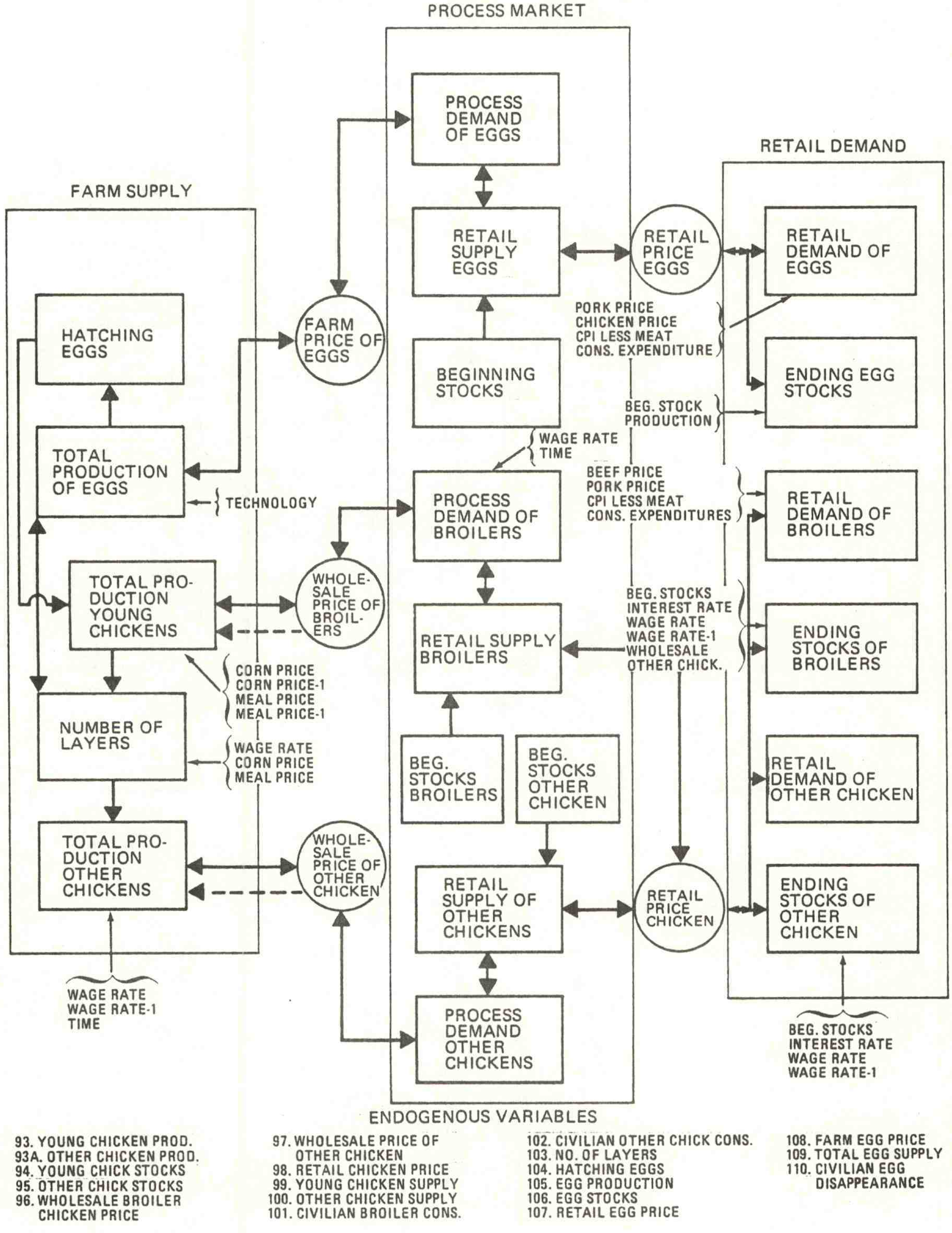
(1) CORN PRICE
MEAL PRICE
BEEF COW INVENT-2
BEEF COW INVENT-3

ENDOGENOUS VARIABLES

70. RETAIL BEEF PRICE
71. FED BEEF PROD.
72. FED BEEF HEIFER AND STEER SLAUGHTER
73. NON-FED BEEF COW SLAUGHTER
74. BEEF COW INVENT.
75. FEEDER COW PRICE
76. BEEF HEIFER AND STEER SLAUGHTER
77. FED CATTLE PRICE
78. HEIFERS FOR BREEDING
79. NON FED PRODUCTION
80. NON FED SLAUGHTER
81. NON FED SUPPLY
82. FED SUPPLY
83. TOTAL BEEF SUPPLY
84. CIVILIAN USE BEEF
85. AVE. WGT. FED CATTLE
86. AVE. WGT. NON FED CATTLE
87. ENDING BEEF STOCKS
88. CALF CROP
89. VEAL PRODUCTION
90. FARM CALF PRICE
91. CALF SLAUGHTER
92. VEAL PRICE

FIGURE 7

CHICKEN AND EGGS SECTOR (ANNUAL MODEL)

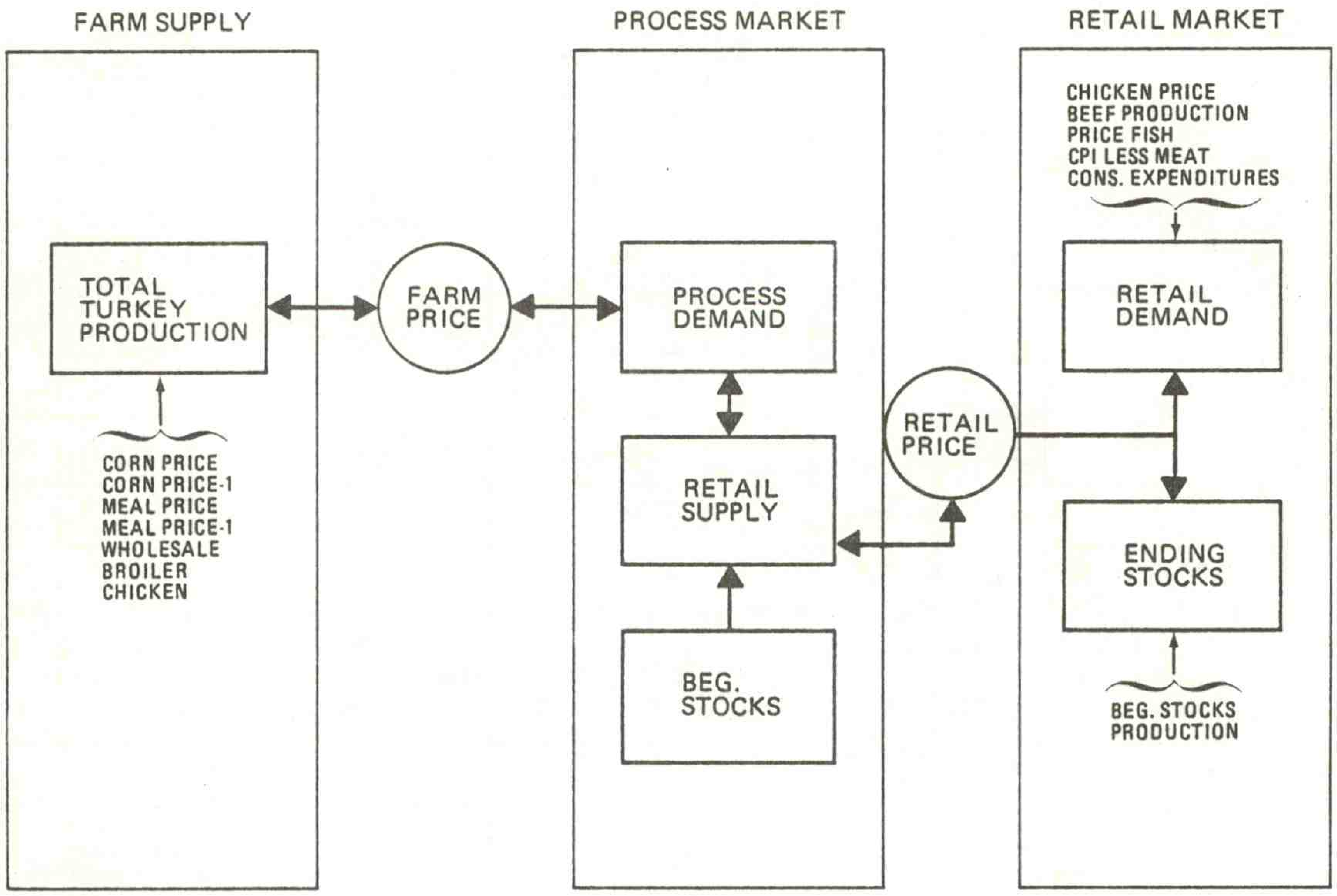


ENDOGENOUS VARIABLES

93. YOUNG CHICKEN PROD.
93A. OTHER CHICKEN PROD.
94. YOUNG CHICK STOCKS
95. OTHER CHICK STOCKS
96. WHOLESALE BROILER CHICKEN PRICE
97. WHOLESALE PRICE OF OTHER CHICKEN
98. RETAIL CHICKEN PRICE
99. YOUNG CHICKEN SUPPLY
100. OTHER CHICKEN SUPPLY
101. CIVILIAN BROILER CONS.
102. CIVILIAN OTHER CHICK CONS.
103. NO. OF LAYERS
104. HATCHING EGGS
105. EGG PRODUCTION
106. EGG STOCKS
107. RETAIL EGG PRICE
108. FARM EGG PRICE
109. TOTAL EGG SUPPLY
110. CIVILIAN EGG DISAPPEARANCE

FIGURE 8

TURKEY SECTOR (ANNUAL MODEL)

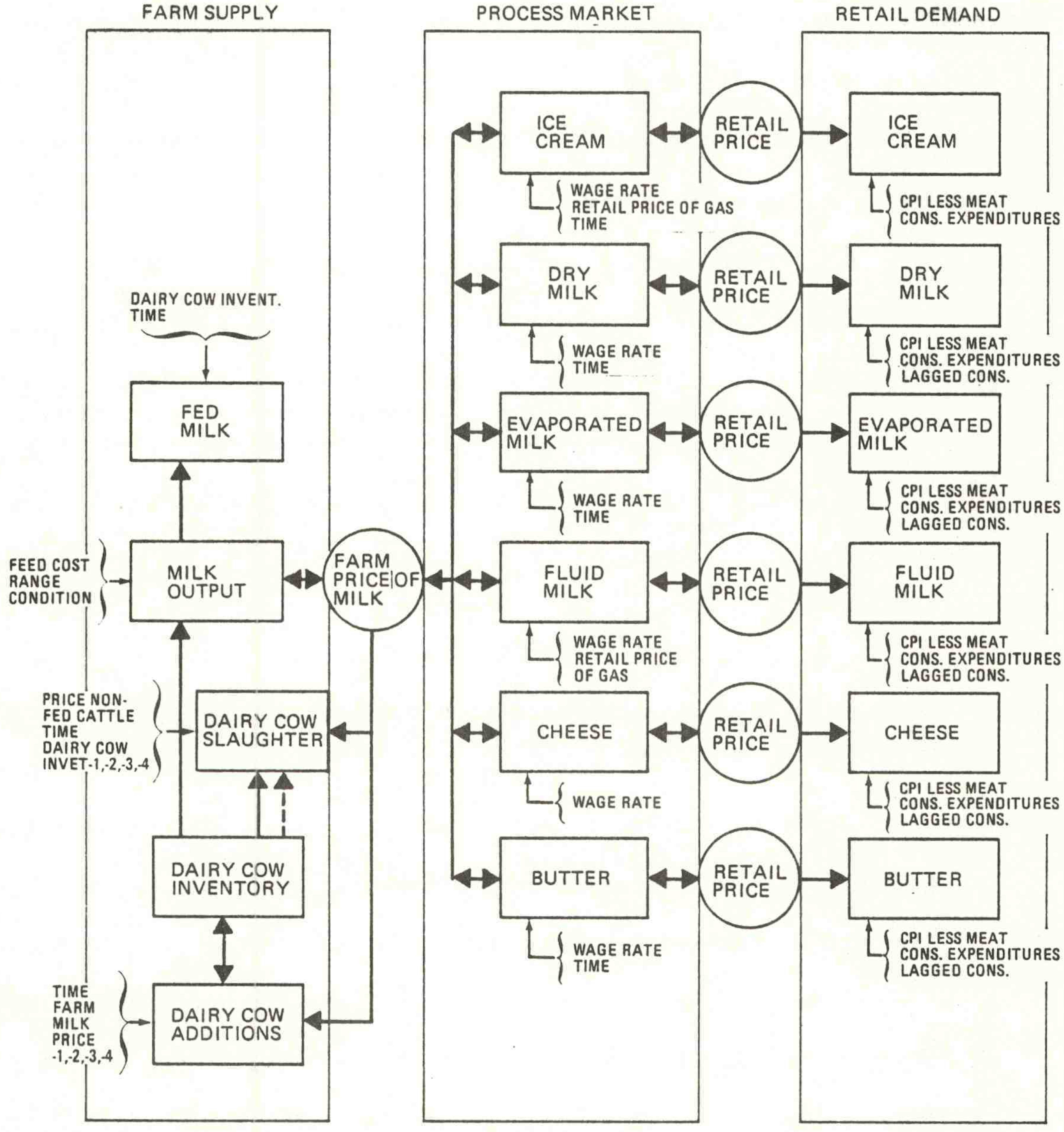


ENDOGENOUS VARIABLES

111. TOTAL PRODUCTION OF TURKEYS
112. ENDING STOCKS OF TURKEYS
113. RETAIL TURKEY PRICE
114. FARM PRICE OF TURKEY
115. TOTAL SUPPLY OF TURKEY
116. CIVILIAN USE OF TURKEYS

FIGURE 9

DAIRY SECTOR (ANNUAL MODEL)



ENDOGENOUS VARIABLES

117. DAIRY COW SLAUGHTER
118. DAIRY COW ADDITIONS
119. MILK FED TO CALVES
120. TOTAL MILK OUTPUT
121. FARM PRICE OF MILK
122. ICE CREAM CONS.
123. DRY WHOLE MILK CONS.
124. EVAP. MILK CONS.
125. FLUID MILK CONS.
126. CHEESE CONS.
127. BUTTER CONS.
128. EVAPORATED MILK PRICE
129. FLUID MILK PRICE
130. ICE CREAM PRICE
131. DRY MILK PRICE
132. BUTTER PRICE
133. CHEESE PRICE
134. DAIRY COW INVENT
135. DAIRY PRICE INDEX
136. FARM PRICE OF MEAT ANIMALS AND EGGS
137. INDEX OF LIVESTOCK AND MILK OUPUT
138. RETAIL PRICE INDEX FOR RETAIL MEAT AT HOME

higher corn prices will result in changes in producer expectations. This profit squeeze is imbedded in the relative price of corn, soybean meal and pork prices. Thus equations specified in this manner will reflect slaughter of inventories and a slow-down in pork production. A smaller herd reflects a "leftward shift" in supply, but the biological nature of production continues, reflecting a cyclical pattern in supply but with a reduced inventory.

Obviously there is a direct link between weather patterns and the livestock cycle. Good or above-normal weather implies higher yield, greener pastures and lower feed prices - a stimulus to profit expectations and corresponding pork supplies and vice versa. Likewise the energy sector will have a direct effect in all three of the indicated blocks or markets.

General Model Specification

As indicated in the above section there are several market activities that must be specified, estimated and solved in a simultaneous-recursive system in order to capture the basic structure of the agricultural industry. In livestock we have discussed retail markets, wholesale market and farm supply. The grains industry, as indicated, is composed of three major sectors - domestic supply, domestic demand, and export demand. These markets are imbedded in the overall general economy, thus reacting to national-international shifts in income, inflation rates, energy prices, exchange rates, interest rates, etc. These several, but distinct, areas of economic theory are discussed in this section to lay groundwork for general equation specification.

Livestock Equations

The livestock component of the forecasting system consists of models which describe the markets for beef, pork, chicken, turkey, eggs, and dairy. This section describes the prototype equations governing model behavior. The general form of each equation is given, together with a theoretical rationale and examples for the beef and pork models.

Within each commodity model are retail and farm level demand, investment demand, supply of both live animals and carcass meat, and product stocks equations. In addition to these are technical conversion relations, inventory accounting equations and supply-demand identities. Each of these equation forms will be discussed in turn.

Notational Convention

y and y' are output commodities
x is an input (e.g., feed) commodity
Ny is the number of y slaughtered
Qy is carcass weight of y
Py and Py' are the prices of y and y'
Pyr and Pyf are the prices of y at retail and at the farm
K is a capital stock variable (e.g., breeding herds)
ESY is the ending stock of commodity y
DPIC is per capita disposable personal income
POP is population
WR is the wage rate in the processing industry
Pk is the price of the capital input (e.g., breeding heifers)

Retail Demand Equations

The retail demand equations are expressed in price-dependent form. They contain prices of both substitute and complement goods. The form of the retail demand equation is:

(1) $Pyr = DPIC * f(Qy/POP, Pyr/DPIC)$.

The partial derivative with respect to the first argument is negative and for the second is positive if y' substitutes for y and negative if they are complements.

All prices and income are nominal variables. Equations of this form describe the retail price of beef, pork, poultry, and veal. The quantity variable in these equations is typically the civilian disappearance variable - the final quantity consumed.

Farm Demand Equations

The farm demand equation relates the farm price to the retail price, processing wage rates, and the numbers of animals slaughtered. This is a derived demand equation in which the wage rate and farm prices of live animals are input prices, the retail price of meat is the output price, and the slaughter number measures the amount of the input demanded. The functional form is:

(2) $Pyf = Pyr * f(ny, WR/Py_r)$.

The partial derivative with respect to quantity should be negative and with respect to the second argument positive. There is no direct income effect, since that is transmitted through the retail price variable.

This is the rationale for the prices of sows, barrows and gilts, fed cattle, feeder cattle, nonfed cattle and slaughter calves.

Investment Demand Equations

The livestock industry is somewhat unique in that the output of the production process can also augment the capital stock for that production process.

The investment demand equations are quantity-dependent, with the capital stock, capital price, and product and other input prices as independent variables. The functional form (recall that investment is the time rate of change in the capital stock) is:

(3) $\frac{dK}{dt} = f(K, Pk, \frac{Py}{Px})$

The partial derivatives with respect to the first two arguments should be negative and with respect to the third positive. The larger the capital stock and the higher the price of the capital good, the less investment (replacement) should occur. A relatively higher product price should increase investment.

This equation characterizes sow slaughter, pigs for breeding, nonfed beef cow slaughter, and beef heifers for breeding. In the equations where it occurs, Px is the feed price variable. Pk and Py may be the same variable but with different time subscripts. This also is a derived demand equation, derived from the farm production process which provides animals for slaughter. On the dis-investment side of this relationship, the equation explains the supply of lower quality (nonfed) slaughter animals.

Farm Supply Equations

The output of the production process is a function of the level of the capital stock and the price of the output relative to the price of the variable inputs. This is of the form:

(4) $Ny = f(k, Py/Px)$.

Both partial derivatives are expected to be positive. Here, the breeding herd is the capital stock, feed is the variable input, and animals for slaughter are the output. This equation form describes the pig crop, barrow and gilt slaughter, beef heifer and steer slaughter, fed beef heifer and steer slaughter, and calf crop and veal production relationships. The price variables were suppressed in the calf crop equation.

Retail Supply Equations

The supply into the retail market is the result of a production process which converts live animals into carcass weight of meat using labor and fixed capital. Because aggregate slaughter numbers are largely determined prior to the packing plant decision process, this supply equation contains the quantity of live animals rather than the price of the live animals in its form. In particular, the form of this equation is:

(5) $Qy = f(Ny, Pyr/WR)$.

The dairy sector has several retail products which are produced from a homogeneous input (milk). The model differentiates between and among them. This is in contrast with, for example, the homogeneous output of beef from the differentiated inputs (fed steers versus cull cows).

In addition, a number of other relations in the model simply convert quantities from one form into another unaffected by price. Mathematically, they are the form:

(6) $Qy^* = f(Qy)$.

These convert numbers of live animals to dead ones and calculate the average carcass weights. The equations in this group include calf and other cattle losses, calf slaughter and average weight of fed and nonfed cattle slaughter.

Product Stocks Equation

The ending stocks of a commodity are related to the beginning stocks and the per capita production. This relates changes in stocks to the excess of current stocks over an "equilibrium" level and per capita production over some "average." For a continuously produced product like beef, the role of such stocks is more of a transaction demand than speculative. This is of the form:

(7) $ESY_t = f(ESY_{t-1}, \frac{Qy}{POP})$, or in continuous time

(7a) $\frac{dESY}{dt} = f(ESY, \frac{Qy}{POP})$.

The partial derivatives of f in equation (7a) are negative with respect to stocks and positive with respect to per capita supplies.

Inventory Accounting Equations

The capital stock variables, such as breeding herds, are accounted for by simply adding (integrating out) all the individual investment items. Mathematically, this takes the form:

(8) $K(t) = K(0) + \int \frac{dK}{dt}\, dt$

This process is represented in the equations for breeding and market hog inventories and beef cow inventory.

Supply-Demand Identities

The remaining equations in the livestock model express the market clearing supply-demand identities for each commodity. These incorporate imports, exports, and military consumption into the retail sector and equate numbers produced with numbers processed.

These equations describe the total supply of pork, civilian disappearance of pork, the number of pigs slaughtered, nonfed cow slaughter, total supply of beef, and the civilian disappearance of beef.

Crop Equations

The crop sector of the cross-commodity forecasting system (linked model) consists of a demand side which is differentiated by source of demand, a supply side whose key elements are acreage response and yield, and an identity which determines the farm level price.

Feed Demand Equations

A primary use of U.S. grains and oilseeds is to feed livestock. The demand for the purpose is, by consequence, a derived demand. The quantity of each grain (or soybean meal) consumed by livestock is a function of livestock numbers, livestock prices, and their own price and prices of competing feeds. These relationships are homogeneous in all price variables and must represent the units of livestock fed, rather than pounds of meat produced. The mathematical form of the feed demand equations is:

(9) $QFEED = f(Pxf/Pyf, Px'f/Pyf, Ny)$.

The crushing demand for soybeans is included in the table of feed demands since it too is a derived demand.

Food Demand Equations

The food usage of grains and soybean oil is most analogous to the retail demand for livestock products. It is affected by consumer incomes, inflation population, and, to an extent, competing product usage. Because food use comprises a relatively small portion of total grain demand and the industrial structure of the cereal and grain processing industries is highly concentrated, perhaps oligopolistic, the entire processing sector is not explicitly modeled. Instead, the food demand is related to farm prices for the commodity, consumer incomes per capita and the CPI for nonfood commodities other than durables. In particular, the form of the equations is:

(10) QFOOD = f(Pxi/CPI, DPIC/CPI, POP).

Export Demand Equations

The export demand for U.S. grains and oilseeds is an excess demand concept. Whatever concepts that affect U.S. domestic use affect the levels of our exports when appropriately transposed to the major importing regions. Similarly, the level of foreign supplies dampen the U.S. export demand. Policy instruments like the European threshold price for corn, Japanese resale price for wheat, and USSR net grain imports also affect our export demands.

U.S. prices are converted effectively into the price our export customers can react to using the exchange rate vis à vis the SDR. Aggregate holding of foreign excange measured in SDRs provides a wealth effect which shifts the net export demand.

Crop Inventory Demand

The inventory demand for U.S. crops is separated into components owned by the CCC and not committed to any transaction and commercial inventory demand, which is the remainder of the measured ending stocks for the commodity.

The commercial stocks demand is an accelerator-type model which incorporates both transactions and speculative components to its explanation. The speculative demand incorporates rational expectations arguments to represent the expected price at which the grain will be sold by the acreage planted for next year's harvest and the current level of ending government stocks. Current farm price is the acquisition cost for new inventory. Production for the current marketing year captures the transactions component of demand and the beginning stocks (lagged dependent variable) represents the accelerator. In mathematical terms:

$$CSTK_t = f(CSTK_{t-1}, QP_t, P_t, ACRES_{t+1}, GSTK_t).$$

The government stocks holdings in the linked model are explained by the historical relationship that the change in government inventories is negatively related to total government holdings and positively related to the ratio of loan rate to the market price:

$$\frac{dGSTK}{dt} = f(GSTK, PL/PM)$$

or in the discrete time format:

$$GSTKt = f(GSTKt-1, PLt/PMt).$$

The ability of the current specification, or minor variants of it, to explain behavior under the farmer reserve program is the subject of current research activity.

Production Response Equations

In each case, the acreage response is related to the relative prices of the own and major competing crop products. The success of the government program is measured by effective support price and diversion payment variables. After the market prices significantly exceeded the support prices in 1972, the measured response was the response to lagged market prices.

The yield per acre for each crop is estimated outside the simultaneous solution process of the linked model, drawing on sophisticated weather information which combines actual weather to the current point in time with 30-year normal observations on the weather variables. Economic factors including acreage planted (or harvested) and crop and fertilizer prices also condition our yield estimates.

Crop Sector Identities

True identity which sets quantity demanded equal to quantity supplied is inverted to obtain the market-clearing farm price. In addition to the components mentioned here, exogenous estimates of imports, seed use, and certain nonmarket export transactions are made in order to fill out the balance sheet.

Free Market Weather Impacts on Corn, Soybeans and Wheat

The U.S. has experienced extremely favorable weather conditions the past two years. Current estimates indicate national record yields for soybeans and corn. Farm prices and futures prices have reflected these events as we progressed through the growing season. The U.S. Department of Agriculture published agricultural supply and demand estimates monthly beginning in July. At that time expected corn yield was set at 95.8 bushels per harvested acre. With a carry-in of around 1.3 billion bushels, total supply was placed at about 8.0 billion bushels. Since we had early warning signals regarding the Soviet crop, export projections were beginning to show substantial strength. This combination indicated a very tight coarse grain situation; projected price of corn was then placed between $2.60 - $3.00 per bushel. The latest supply and demand estimates peg yield of corn at a record 106.4 bushels and a total supply estimate of around 8.7 billion bushels, or an increase over the mid-July estimate of about

700 million bushels. This resulted in a price adjustment to a lower range of \$2.35 - \$2.65 per bushel. The first center was at \$2.80, the second at \$2.50. Comparing most likely estimates, this additional supply factor was a primary force behind moving the price range down by 30 cents per bushel.

During this period of time the futures market responded to these market signals and we saw corn price break through \$3.00 in mid-summer. As the additional supply unfolded the market started a slow, cautious downward adjustment. But this crop seems to have finally come into focus and the price on the Chicago exchange dropped 30 cents in mid-October 1979 to a low of about \$2.25 per bushel. Obviously the grain producer who was on the high side of the market and took advantage of the mid-summer high price is considerably better off than farmers currently holding unsold grain. This drop of about one dollar per bushel over the past four months represents an 8.7 billion dollar change when applied to the total corn crop supply.

Since soybeans are grown in the same geographic regions as corn we have seen a very similar pattern unfold. Unfortunately for the U.S. producer, world supplies of oil seeds are currently strong; with no export buffer we have seen bean price move from above \$8.00 to levels now below \$6.00 per bushel. Applied to current estimated total supply this will be a change in income to the farm sector in excess of 4.8 billion dollars. This comparison, as in the case of corn, is calculated from the highest prices observed this summer. The total for the two industries reflects a loss in income of around 13.5 billion dollars.

Obviously weather has a significant impact on the U.S. feedgrain-livestock sector. Of course the flip side of this situation is cheaper grain for the livestock industry, reassessment of profit expectations, and a likely increase in the livestock supply - reflecting lower meat prices at retail.

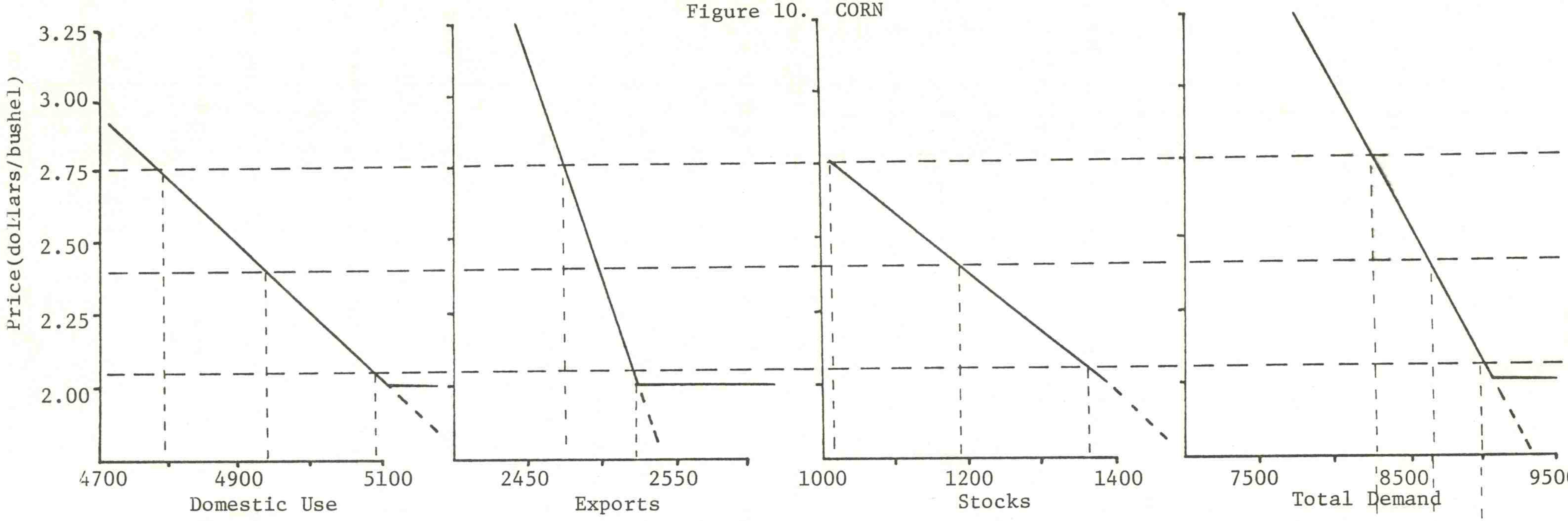
The following figures are designed to reflect these production impacts on each of the three major industries - corn, soybeans and wheat. In Figure 10 three levels of corn yield have been imposed (lower left-hand block). The lower right block reflects total supplies which are traced through the demand components as indicated in upper blocks. Production extremes, 101.3 to 111.3 bushels per harvested acre, imply a range of prices from $2.05 to $2.75 per bushel. Domestic use which goes primarily into livestock feed ranges from 4.8 to 5.1 billion bushels.

Figure 11 is a similar representation for the soybean industry. Beans were allowed to vary from 30 to 33 bushels; corresponding price impacts range from $5.05 to $6.55 per bushel. The higher price scenario chokes off domestic, export and stock use - less quantities are consumed at higher prices. But as supply increases price pressure is less and utilization in all sectors increases.

Figure 12 represents the wheat industry. The same type of scenario is traced out in this graph where yield ranges from 32 to 36 bushels.

These graphs are fairly accurate representations of imbedded structure in the model currently under development at the University of Missouri. It is fairly apparent that these industries are inelastic - for relative changes in supply, substantially larger changes are observed in prices.

Figure 10. CORN



Projected 1979/1980 (Mil.Bu.)			
Area (Mil.Acres)			
Planted	80	80	80
Harvested	69.5	69.5	69.5
Yield per Harvested Acre	101.3	106.3	111.3
Beginning Stocks	1237	1237	1237
Production	7042	7390	7738
Supply, Total	8279	8627	8975
Domestic Use	4790	4940	5090
Exports	2476	2500	2524
Stocks, Government	1013	1187	1361
Price $/Bu.	2.75	2.40	2.05
Loan Price $/Bu.	2.00	2.00	2.00

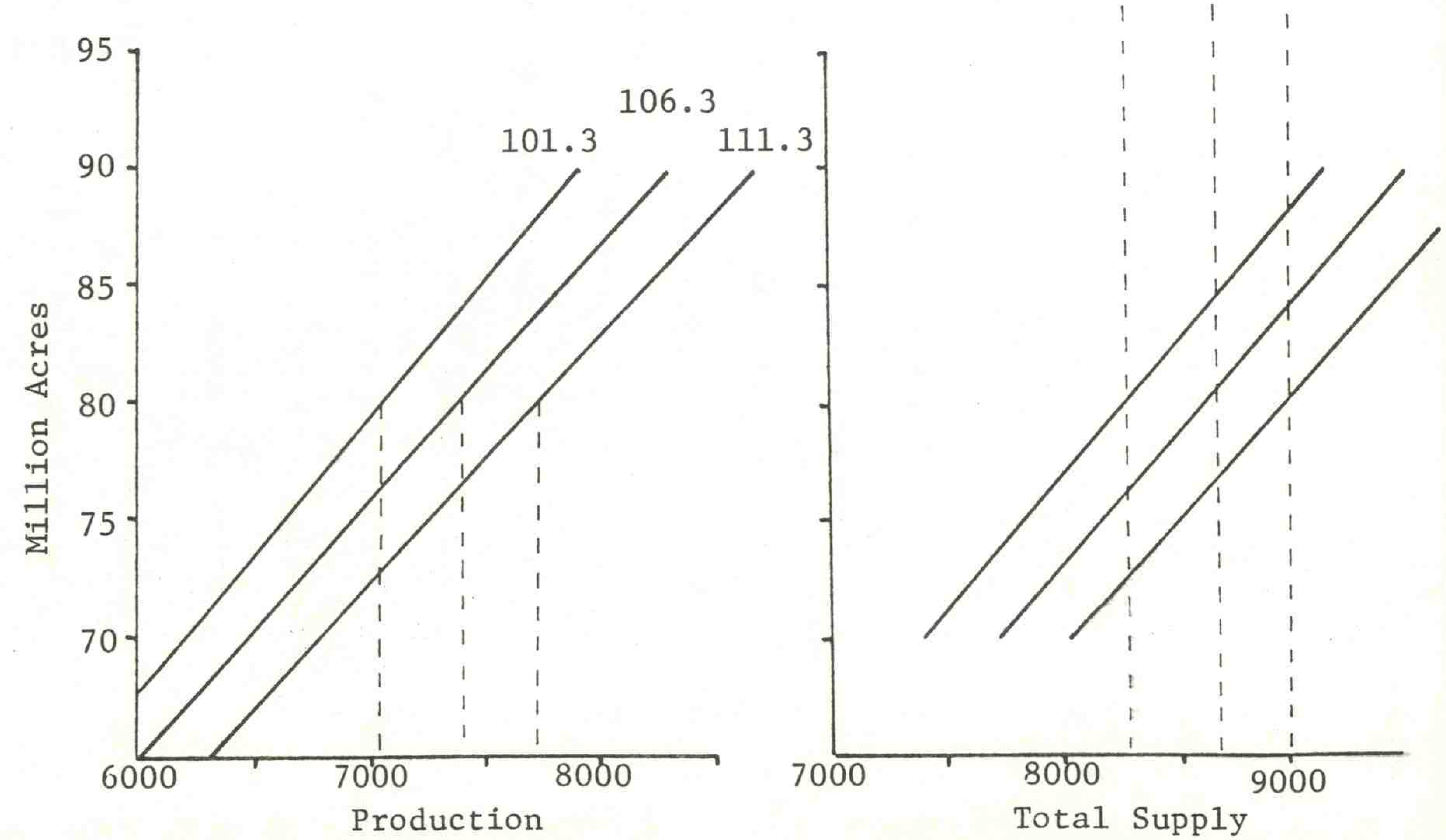
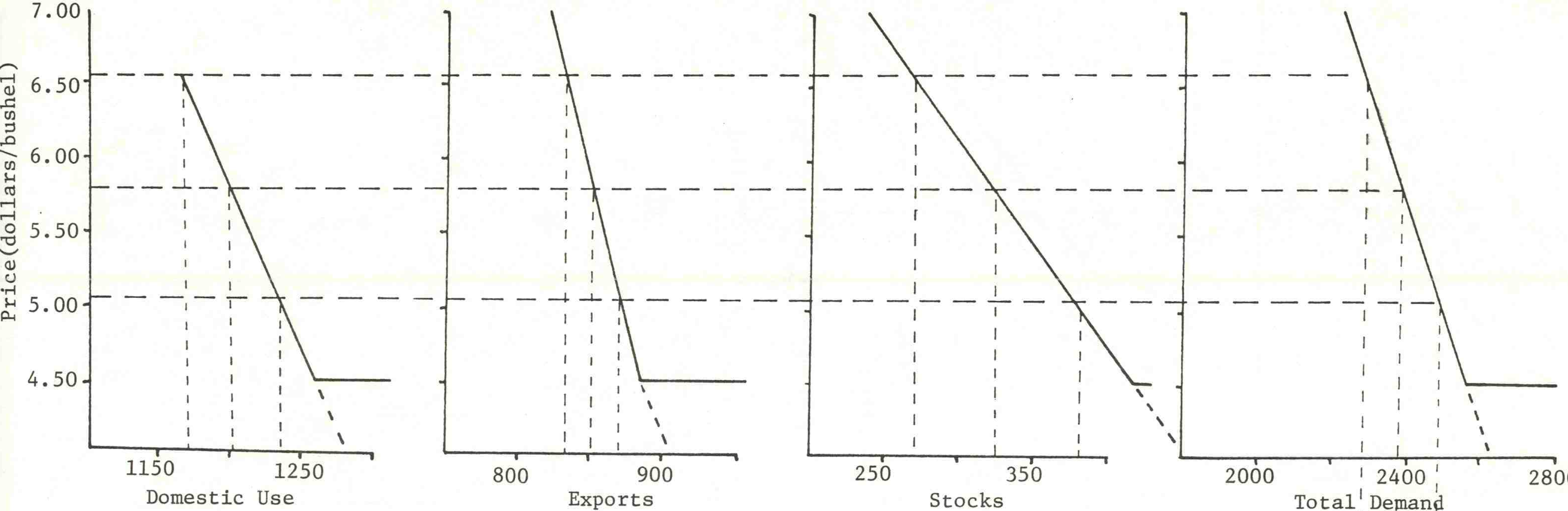


Figure 11. SOYBEANS



Projected 1979/1980

Area (Mil.Acres)			
Planted	71.5	71.5	71.5
Harvested	70.3	70.3	70.3
Yield per Harvested Acre	30	31.5	33
Beginning Stocks(Mil.Bu)	160	160	160
Production	2108	2213	2318
Supply, Total	2268	2373	2478
Domestic Use	1167	1200	1233
Exports	832	850	868
Stocks, Government	268	323	378
Price $/Bu.	6.55	5.80	5.05
Loan Price $/Bu.	4.50	4.50	4.50

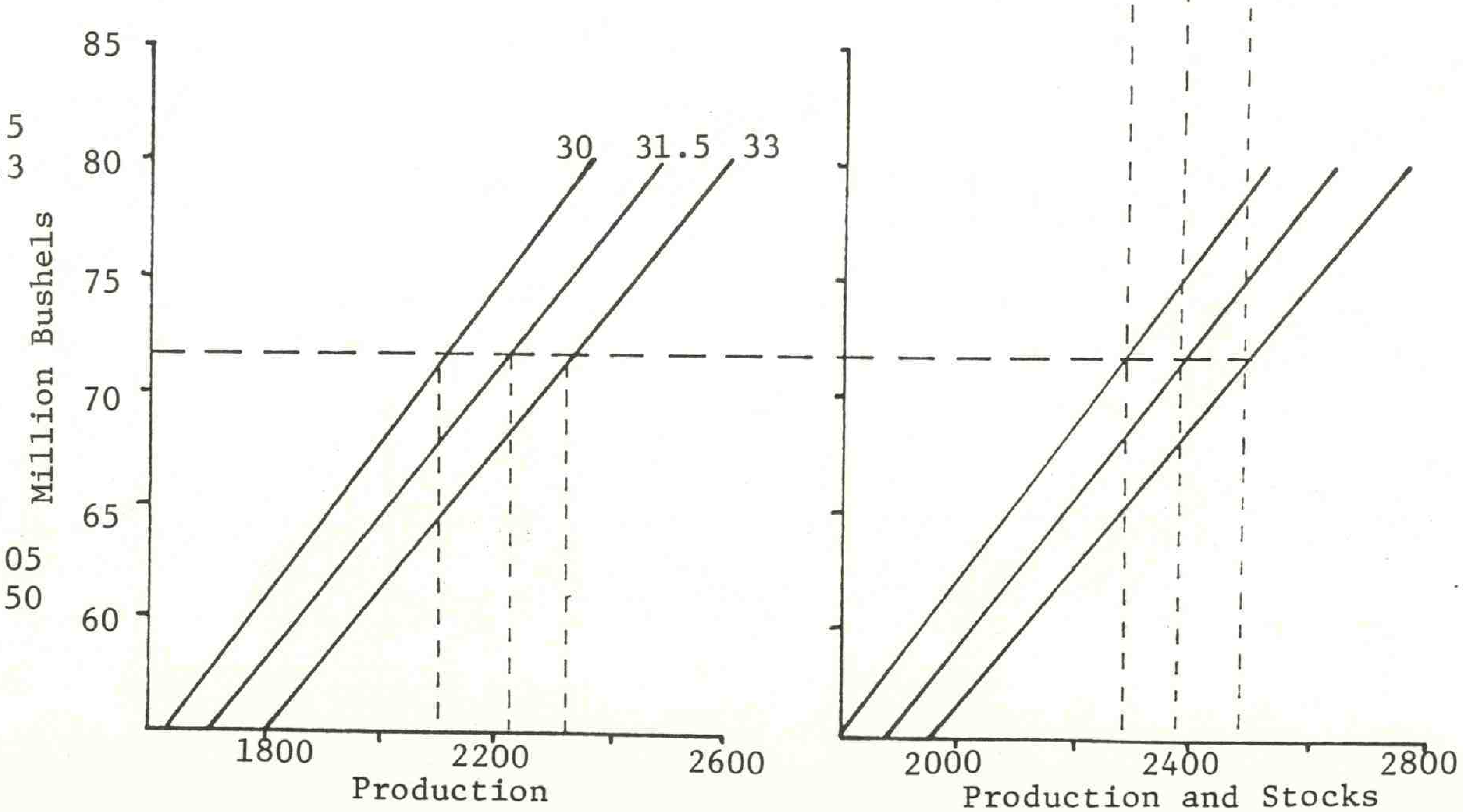
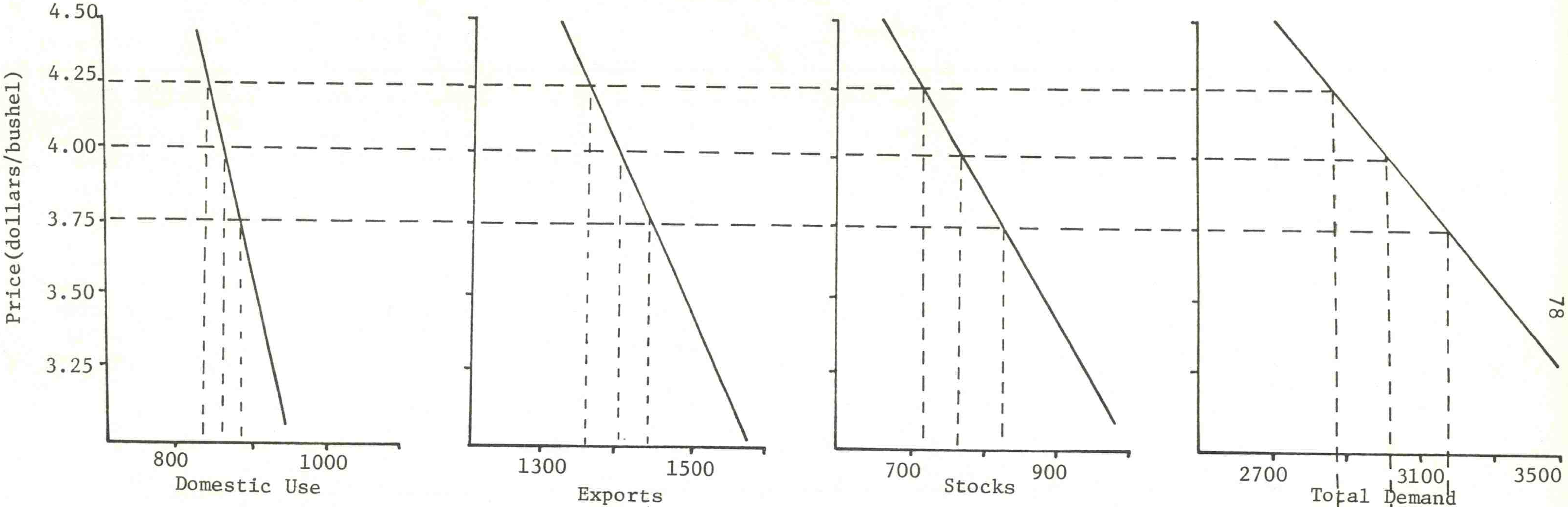
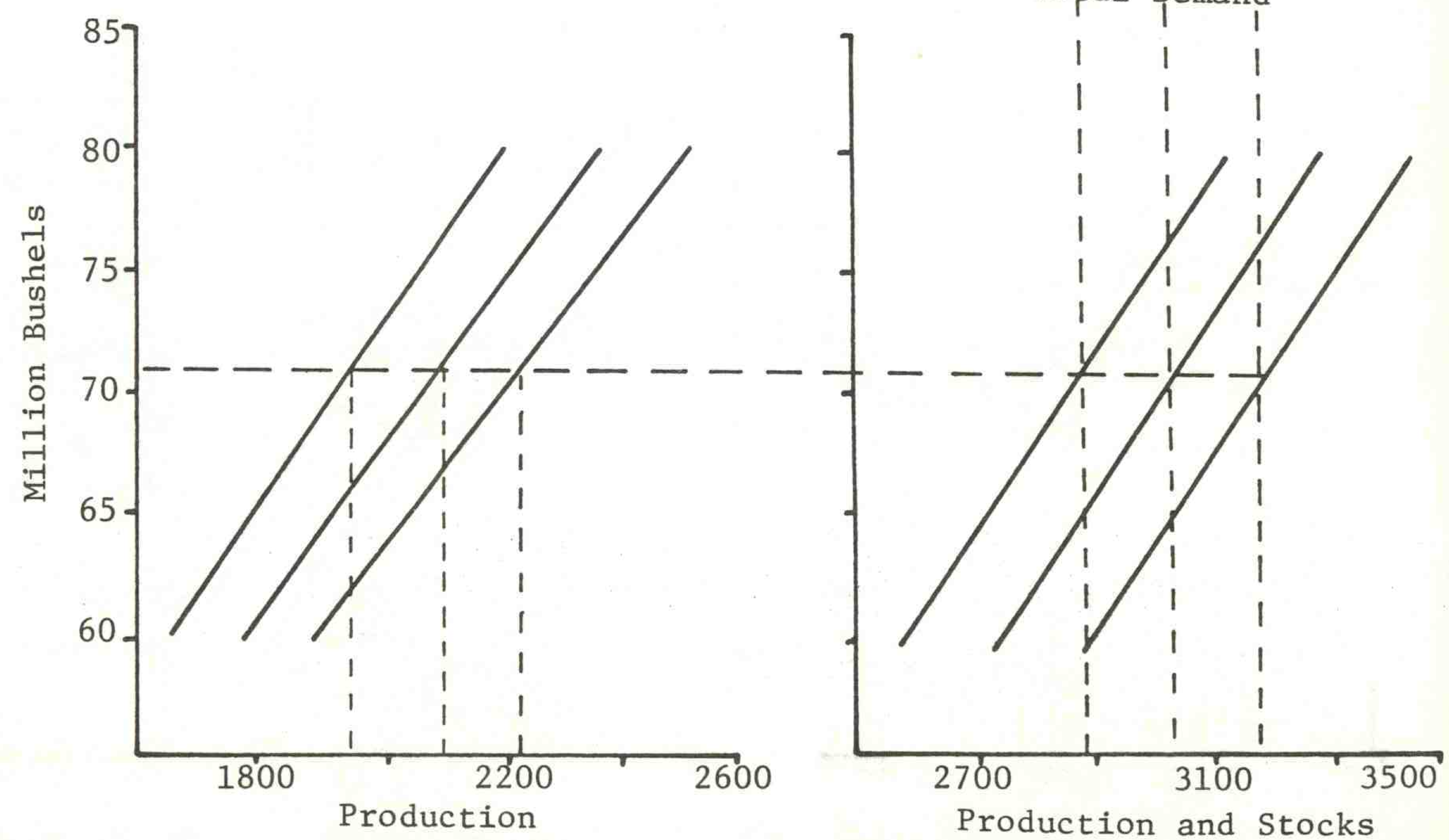


Figure 12. WHEAT



Projected 1979/1980

Area (Mi.Acres)			
Planted	71.2	71.2	71.2
Harvested	62.2	62.2	62.2
Yield per Harvested Acre	32	34	36
Beginning Stocks(Mil.Bu)	922	922	922
Production	1990	2113	2236
Supply, Total	2912	3035	3158
Domestic Use	843	865	887
Exports	1356	1400	1444
Stocks, Government	713	770	827
Price $/Bu.	4.25	4.00	3.75
Loan $/Bu.	2.25	2.25	2.25



As indicated, the soybean industry is much more price-sensitive than the other two industries.

Impact Multipliers - Key Variables

The tables in this section reflect a set of measured, reduced form impacts on the crops sector. In this case a base solution was generated and stored in the computer. A second run was made that isolated separate external impacts. In Table I, for example, corn supply has been changed 100 million bushels. The resulting impacts are the difference between the two runs. These results provide very good "rule-of-thumb" from the impact of an additional 100 million bushels of corn supplies. Price will drop about 10 cents, feed utilization will increase 40 million bushels, food use 2 million, exports 7 million and stocks about 50 million bushels. These first differences can easily be applied to a nearby base to form a new set of equilibrium market statements.

Other tables included were produced in similar fashion.

Supply impacts, which are to a large extent weather oriented, are given in Table I for the corn industry, Table III for the soybean industry, and Table V for the wheat industry. Soybeans are the "most price responsive" for a 100 million bushel increase in supply - price declines about 72 cents per bushel, wheat price drops about 20 cents, and corn price declines about 10 cents.

The magnitude of these impacts can be deduced from the reported variability in production. Agricultural supply and demand estimates reported two-thirds probability ranges on July 13, 1979 for corn, soybeans, and wheat respectively as 535, 150, and 70 million bushels. Applying the above multipliers, it is apparent that changes in domestic production can and do have a significant impact on the prices of U.S. commodities.

Table V has been included to show the impact of foreign production on the U.S. economy. Brazil produces about 14 million metric tons of soybeans each year. They normally export about 4 million metric tons. Analyses conducted at the University of Missouri and the USDA indicate that each additional million metric ton change in exports by Brazil drops the U.S. price by about 22 cents per bushel. Likewise, changes in their export decisions of soybean meal also impact our market - for each additional million metric ton exported our price drops about 14 cents per bushel.

Conclusion

Econometric models that quantify the U.S. agricultural industry are fairly consistent with regard to estimated structure. The grains or crops sector is characterized as a fairly inelastic industry. This implies that relative changes in quantities are associated with somewhat larger changes in prices. From the class of variables utilized to explain the economic behavior of this industry it can also be concluded that weather-related production impacts have substantially larger variations than any other class of variables in the system. Recall that the crops industry faces a livestock-food industry as the principal outlet. These industries are much more rigid in nature and therefore much more predictable in the short run. We estimate, for example, that each additional 1% increase in the production of grain-consuming animal units will increase the price of corn about 5 cents per bushel. We are estimating an approximate 3% increase this year - a rather larger production year would be 10%,

TABLE I. CORN BALANCE SHEET
(Million Bushels)

	CHANGE IN SUPPLY +Δ 100 Mil. Bu.	POLICY EXPORTS Δ 100 Mil. Bu.
DISAPPEARANCE:		
FEED	40	-50
FOOD, INDUSTRY, SEED	2	- 3
TOTAL DOMESTIC	42	-53
EXPORTS	7	- 7 (93)*
TOTAL DISAPPEARANCE	49	-60
ENDING STOCKS:	50	-40
PRICE	- 0.10	.13

*Commercial Exports Drop by 7 Mil. Bu. Thus Total Exports Increase 93 Mil. Bu.

TABLE II. CORN BALANCE SHEET
(Million Bushels)

	CHANGE IN SOYBEAN SUPPLY 100 Mil. Bu.	CHANGE IN GOVMT. PURCHASES 100 Mil. Bu.
DISAPPEARANCE:		
FEED	-32	-40
FOOD, INDUSTRY, SEED	5	- 2
TOTAL DOMESTIC	-27	-42
EXPORTS	-42	- 6
TOTAL DISAPPEARANCE	-69	-48
ENDING STOCKS:	69	-52 (48)*
PRICE	- .21	.11

*Commercial Stocks Drop by 52 Mil. Bu. Thus Total Stocks Increase 48 Mil. Bu.

TABLE III. SOYBEAN BALANCE SHEET
(Million Bushels)

	ΔIN SOYBEAN SUPPLY 100 Mil. Bu.	ΔIN POLICY EXPORTS 100 Mil. Bu.
DISAPPEARANCE:		
CRUSH	31	-33
EXPORTS	17	-29 (81)*
SEED, INDUSTRY, RESIDUAL	-	-
TOTAL DISAPPEARANCE	48	48
ENDING STOCKS:	52	-48
PRICE	- 0.7154	0.65

*Commercial Exports Drop by 29 Mil. Bu. Thus Total Exports Increase 81 Mil. Bu.

TABLE IV. SOYBEAN BALANCE SHEET
(Million Bushels)

	CHANGE IN BRAZIL SOYBEAN EXPORTS 1 MMT.	CHANGE IN BRAZIL SOYBEAN MEAL EXPORTS 1 MMT.
DISAPPEARANCE:		
CRUSH	11	- 8
EXPORTS	-29	- 3
SEED, INDUSTRY, RESIDUAL	-	-11
TOTAL DISAPPEARANCE	18	-
ENDING STOCKS:	-18	11
PRICE	- .22	- .14

TABLE V. WHEAT BALANCE SHEET
(Million Bushels)

	Δ IN WHEAT SUPPLY 100 Mil. Bu.	Δ IN WHEAT POLICY EXPORT 100 Mi. Bu.
DISAPPEARANCE:		
DOMESTIC	18	-11
EXPORTS	36	-77 (23)*
TOTAL DISAPPEARANCE	54	-88
ENDING STOCKS:	46	-12
PRICE	- .20	.12

*Commercial Exports Drop 77 Mil. Bu. Thus Total Exports Increase by 23 Mil. Bu.

TABLE VI. WHEAT BALANCE SHEET
(Million Bushels)

	Δ IN WHEAT GOVERNMENT PURCHASES 100 Mil. Bu.	PRICE OF FED CATTLE, ONE UNIT CHANGE
DISAPPEARANCE:		
DOMESTIC	-23	3
EXPORTS	-41	- 2
TOTAL DISAPPEARANCE	-64	1
ENDING STOCKS:	-36 (64)*	- 1
PRICE	.23	.01

*Commercial Stocks Drop 36 Mil. Bu. Thus Total Stocks Increase 64 Mil. Bu.

implying a price impact of about 50 cents per bushel. But the uncertainty about this series is around 2 to 3%, so variation on corn price derived from this sector is normally around 15 cents per bushel. Normal production change for corn, as estimated by the USDA, is 535 million bushels. This implies a 53.5 cent price impact.

Also we are measuring and continually monitoring weather-related influence from the Soviet Union - the short crop this year is creating substantial up-side pressure on our markets. Recognizing this level of variability in domestic and foreign production, the USDA has taken steps to reduce this uncertainty by implementing a stocks reserve program. Thus an attempt has been made and a farm program devised to overcome the very elementary fact that we cannot forecast weather and therefore must develop strategies that protect the U.S. producers and consumers from these random but powerful impacts that weather phenomena have on the U.S. agricultural economy.

SIMULTANEOUS SYSTEMS - GENERAL NOTATION AND SOLUTION TECHNIQUE

$$Y_{ti} = -\sum_{\substack{j=1 \\ i \neq j}}^{M} \gamma_{ji} Y_{tj} - \sum_{k=1}^{K} \beta_{ki} X_{tk} + \varepsilon_{ti} \qquad (1)$$

is a simultaneous system of equations where:

Y_{tj} = jth dependent variable as of time t,

X_{tk} = kth exogenous variable as of time t,

M = equations in M endogenous variables,

K = exogenous variables.

Consolidation of endogenous variables in (1) implies

$$\sum_{j=1}^{M} \gamma_{ji} Y_{tj} + \sum_{k=1}^{K} \beta_{ki} X_{tk} = \varepsilon_{ti} \text{ , } (i = 1,\ldots,M) \qquad (2)$$

(γ_{ii} = 1 by convention)

In matrix form this system for M equations and M unknowns can be expressed in a dynamic framework for a time period of T observations on X and Y. More precisely,

$$\underset{T\times M}{Y} \; \underset{M\times M}{\Gamma} + \underset{T\times K}{X} \; \underset{K\times M}{\beta} = \underset{T\times M}{\varepsilon} \qquad (3)$$

To solve for the reduced system:

$$Y \; \Gamma + X \; \beta = \varepsilon \qquad (4)$$

$$Y \; \Gamma = -X \; \beta + \varepsilon \qquad (5)$$

$$\underset{T\times M}{Y} = -\underset{T\times K}{X} \; \underset{K\times M}{\beta} \; \underset{M\times M}{\Gamma^{-1}} + \underset{T\times M}{\varepsilon} \; \underset{M\times M}{\Gamma^{-1}} \qquad (6)$$

$$= \underset{T\times K}{X} \; \underset{K\times M}{\pi} + \underset{T\times M}{V} \quad \text{where } \pi = -\beta\Gamma^{-1} \qquad (7)$$

COMMODITY MODEL

I. 1. $QDD_t = 250 - 12P_t + 14X_1$ Domestic Feed Demand

2. $QDS_t = 100 - 3P_t + 2X_2 - X_1$ Stock Demand

3. $QDX_t = 200 - 50P_t + 33X_3$ Export Demand

4. $QP_t = -140 + 50P_{t-1} - 80X_4 - 75X_5$ Production

5. $QP_t + QDS_{t-1} = QDD_t + QDS_t + QDX_t$ Identity

II. MATRIX NOTATION $AY = BX$

$$
\begin{array}{l} 1. \\ 2. \\ 3. \\ 4. \\ 5. \end{array}
\begin{bmatrix} 1 & 0 & 0 & 0 & 12 \\ 0 & 1 & 0 & 0 & 3 \\ 0 & 0 & 1 & 0 & 50 \\ 0 & 0 & 0 & 1 & 0 \\ -1 & -1 & -1 & 1 & 0 \end{bmatrix}
\begin{bmatrix} QDD_t \\ QDS_t \\ QDX_t \\ QP_t \\ P_t \end{bmatrix}
=
\begin{bmatrix} 250 & 14 & 0 & 0 & 0 & 0 & 0 & 0 \\ 100 & -1 & 2 & 0 & 0 & 0 & 0 & 0 \\ 200 & 0 & 0 & 33 & 0 & 0 & 0 & 0 \\ -140 & 0 & 0 & 0 & -80 & -75 & 50 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \end{bmatrix}
\begin{bmatrix} 1 \\ X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \\ P_{t-1} \\ QDS_{t-1} \end{bmatrix}
$$

III. SOLUTION TO THE SIMULTANEOUS SET OF EQUATIONS

a. If "A" is non-singular "A^{-1}" exists.

b. $A^{-1}AY = A^{-1}BX$

$In\ Y = A^{-1}BX$ (solution matrix)

c.

$$
A^{-1} = \begin{bmatrix} \frac{53}{65} & \frac{-12}{65} & \frac{-12}{65} & \frac{12}{65} & \frac{-12}{65} \\ -\frac{3}{65} & \frac{62}{65} & -\frac{3}{65} & \frac{3}{65} & -\frac{3}{65} \\ \frac{-50}{65} & \frac{-50}{65} & \frac{15}{65} & \frac{50}{65} & \frac{-50}{65} \\ 0 & 0 & 0 & 1 & 0 \\ \frac{1}{65} & \frac{1}{65} & \frac{1}{65} & -\frac{1}{65} & \frac{1}{65} \end{bmatrix}
$$

IV. $$\begin{bmatrix} \frac{53}{65} & -\frac{12}{65} & -\frac{12}{65} & \frac{12}{65} & -\frac{12}{65} \\ -\frac{3}{65} & \frac{62}{65} & -\frac{3}{65} & \frac{3}{65} & -\frac{3}{65} \\ -\frac{50}{65} & -\frac{50}{65} & \frac{15}{65} & \frac{50}{65} & -\frac{50}{65} \\ 0 & 0 & 0 & 1 & 0 \\ \frac{1}{65} & \frac{1}{65} & \frac{1}{65} & \frac{-1}{65} & \frac{1}{65} \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 & 12 \\ 0 & 1 & 0 & 0 & 3 \\ 0 & 0 & 1 & 0 & 50 \\ 0 & 0 & 0 & 1 & 0 \\ -1 & -1 & -1 & 1 & 0 \end{bmatrix} \begin{bmatrix} QDD_t \\ QDS_t \\ QDX_t \\ QP_t \\ P_t \end{bmatrix} = \begin{bmatrix} \frac{53}{65} & -\frac{12}{65} & -\frac{12}{65} & \frac{12}{65} & -\frac{12}{65} \\ -\frac{3}{65} & \frac{62}{65} & -\frac{3}{65} & \frac{3}{65} & -\frac{3}{65} \\ -\frac{50}{65} & -\frac{50}{65} & \frac{15}{65} & \frac{50}{65} & -\frac{50}{65} \\ 0 & 0 & 0 & 1 & 0 \\ \frac{1}{65} & \frac{1}{65} & \frac{1}{65} & \frac{-1}{65} & \frac{1}{65} \end{bmatrix} \begin{bmatrix} 250 & 14 & 0 & 0 & 0 & 0 & 0 & 0 \\ 100 & -1 & 2 & 0 & 0 & 0 & 0 & 0 \\ 200 & 0 & 0 & 33 & 0 & 0 & 0 & 0 \\ -140 & 0 & 0 & 0 & -80 & -75 & 50 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 \end{bmatrix} \begin{bmatrix} 1 \\ X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \\ P_{t-1} \\ QDS_{t-1} \end{bmatrix}$$

V. IMPACT MULTIPLIERS

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} QDD_t \\ QDS_t \\ QDX_t \\ QP_t \\ P_t \end{bmatrix} = \begin{bmatrix} 122.62 & 11.23 & -.369 & -6.092 & -14.769 & -13.846 & 9.231 & .185 \\ 68.15 & -1.60 & 1.908 & -1.523 & -3.692 & -3.462 & 2.308 & .046 \\ -330.77 & -10.00 & -1.538 & 7.615 & -61.538 & -57.692 & 38.462 & .769 \\ -140.00 & 0.0 & 0.0 & 0.0 & -80.0 & -75.0 & 50.0 & 0.00 \\ 10.62 & 0.2 & 0.031 & 0.508 & 1.231 & 1.154 & -0.769 & -.0154 \end{bmatrix} \begin{bmatrix} 1 \\ X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \\ P_{t-1} \\ QDS_{t-1} \end{bmatrix}$$

VI. REDUCED FORM EQUATION FROM IMPACT MULTIPLIERS

1. $QDD_t = 122.62 + 11.60X_1 - 369X_2 - 6.092X_3 - 14.769X_4 - 13.846X_5 + 9.231P_{t-1} + .185QDS_{t-1}$
2. $QDS_t = 68.15 + 1.60X_1 + 1.908X_2 - 1.523X_3 - 3.692X_4 - 3.462X_5 + 2.308P_{t-1} + .046QDS_{t-1}$
3. $QDX_t = -330.77 - 10.0X_1 - 1.538X_2 + 7.615X_3 - 61.538X_4 - 57.692X_5 + 38.462P_{t-1} + .769QDS_{t-1}$
4. $QP_t = -140.0 \quad -80.0X_4 - 75.0X_5 + 50.0P_{t-1}$
5. $P_t = 10.62 + .2X_1 + 0.031X_2 + 0.508X_3 + 1.231X_4 + 1.154X_5 - 0.769P_{t-1} - .0154QDS_{t-1}$

This example is characteristic of the type of situation that exists in the agriculture sector:

QDD_t: Domestic demand for commodity Q,

QDS_t: Domestic stocks of commodity Q,

QDX_t: Net exports of commodity Q,

QP_t: Domestic production of commodity Q

P_t: Price of the commodity in year t.

System I represents the set of simultaneous equations that have each been estimated separately using "some" regression package.

System VI represents the solution to this system as given in I.

The basic differenc between System I and System VI is that System VI gives the solution to the entire set of equations, i.e., the vector of solutions that satisfy all equations simultaneously. Notice that equation (4) is not simultaneous to the system and therefore is exactly reproduced in System VI.

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V. REGIONAL INPUT-OUTPUT MODELS: UNDERSTANDING THEIR APPLICATION

Charles Lamphear

The first known input-output system of accounts was developed by Wassily Leontief in his "Quantitative Input-Output Relations in the Economic System of the United States" in The Review of Economics and Statistics (August, 1936). Input-output analysis did not, however, attract much attention in the U.S. until the early 1950's. Moreover, such techniques did not become a part of study at most institutions of graduate education until the late 1950's. In short, the early acceptance of input-output analysis was scant, but its growth in the 60's was extraordinary and its current use in the study of national and regional economics is extensive.

The first Nebraska input-output system of accounts (model) was developed in 1967 for the year 1963 (4). The purpose and initial use of this model was to indicate systematically the relation between irrigated agriculture and other producing (supplying) sectors of the Nebraska economy. The unique feature of an input-output model is its breakdown of economic activity that identifies how the components of an economy fit together and influence one another. By decomposing the Nebraska economy into its finer working units (that is, to identify inter-industry transactions), it was possible to trace the economic effects of irrigated agriculture on the rest-of-the-State's economy. Without the use of input-output analysis for this purpose, many of the economic effects of irrigation (particularly the indirect effects) would have been undetected.

The application of input-output analysis to the irrigation sector led to its application in other areas of the State's economy. Its continued use necessitated the updating of the 1963 model for later time periods. To this end, the 1963 model was followed by the 1967 and 1970 Nebraska input-output models (2,3). The most recent Nebraska input-output model is for 1976 (1).

Input-output analysis provides satisfactory answers to many practical economic questions that relate to economic repercussions (or economic impacts). Such economic issues as industry expansion or contraction, energy shortages, labor migration, personal income changes, revenue forecasts, droughts, and the like involve the same basic issue: economic impact. Clearly, input-output analysis is a very important tool for those who must deal with these kinds of questions on a regular basis. In view of this, the primary purpose of this paper is to present input-output techniques in such a way that the unseasoned user will understand 1) how input-output analysis can be applied to certain economic questions, and 2) how the results of such an analysis can be interpreted. The paper's discussion will focus on so-called regional input-output models.

Understanding Input-Output Tables

At the outset, it is important to be aware of 1) the designated study area used in the development of an input-output model, that is, a regional economy vs. a national economy, and 2) the distinction between a static model and a dynamic model. This paper is primarily intended for users of input-output models who are involved in subnational economic issues. Therefore, the discussion will feature the regional concept. In addition, it will be limited to a static analysis of interindustry relationships. This means that the identified structure of a region's economy, with all its components (producing sectors), represents an economic snapshot for a particular point in time. This snapshot will not systematically reveal the dynamic characteristics of the region's economy. That is, like a picture, this economic snapshot will not indicate how the region's producing sectors developed to their current size. In practice, inadequate data at the regional level precludes the construction of dynamic regional input-output models. This explains why static input-output models are periodically updated to capture current changes in the structure of the region's economy which are due mainly to changes in plant investment activity and/or to changes in technology.

The usual set of tables that make up a regional input-output model are 1) the transactions table, 2) the direct requirements table, and 3) the total requirements table.[1] The transactions table, which will be discussed first, is a system of economic accounts for the region. This makes it a descriptive table, similar but not identical to the typical system of accounts used in business. The direct and total requirements tables are referred to as analytical tables, since they are derived from the transactions tables. The four tables are commonly referred to as a regional input-output model.

Transactions Table

Viewing the transactions table as a system of accounts, its single most important feature is the systematic classification of interindustry transactions. This feature will become evident with the discussion of Table 1, which presents in schematic fashion a transactions table's format.

Quadrant I

This portion of the transactions table contains the producing sectors, or more completely the producing, processing, trading and servicing sectors of the economy. Among them we would find agricultural production, mining, manufacturing, trade, services, transportation, finance, insurance, real estate, utilities, construction, and households. These sectors, which represent groupings of similar business establishments, are involved in the Quadrant I portion of Table I by row and column headings. A customary feature of Quadrant I is that the row order for listing the producing sectors is the same as the column order for the same sectors.

The individual cell values of Quadrant I indicate the economic relationships between the producing sectors. These relationships can be expressed in monetary units or physical units. However, monetary units generally are used. Reading across a sector's row shows sales by that sector to the designated sector columns. Reading down a sector's column shows the purchases by that sector from the designated sector rows. This row-and-column interpretation means that an input-output transactions table is a double entry bookkeeping system of accounts.

Quadrant II

All of the columns in this quadrant, which extend into Quadrant IV, are referred to collectively as the final demand component of the trans-

Table 1
Basic Format of Transactions Table

The Endogenous and Exogenous Parts of the Transactions Table		PURCHASING SECTORS: Internal Sectors						External Sectors (Final Demand)					
		Agricultural Sectors	Mining	Manufacturing Sectors	Noncommodity Sectors	Construction	Households	State-Local Gov.	Fed. Gov't.	Private Capital Formation	Net Change in Inventories	Exports	Total (Gross Outlay)
SELLING SECTORS: Internal Sectors	Agricultural Sectors												
	Mining												
	Manufacturing Sectors			Quadrant I					Quadrant II				
	Noncommodity Sectors			endogenous transactions					exogenous transactions				
	Construction												
	Households												
External Sectors (Other payments)	State-Local Government Federal Government Depreciation Imports & Other Expenses			Quadrant III exogenous transactions					Quadrant IV				
	Total (Gross Outlay)												

actions table. The final demand sectors make up the autonomous portion of the transactions table; that is, the structural part of a region's economy in which the initial changes occur that are transmitted throughout the rest of the region's economy. For illustrative purposes, the final demand portion of Table 1 includes: 1) state and local governments, 2) federal government, 3) gross private capital formation, 4) net changes in inventories, and 5) exports. The state and local government sector represents purchases by various agencies of state and local government from the sectors indicated along the left-hand side of the table. The federal government column represents purchases by federal agencies. The column headed gross private capital formation records the sales on capital account by capital producing sectors. To avoid confusion later, it is important to note here that sales to the gross private capital formation sector represent capital formation and not current consumption. The net inventory column records net changes in the net inventory of produced items during the accounting period. Finally, the export column records sales by the region's producing sectors to buyers located outside the region. Sales to federal government agencies are excluded from the export category since there is a separate federal government sector.

Quadrant III

The rows in this section of the transactions table, which extend through Quadrant IV, are referred to collectively as the other payments sectors. State and local government, federal government, depreciation, and imports and other expenses are illustrated in Table 1 as the other payments sectors. Payments to the government sectors represent tax payments made during the accounting period. Cell entries for the depreciation row record the amount of calculated capital "used up" during the production period. Finally, the imports and other expenses row represents, for the most part, the purchase of goods and services from producers located outside the region. Other kinds of payments not recorded elsewhere, such as retained earnings, association dues, donations to charitable and nonprofit organizations, and the like are shown in Table 1 to be included in the imports and other expenses row. Depending upon the availability of data, these types of expenses can be disaggregated to form additional other payments sectors.

Quadrant IV

This portion of the transactions table records the interindustry-type transactions between the "other payments" sectors and the final demand sectors. For instance, a figure recorded in the cell representing the intersection of the federal government column with the state and local government row would indicate a transfer of federal revenue to state and local government.

Total Output

The last row of Table 1 records the total gross outlay by each of the producing sectors and the final demand sectors. By definition, the total gross outlay of each producing sector equals its total gross output, adjusted for changes in inventory. It is not the case, however, that row and column totals for sectors common to both the final demand and other payments portions of the table should be equal.

Table 2 represents a gross consolidation of Nebraska's economic activity into a very few sectors for 1976. The intact transactions table for 1976 includes forty-seven producing sectors and one final demand sector (1). A consolidated version of the 1976 Nebraska transactions table is being presented here to use in the discussion of the direct and total requirements tables. For Table 2, the State's economy is consolidated into nine producing sectors: agriculture; mining and manufacturing; trade; services; finance, insurance, and real estate (F.I.R.E.); transportation, communications and utilities (T.C.U.); construction; maintenance and repair; and households. The total gross output of each sector is evaluated in monetary terms in hundred thousands of dollars. Final demand and other payments are each shown as a single sector.

Rows one through nine of Table 2 detail the distribution of the producing sectors' outputs. Columns one through nine detail their purchases. Column ten records the producing sectors' sales to final demand. And row ten lists, by sector, other payments expenses. Quadrant I, which is the most important component of an input-output transactions table, consists of the nine rows and columns of Table 2.

Direct Requirements Table

The direct requirements table is derived from the accompanying transactions table. This will be illustrated with the use of Table 2.

A direct requirements table is calculated on the basis of 1) the information contained in Quadrant I of the accompanying transactions table and 2) the total gross outlay figures for the producing sectors.

Table 2

Consolidated Nebraska Transactions - Table for 1976

(Each cell shows the sale of output of the row sector to the column sector. The units are 100,000s of dollars).

SELLING SECTORS			PURCHASING SECTORS Internal Nebraska Sectors Agric. (1)	Min. & Manuf. (2)	Trade (3)	Ser-vices (4)	F.I.R.E. (5)	T.C.U. (6)	Constr. (7)	Maint. & Repair (8)	House-holds (9)	Final Demand (10)	Gross Outputs (11)
Internal Nebraska Sectors	Agric.	(1)	1,058.4	2,167.2	1.6	3.3	---	---	---	---	17.9	1,237.2	4,485.6
	Min. & Manuf.	(2)	311.2	394.6	48.3	24.6	18.8	11.5	153.4	---	839.4	7,053.5	8,857.6
	Trade	(3)	201.7	37.4	30.7	27.9	15.8	20.6	40.0	---	1,374.0	458.6	2,206.7
	Services	(4)	92.9	75.9	44.6	58.8	65.2	55.6	16.7	---	1,252.2	1,076.1	2,738.0
	F.I.R.E.	(5)	367.5	44.4	180.5	149.2	150.8	62.0	24.2	---	1,783.0	216.9	2,978.3
	T.C.U.	(6)	80.5	148.0	97.8	50.4	42.9	37.3	7.1	---	329.7	1,142.3	1,936.0
	Const.	(7)	---	12.5	---	---	---	---	401.4	244.3	---	987.5	1,645.7
	Maint. & Repair	(8)	22.6	55.6	15.0	15.0	11.6	8.2	4.5	---	88.3	23.5	244.3
	House-holds	(9)	731.8	1,373.9	1,235.6	1,621.5	1,436.2	428.2	501.0	---	119.3	2,102.5	9,850.0
Other Payments		(10)	1,616.9	4,548.1	552.6	787.3	1,237.0	1,012.6	497.4	---	4,046.2		
Total Gross Outlay		(11)	4,485.6	8,857.6	2,206.7	2,738.0	2,978.3	1,136.0	1,645.7	244.3	9,850.0	14,298.1	34,942.2

Source: The Nebraska Transactions Table for 1976, which is presented later in this document.

The derivation involves dividing each producing sector's purchases, which are identified by reading down its column, by its total gross outlay. It should be emphasized that while items included under other payments represent purchases, these payments are usually excluded in the derivation of a direct requirements table because they do not represent the region's production of goods and services.

Table 3 is the direct requirements table for the input-output transactions table of Table 2. Illustrating its interpretation, the Nebraska agriculture sector purchased, on the average, 7 cents from Nebraska mining and manufacturing to produce one dollar of food products for 1976 ($311.2/$4,485.6 = 0.06938). In addition, agriculture purchased, on the average, 24 cents from agriculture, 4 cents from trade, 2 cents from services, 8 cents from the F.I.R.E. group, 2 cents from the T.C.U. group, ½ cent from maintenance and repair, and paid out approximately 16 cents for labor to Nebraska households for a total of 63 cents of in-state produced inputs in order to produce one dollar of output. As just illustrated, the information contained in a direct requirements table is interpreted by reading down the columns. It should be noted that the input coefficients or direct requirements coefficients of Table 3 are average relationships. If they are used to estimate the direct purchases needed by a column sector to produce an additional quantity of output, it is important to recognize that these average relationships are being assumed. Additional assumptions will be noted later.

Finally, Table 3 contains a maintenance and repair sector, referred to in the literature as a "dummy" sector. This business activity is

Table 3
Consolidated Direct Requirements Table for Nebraska, 1976
(Each cell shows requirements of the column sector upon the row sector per dollar of output by the column sector.)

	Agric.	Min. & Manuf.	Trade	Services	F.I.R.E.	T.C.U.	Constr.	Maint. & Repair	Households
Agric.	.23596	.24467	.00073	.00121	0	0	0	0	.00182
Min. & Manuf.	.06937	.04455	.02189	.00899	.00631	.00594	.09321	0	.08522
Trade	.04497	.00423	.01391	.01019	.00531	.01064	.02430	0	.13949
Services	.02071	.00857	.02021	.02148	.02189	.02872	.01015	0	.12713
F.I.R.E.	.08188	.00501	.08180	.05449	.05063	.03202	.01470	0	.18102
T.C.U.	.01795	.01671	.04432	.01841	.01440	.01927	.00431	0	.03347
Constr.	0	.00141	0	0	0	0	.24391	1.00000	0
Maint. & Repair	.00504	.00628	.00680	.00548	.00389	.00424	.00273	0	.00896
Households	.16314	.15511	.55993	.59222	.48222	.37614	.30443	0	.01211

Source: Derived from the consolidated 1976 Nebraska input-output transactions table of Table 2.

actually a part of the construction trades. But, for input-output accounting reasons, a separate sector is created for the maintenance and repair activity. The special characteristic of a dummy sector is that it makes only one purchase, and in the case of the maintenance and repair sector of Table 3, that purchase is from the construction sector. For the maintenance and repair sector to produce one dollar of output, it must purchase one dollar of activity from the construction sector, showing that the maintenance and repair sector is simply a "pass through" sector for the input-output system of accounts.

Total Requirements

The great advantage of an input-output system of accounts comes from the derivation of a total requirements table, as illustrated in Table 4.

The total requirements table is algebraically derived from the direct requirements table, which in turn is derived from the transactions table. Hence, the algebraic explanation of the derivation of the total requirements table begins with the following accounting equation, reflecting the interindustry transactions recorded in a transactions table.

$$(1) \quad X_i = \sum_{j=1}^{n} x_{ij} + Y_i \qquad (i = 1,2,\ldots,n)$$

This accounting equation shows that the total output of a producing sector, X_i, is equal to the sum of its sales to all producing sectors, $\sum_{j=1}^{n} x_{ij}$, plus sales to final demand, Y_i. In short, equation one represents the individual producing sector rows of a transactions table.

The algebraic formulation of the coefficients of a direct requirements table is equally straightforward.

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Let

$$a_{ij} = \frac{x_{ij}}{X_j}$$

where a_{ij} expresses the per dollar requirements of column sector j for sector i.

From the definition of a_{ij}, it is apparent that x_{ij} is equal to $a_{ij}X_j$. Therefore equation one can be rewritten as

$$(2) \quad X_i = \sum_{j=1}^{n} a_{ij} X_i + Y_i \qquad (i = 1,2,\ldots,n)$$

The only purpose for rewriting equation one as equation two is to carry out the algebraic derivation of the total requirements table.

A system of equations of the type shown as equation two above exists, one equation for each producing sector. The output totals of this system form a column vector, the input coefficients of the direct requirements table form a matrix, and the final demand sectors can be aggregated to form a column vector. In matrix algebra, this system of equations can be formulated as:

$$\begin{bmatrix} X_1 \\ X_2 \\ X_3 \\ \cdot \\ \cdot \\ \cdot \\ X_n \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots a_{1n} \\ a_{21} & a_{22} & a_{23} & \cdots a_{23} \\ a_{31} & a_{32} & a_{33} & \cdots a_{33} \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ a_{n1} & a_{n2} & a_{n3} & \cdots a_{nn} \end{bmatrix} \cdot \begin{bmatrix} X_1 \\ X_2 \\ X_3 \\ \cdot \\ \cdot \\ \cdot \\ X_n \end{bmatrix} + \begin{bmatrix} Y_1 \\ Y_2 \\ Y_3 \\ \cdot \\ \cdot \\ \cdot \\ Y_n \end{bmatrix}$$

Letting $\underline{X}$ represent the column vector of output totals, $\underline{A}$ represent the matrix of input coefficients, and $\underline{Y}$ represent the column vector of final demand, we can write the total set of equations as

(3) $X = AX + Y$

The total requirements table, which is derived from the above set of equations, measures regional economic impact due to some change in regional sales to final demand. Therefore, equation three is reformulated to express regional output as a function of final demand. Employing the use of the identity matrix and matrix algebra, equation three is converted to:

(4) $X = (I - A)^{-1} Y$

where $(I - A)^{-1}$ is the matrix of total requirements.

Turning to interpretation, the total requirements table shows the total transactions (that is, the direct and indirect requirements) for each of the producing sectors to deliver an additional $1.00 of output to final demand. More specifically, the columns show the total requirements that are necessary for the column sector to produce and sell an additional $1.00 of output to final demand.[2] For example, the total requirements table of Table 4 shows that for the agriculture sector to increase its sales to final demand by one dollar, a total of $2.65 of activity is generated in the Nebraska economy. The $2.65 represents the column's sum for agriculture of 2.65218 rounded to the nearest cent. Included in the total of $2.65 is the one dollar of increased agriculture sales to final demand. (Recall that final demand includes sales to establishments located outside the region, i.e., exports, of other state and local governments, and federal government.) The individual sector amounts that make up the sum of $2.65 show how each producing sector was affected by agriculture's sale of one dollar to final demand. For example, the agriculture sector had to increase its total activity by $1.36 (or 1.36032 from the agriculture sector column of Table 4). However, as already

Table 4
Consolidated Total Requirements Table for Nebraska, 1976

(Each cell shows the total requirements on the row sector per dollar of sales to final demand by the column sector.)

	Agric.	Min. & Manuf.	Trade	Services	F.I.R.E.	T.C.U.	Constr.	Maint. & Repair	Households
Agric.	1.36032	.35842	.04348	.03923	.03042	.02489	.06788	.06788	.05164
Min. & Manuf.	.15563	1.11546	.12332	.10891	.08790	.07194	.20553	.20553	.14835
Trade	.14328	.08234	1.15937	.15497	.12381	.10610	.14102	.14102	.21857
Services	.11117	.07744	.16233	1.16195	.13703	.12165	.11856	.11856	.20964
F.I.R.E.	.24291	.12935	.30294	.27257	1.22936	.17663	.18472	.18472	.32238
T.C.U.	.05834	.04689	.09613	.06877	.05560	1.05295	.04638	.04638	.07286
Constr.	.02085	.02096	.02688	.02461	.01937	.01720	1.34180	1.34180	.02511
Maint. & Repair	.01554	.01427	.02015	.01846	.01452	.01291	.01423	1.01423	.01878
Households	.54414	.41487	.97374	.97480	.79838	.64090	.71580	.71580	1.48649
Sector Multiplier	2.65218	2.26000	2.90834	2.82427	2.49639	2.22517	2.83592	3.83592	2.53291

Source: Derived from the consolidated 1976 Nebraska input-output transactions table of Table 2.

indicated, one dollar of this amount represents agriculture's increased sale of one dollar to final demand. The difference of 36 cents ($1.36 - $1.00) represents direct and indirect requirements for agricultural products that developed as a result of agriculture's initial sale of an additional dollar of output to final demand. What this shows is how an initial change in one producing sector, for example agriculture, creates responsive changes in the outputs of other producing sectors. The sum of these changes in output levels (that is, the column sum of each producing sector of Table 4) reflects the total of direct and indirect effects associated with the producing sector increasing its sales to final demand by one dollar. A more complete understanding of the distinction between direct and indirect effects comes from an alternative analytical procedure for deriving the total requirements table. Before we begin, however, it is important to note that this alternative procedure, called the method of successive approximations, is not typically used. Its use here is simply as a pedagogic aid.

Using the method of successive approximations, we will trace out the various rounds of transactions or total requirements if, for instance, the agriculture sector of Table 2 increases its sale to final demand by an arbitrary amount, say $10,000. To proceed, we need to think of the additional sale of $10,000 to final demand also as an increase in agricultural output. Thinking of the $10,000 figure as agricultural output, we know from column 1 of Table 3 that certain direct inputs are required in order for the agriculture sector to produce $1.00 of output. Using a constant-input assumption, this relationship remains proportional as we expand output. Thus, the direct requirements or inputs associated with \$10,000 of output can be determined by multiplying the input coefficients for the agriculture sector by the \$10,000. The computed direct requirements (by sectors) are recorded in column 1 of Table 5. For example, notice that from column 1 of Table 5, \$2,360 worth of product from the agriculture sector is required by the agriculture sector for the production of an additional \$10,000 of output (0.23596 x \$10,000 = \$2,259.60). In addition, the agriculture sector will purchase an additional \$694 from mining and manufacturing, \$450 from trade, \$207 from services, and so on in order to produce an additional \$10,000 of agricultural output.

The calculation of direct requirements (the <u>first round</u> of transactions) represents only a part of the total requirements associated with the agriculture sector's initial increase of \$10,000 of output. The increase in output for the agriculture sector requires those sectors supplying inputs to the agriculture sector to increase <u>their</u> level of input requirements because of an increase in demand for their products. New input-requirement levels for these sectors, however, imply new output levels for their suppliers. The whole process has numerous rounds which require a large number of calculations in order to estimate total requirements, or total economic impact. As we illustrate the process by which we obtain the so-called <u>indirect</u> requirements from the direct requirements of Table 5, each successive round will refer to the various stages of calculations and the various sets of requirements obtained. For example, round 1 will be used to refer to the direct requirements shown in column 1 of Table 5. Round 2 will be used to refer to the first round of indirect requirements, round 3 for the second round of indirect requirements, and so on.

Table 5
Increased Production Requirements Resulting from a
$10,000 Increase in Agriculture Output*

Purchases From	Direct Requirements Round 1	Indirect Requirements - Round 2									
		Agri.	Mining & Manu.	Trade	Services	F.I.R.E.	T.C.U.	Constr.	Maint. & Repair	Households	Total
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Agriculture	$2,360	$557	$170	$--	$--	$ 0	$ 0	$ 0	$ 0	$ 3	$ 730
Mining & Manu.	694	164	31	10	2	5	1	0	0	139	352
Trade	450	106	3	6	2	4	2	0	0	228	351
Services	207	49	6	9	4	18	5	0	0	207	298
F.I.R.E.	819	193	3	37	11	41	6	0	0	295	586
T.C.U.	180	42	12	20	4	12	3	0	0	55	148
Constr.	0	0	1	0	0	0	0	0	50	0	51
Maint & Repair	50	12	4	3	1	3	1	0	0	15	39
Households	1,631	385	108	252	123	395	68	0	0	20	1,351

Source: Derived from Table 3.

*Calculation results are rounded to the nearest dollar. As a result of this rounding procedure, several transaction calculations round to zero. A hyphen is used to indicate this outcome. In contrast, a zero entry indicates that no transaction occurred.

The calculation of total requirements resulting from the initial increase of $10,000 of output by the agriculture sector will be carried through three rounds in Tables 5 and 6. The derivation of the first round of transactions (shown in column 1 of Table 5) has already been discussed. Using the information in column 1, round 2 can be calculated. For example, the direct input requirement from the agriculture sector of $2,360 requires an additional increase in output for that sector. What are the inputs required for this additional production? Reading from column 2 of Table 5 for the agriculture sector, they are $557 from agriculture, $164 from trade, and so on. These input requirements are calculated by multiplying the $2,360 by the appropriate input coefficient for the agriculture sector as shown in Table 3. Reading from Table 3, the agriculture sector will purchase $0.23596 from the agriculture sector, $0.06937 from the mining and manufacturing sector, $0.04497 from the trade sector, and so on. To determine the input requirements associated with an increase of $2,360 of agricultural output, the figure of $2,360 is multiplied by each of these input coefficients.

The other entries for round 2 are determined in a similar manner. For the mining and manufacturing sector, the direct requirement of $694 is multiplied by the input coefficients for the mining and manufacturing sector column of Table 3. These second-round transactions are recorded in column 3 of Table 5. The remaining columns of Table 5 are figured in the same way. It should be noted that the calculated requirements for the household sector represent household consumption for some level of income. For example, the figures in column 10 of Table 5 show household consumption associated with the increase in household income of $1,631 (column 1 of Table 5). More will be said about understanding the household sector in the next section.

The sector totals for the second round of transactions are found by summing across columns 2 through 10. These totals, by sector, are entered in column 11 of Table 5. The sector totals in Column 11 represent additional outputs induced by the agriculture sector's initial increase in output of $10,000.

To carry the illustration through one more round of transactions, the third, the sector row totals for the second round of transactions (column 11 of Table 5) are viewed as additional increases in output; therefore, additional inputs are required. For example, because of the transactions considered in round 2, the agriculture sector must increase its output by an additional $730. Therefore, the agriculture sector will have to increase its purchase of inputs in order to produce this additional amount of output. The third round of transactions for the agriculture sector is calculated by multiplying the input coefficients for the agriculture sector (Table 3) by the $730. These figures are entered in column 2 of Table 6. The entries for columns 3 through 10 are determined by repeating the process used to complete column 2 of Table 6. The last step in determining the third round of transactions is to total the figures in columns 2 through 10 of Table 6 for each sector. These totals, by sector, are entered in column 11 of Table 6.

Although we have considered only the first three rounds of transactions, it is important to keep in mind that the impact associated with the initial $10,000 of increased output by the agriculture sector does not stop at the end of the third round. Additional rounds of spending and respending will occur. The size of each successive round of transactions, however, becomes smaller and smaller since each round is "dampened down" by the leakage of transactions from the regional economy. The major type of leakage is the purchase of inputs from suppliers outside the region. Therefore, a point is reached where the round-by-round transactions associated with some initial change in the regional economy (e.g., an increase of $10,000 in the agriculture sector's output) become negligible.

Aside from the pedagogical value of the successive approximations procedure, it is not used for deriving a total requirements table. Its disuse should be obvious. As indicated earlier, the relationships we have been discussing can be expressed as a system of simultaneous equations and solved on a computer in a matter of seconds. Even for a very large table, the total requirements table can be calculated in only a few minutes with a computer.

As the next section will indicate, most of the application of input-output models is by way of the various sector multipliers that are derived from the total requirements table. Several important assumptions are involved in the analytical derivation of the total requirements, and for a proper use of sector multipliers these assumptions should be reviewed. First, it is important to recall from an earlier discussion that the direct requirement coefficients, or input coefficients, are average relationships. Next, it is assumed that the relationship between input and output is proportional. Therefore, if the quantity of each input is doubled, the output is also doubled. Finally, it is assumed that there is no substitution of production factors. It should be further noted that at the

Table 6
Increased Production Requirements resulting from a $10,000 Increase in Agriculture Output*

Rounds 2 and 3

Purchases From	Direct Requirements Round 2	Indirect Requirements - Round 3									
		Agri.	Mining & Manu.	Trade	Services	F.I.R.E.	T.C.U.	Constr.	Maint & Repair	Households	Total
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Agriculture	$730	$172	$86	$ -	$ -	$ 0	$ 0	$ 0	$ 0	$ 2	$260
Mining & Manufacturing	352	51	16	8	3	4	1	5	0	115	203
Trade	351	33	1	5	3	3	2	1	0	188	236
Services	298	15	3	7	6	13	4	1	0	172	221
F.I.R.E.	586	60	2	29	16	30	5	1	0	245	388
T.C.U.	148	13	6	16	5	8	3	-	0	45	96
Constr.	51	0	-	0	0	0	0	12	39	0	51
Maint. & Repair	39	4	2	2	2	2	1	-	0	12	25
Households	1,351	119	55	197	176	283	56	16	0	16	918

Source: Derived from Tables 3 and 5.

*Calculation results are rounded to the nearest dollar. As a result of this rounding procedure, several transaction calculations round to zero. A hyphen is used to indicate this outcome. In contrast, a zero entry indicates that no transaction occurred.

regional level, the input coefficients are not the same as technical input coefficients. Because of the substantial amount of trade with other regions, regional input coefficients are, in fact, trade coefficients. That is, for any column in the direct requirements table, each input coefficient shows the amount the producing sector purchased from the region in order to produce one dollar of output. An additional amount of the same input may have been purchased from outside the region. The amount purchased from within the region plus the amount purchased outside the region per dollar of output approximates the technical input coefficient for that input. But the assumption of "no substitution" means that regional input sources are not substitutable for "outside" input sources, and vice versa, which may not be a reasonable assumption for small areas. Generally speaking, a small area, for example a county, is likely to show a greater variation in its trade pattern over time than will a multi-state region.

Before turning to a brief discussion of some applications of input-output models, a point made earlier that a total requirements table may include the household sector as a producing sector, such as Table 4, needs to be reemphasized. Recall from an earlier footnote that the incorporation of the household sector as a producing sector means that the effects of consumer income and spending are included in the total requirements table. For certain kinds of analysis, the household sector is not defined as a producing sector, as shown in the following section.

Applications of Input-Output Models

The primary purpose of this section is to indicate some of the major applications of input-output models at the state or regional level, with an emphasis on sector multipliers. It is hoped that this discussion will provide the reader with a reasonable understanding of how input-output models can be applied to economic matters at the local level. The section concludes with a discussion of the reliability of economic estimates that are derived from an input-output model. This discussion focuses on the assumptions or limitations of input-output models.

Applications (Some Hypothetical Considerations)

A national firm has just announced plans to build a branch plant in a certain midwestern, rural community. To what extent will the branch plant increase employment within the community? Besides the expanded employment opportunities, what additional benefits will the community gain from the new plant? Once the plant is constructed, what will be the plant's demand for public services? Will the benefits of increased employment opportunities at least match the additional cost for more public services?

An existing government installation located in a certain community is scheduled to be phased out. How will the eventual closing affect the economy of the community? Will there be additional kinds of structural problems: for example, will there be a significant loss of tax revenue and hence a possible shortage of funds to finance public services?

It is expected that a region's exports will increase substantially over the next five years. Since an increase in export sales means an increase in regional output, what will be the additional labor requirements for the next five years? More specifically, what kinds of labor skills will be required to meet the added production needs. In order to meet these labor needs, will it require changes in the region's vocational-technical training programs? What will be the increase in tax revenue due to the expected increase in exports? Finally, will additional capital investments for production purposes be required?

A drought condition is simulated for a region. To what extent will this condition affect the non-agricultural sectors of the region's economy?

A state decides to change its income tax rates on business and household income. To what extent will the new rates change state revenue? What sectors of the state's economy will be most, or least, affected by the new rates?

Because of its analytical features, an input-output model is quite useful in developing answers for many of these questions. The analytical quality of input-output tables stems from the various sector multipliers that can be derived from the input-output tables. Unfortunately, it is impossible to deal individually with the above examples within the limited space of this paper. At best, we can discuss the types of sector multipliers that are used to furnish answers to these kinds of questions.

Development of Sector Multipliers

Several types of sector multipliers can be derived from input-output tables, where each type is suited to certain economic questions. All types of sector multipliers are calculated, however, from the total requirements table. For this reason, it is appropriate to expand our discussion of the total requirements table of the last section.

Final Demand Multipliers

One type of sector multiplier that is frequently derived from the total requirements table is the sector final demand multiplier. A sector's final demand multiplier can be measured in terms of gross transactions or in terms of labor units. Since both measures are useful for regional analysis, it is appropriate to devote some discussion to both answers.

Final demand multipliers, measured in terms of gross transactions, come directly from the total requirements table. Recall from the previous section that a total requirements table gives the total of direct and indirect requirements that stem from a producing sector's sales of one dollar of output to final demand. From the previous section, we learned that a dollar of sales to final demand is a dollar's worth of sector output. Understandably, the sector had to purchase various inputs to produce the dollar's worth of output. These inputs are called <u>direct requirements</u>, and they make up the direct requirements table (Table 3). To move one step further, these inputs of direct requirements are outputs of other producing and supplying sectors, and these suppliers had to purchase inputs in order to produce these outputs. At this stage, we are discussing transactions that are "one round" removed from the initial sector selling to final demand (called round 2 in Table 5). These transactions, or inputs, are called <u>indirect requirements</u>. But keep in mind that we have noted here only one round of indirect requirements beyond the initial direct requirements. In reality, numerous rounds of spending and respending accompany the production and distribution of a product to final demand, which means that a multiplying effect occurs within the economy as a result of increased sales to final demand. This multiplying effect is measured by means of the derivation of the total requirements table (Table 4), which summarizes the direct and indirect requirements associated with a producing sector's sale of one dollar of output to final demand.

Now, we are in a better position to discuss the reason why the household sector is treated like a producing sector in the derivation of the total requirements table. First, recall that the household row of the transactions table records the amount of wages, salary, dividends, interest, and rent paid, by sector, to in-state households for their labor and financial contributions to production. Next, recall that the household row of the direct requirements table averages the amount of income paid to households per dollar of sector output. This payment is a direct requirement for production, which means that it is similar to but not identical with the purchase of material and/or service inputs for production purposes. Adding the household row to the group of producing sectors for the derivation of the total requirements table picks up the rounds of spending and respending of household incomes, which have a multiplying effect similar to the spending and respending effects noted earlier for the inputs of goods and services used up in production.

Table 4 includes households as a producing sector. Therefore, the multiplying effects recorded in this table summarize the combined spending and respending effects of 1) goods and services inputs for production and 2) household incomes. The contribution that the spending and respending of household incomes makes to the total multiplying effect can be measured by the derivation of a second total requirements table that excludes the household sector from the group of producing sectors (Table 8). The summarized multiplying effects recorded in this second table will be less than that of the first total requirements table by an amount equal to the multiplying effects of household incomes.

While final demand multipliers are usually expressed in terms of gross transactions, an alternative procedure is to use labor as the unit of measurement. This is done by converting the gross transactions of the total requirements table to labor units. Recall that each column of the total requirements table shows the dollar amounts of the various input requirements in the sale of one dollar of output to final demand by that column sector. Some amount of labor was required in the production of each of the input requirements. Knowing the amount of labor required to produce a dollar's worth of each of the requirements means that the total requirements figures of Table 4 can be converted to total labor requirements figures. To demonstrate this, we will use the household input coefficients of Table 3, which are repeated in Table 7. For convenience, we will assume that these coefficients represent only labor requirements. Recall from an earlier discussion that these coefficients actually measure all household income per dollar of sectoral output. In other words, the labor income of wages and salary is only a part of total household income reflected in the household input coefficients of Table 3. To reiterate, it is important to remember that the only reason for the above assumption is to expedite our discussion of labor requirements. For an actual study of regional labor requirements, it would be necessary to break out wage and salary payments from other forms of household income in order to measure labor input requirements. With this in mind, Table 7 shows hypothetically that 16 cents of labor was required to produce one dollar's worth of agricultural output for 1976. Similarly, approximately 16 cents of labor

Table 7
Labor Requirements Coefficients

	Agric.	Min. & Manuf.	Trade	Services	F.I.R.E.	T.C.U.	Constr.	Maint. & Repair
Labor (Households)	.16314	.15511	.55993	.59222	.48222	.37614	.30443	0

Source: Extracted from Table 3.

was required to produce one dollar's worth of mining and manufacturing output for 1976. The remaining labor input figures of Table 7 are to be interpreted in the same manner. Multiplying these labor input coefficients by the appropriate cell figures of the original total requirements table (Table 4) yields a total requirements table in terms of labor. More specifically, the labor input coefficient for, say, the agriculture sector (Table 7), is multiplied by the row figures for the agriculture sector in the total requirements table of Table 4. These products are recorded in the first row of Table 8. Next, the labor coefficient for the mining and manufacturing sector is multiplied by the row figures for the mining and manufacturing sector of Table 4. These products are recorded in the second row of Table 8. The same procedure is used to compute the remaining row figures of Table 8. It should be noted that the household row of the original total requirements table (Table 4) is not included in the total labor requirements table (Table 8). To include the household row in a total labor requirements table would be repetitious of the total labor requirements just calculated for the producing sectors of Table 8. Notice, for example, that the household row figure for the agriculture sector (Table 4) is approximately the sum of the labor input figures for the agriculture sector column of Table 8; the figures differ slightly because of rounding errors. The calculation of a total labor requirements table is useful for regional analysis because it provides a sector breakdown of labor inputs.

Final demand multipliers are quite useful for measuring the economic impact of a change in sales to final demand. At the regional level, for example a state, the single most important final demand sector of the input-

Table 8
Total Labor Requirements for the Consolidated
1976 Nebraska Input-Output Model

	Agric.	Min. & Manuf.	Trade	Services	F.I.R.E.	T.C.U.	Constr.	Maint. & Repair
Agric.	.22192	.05847	.00709	.00640	.00496	.00406	.01107	.01107
Min. & Manuf.	.02414	.17302	.01913	.01689	.01363	.01116	.03188	.03188
Trade	.08023	.04610	.64917	.08677	.06932	.05941	.07896	.07896
Services	.06584	.04586	.09614	.68813	.08115	.07204	.07021	.07021
F.I.R.E.	.11714	.06238	.14608	.13144	.59282	.08517	.08908	.08908
T.C.U.	.02194	.01764	.03616	.02587	.02091	.39606	.01745	.01745
Constr.	.00635	.00638	.00818	.00749	.00590	.00524	.40848	.40848
Maint. & Repair	0	0	0	0	0	0	0	0

Source: Derived from Tables 4 and 7.

output transactions table may be the exports column. The ability of a region to export products or services and derive income from "outside" the region greatly determines its rate of economic expansion. It is possible to measure the extent of regional economic expansion by using the total requirements table or the total labor requirements table. The total requirements table gives the total transactions associated with an expected change in sales to final demand. The total labor requirements table details the labor requirements necessary to support the expected change in sales to final demand.

Output Multipliers

A second type of sector multiplier is the sector output multiplier. Sector output multipliers can also be determined directly from a total requirements table. Basically, they are derived by dividing the cell values in each column of the total requirements table by that column's total requirement figure that has the same row and column heading. Consider, for example, the agriculture column of Table 4. The total requirements figure in the agriculture column with the same row and column heading is 1.36032. The figure of 1.36032 is divided into each of the cell values for the agriculture column. This gives the first column of Table 9. To give another example, the total requirements figure in the mining and manufacturing column (Table 4) with the same row and column heading is 1.11546. This figure is divided into each of the cell values for the mining and manufacturing column and forms the second column of Table 9. To complete Table 9, this procedure is repeated for the other producing sectors defined in Table 4. Note that Table 9 expresses output multipliers in terms of total transactions.

Table 9
Sector Output Multipliers for the Consolidated
1976 Nebraska Input-Output Model.

	Agric.	Min. & Manuf.	Trade	Services	F.I.R.E.	T.C.U.	Constr.	Maint. & Repair	Households
Agric.	1.00000	.32132	.03750	.03376	.02474	.02364	.05059	.06693	.03474
Min. & Manuf.	.11441	1.00000	.10637	.09373	.07150	.06832	.15317	.20265	.09980
Trade	.10533	.07382	1.00000	.13337	.10071	.10076	.10510	.13904	.14704
Services	.08172	.06942	.14002	1.00000	.11146	.11553	.08836	.11690	.14103
F.I.R.E.	.17857	.11596	.26130	.23458	1.00000	.16775	.13767	.18213	.21687
T.C.U.	.04289	.04204	.08292	.05918	.04523	1.00000	.03457	.04573	.04901
Constr.	.01533	.01879	.02319	.02118	.01576	.01634	1.00000	1.32297	.01689
Maint. & Repair	.01142	.01279	.01738	.01589	.01181	.01226	.01061	1.00000	.01263
Households	.40001	.37193	.83989	.83893	.64943	.60867	.53346	.70576	1.00000
	1.94968	2.02607	2.50857	2.43062	2.03064	2.11327	2.11353	3.78211	1.71801

Source: Derived from Table 4.

Although output multipliers and final demand multipliers are both determined from a total requirements table, there is an interpretative difference. This can be made clear by taking a closer look at the final demand multiplier for the agriculture sector (2.65218). Recall that this figure was determined by summing the cell figures for the agriculture column, and it gives the total requirements (transactions) associated with a dollar of sales to final demand by the agriculture sector. Of particular importance in this discussion is the cell value of 1.36032. This figure means that in order for the agriculture sector to sell one dollar of its output to final demand in 1976, it produced approximately $1.36 of output. Thus, the actual output produced, $1.36, exceeded the amount sold to final demand, $1.00, by the increase in interindustry demands that stemmed from the agriculture sector's sales of one dollar of its output to final demand. With an understanding as to why the actual output of the agriculture sector exceeds its dollar of sales to final demand, all figures in the agriculture column of Table 4 can be logically scaled down to give the total requirements associated with one dollar of agricultural output. The method for scaling down the column figures has already been indicated where this procedure is based on our earlier assumption of a proportional relationship between inputs and output.

Turning now to the output multiplier for the agriculutre sector in Table 9, the figure 1.94968 represents approximately $1.95 of activity generated in the State's economy when the agriculture sector produced one dollar of output in 1976. Similarly, the output multiplier for the mining and manufacturing sector represents 2.02607 of activity generated in the Nebraska economy for 1976 when mining and manufacturing produced a dollar of output.

From our earlier discussion of final demand multipliers, we anticipate that output multipliers can also be expressed in terms of labor requirements. This is done by multiplying the labor requirements coefficients of Table 7 by the appropriate rows in Table 9. We shall not make these calculations here since the procedure is identical to that used earlier in the derivation of Table 8.

Several uses can be made of output multipliers. Returning to the opening paragraphs of this section, we noted several questions relating to the closing of a government installation. With the use of the appropriate output multiplier, the total community economic impact of the installation's closing can be estimated. Suppose that an input-output model had been constructed for the community while the installation was still in operation. From the community input-output model, it would be possible to compute an output multiplier for the installation. Recall that an output multiplier estimates total requirements associated with $1.00 of output. Multiplying the output multiplier by the installation's current level of output gives the total requirements associated with the installation's operation. These requirements represent demands placed upon the community and viewed another way represent benefits to the community. Once the installation ceases its operation, these benefits are lost to the community.

Since the lost benefits represent outputs of supplying industries located in the community, it is possible to estimate the loss of tax revenue to the community. First, this requires the calculation of tax revenue per dollar of output for each producing industry located in the community. Such tax information is easily derived from an input-output transactions table that contains a local government sector as part of their payments. Next, each industry tax revenue coefficient is multiplied by that industry's estimated loss in output as a result of the closing of the installation. Finally, summing these products gives an estimate of the expected loss in tax revenue to the community.

The foregoing discussion is based on the use of an output multiplier that is figured from a total requirements table that reflects transactions. Calculating an output multiplier from the total labor requirements table (Table 8) would yield estimates of employment impact. In this case, the output multiplier would provide an estimate of the total number of persons who would become unemployed as a result of the closing of the installation.

The methodology just summarized to estimate the economic impact connected with the closing of an installation can also be used to estimate the economic benefit stemming from the construction and operation of a new industry in a community. For brevity of discussion, we shall discuss only the basic steps involved in this kind of study. First, it would require knowledge of the industry's production needs. One source of such information is input-output models of other areas that have this industry. Next, the production input information and knowledge of the community's resources would be combined to determine the extent to which the local community can supply these production needs. Finally, the estimates of the local supply of input requirements would be combined with the community's industry output multipliers to give an estimate of the economic impact in the community as a result of the new industry.

Income Multipliers

Income multipliers provide a third way to measure economic impact due to some change in industry output, where economic impact is measured in terms of income. Income multipliers can be computed from data contained in an input-output transactions table.

The most common income multipliers are Type I and Type II. The Type I multiplier is sometimes referred to a a "simple" income multiplier since it takes into account only the direct and indirect changes in income resulting from the interindustry requirements among the producing sectors. Therefore, the calculation of the Type I multiplier requires the derivation of a total requirements table that does not include households as a producing sector. Recall that the total requirements table of Table 4 includes households as a producing sector. The Type II multiplier is a more complete measure of income effects since it takes into account the direct and indirect effects among business establishments, i.e., the total requirements table that does not include households as a producing sector, plus the induced changes in income resulting from the increased consumer spending, i.e., the difference between the total requirements table that includes households as a producing sector and the total requirements table that does not include households as a producing sector. Thus, we should expect that for each producing sector the Type II multiplier will always be larger than its Type I counterpart.

The calculations associated with the derivation of both types of income multipliers are quite straightforward, using figures from a direct requirements table (Table 3), total requirements table with households in (Table 4), and a total requirements table with households out (Table 10).

Table 10
Consolidated Total Requirements Table for Nebraska, 1976, without Households
(Each cell shows the total requirements on the row sector per dollar of sales to final demand by the column sector)

	Agric.	Min. & Manuf.	Trade	Services	F.I.R.E.	T.C.U.	Constr.	Maint. & Repair
Agric.	1.34141	.34400	.00965	.00536	.00268	.00262	.04301	.04301
Min. & Manuf.	.10130	1.07406	.02614	.01162	.00822	.00798	.13409	.13409
Trade	.06327	.02133	1.01619	.01164	.00642	.01186	.03577	.03577
Services	.03443	.01893	.02500	1.02448	.02443	.03126	.01761	.01761
F.I.R.E.	.12490	.03937	.09176	.06116	1.05621	.03764	.02948	.02948
T.C.U.	.03167	.02656	.04841	.02099	.01647	1.02154	.01130	.01130
Constr.	.01165	.01395	.01043	.00815	.00588	.00638	1.32971	1.32971
Maint. & Repair	.00867	.00903	.00785	.00614	.00444	.00481	.00519	1.00519
Sector Multiplier	1.71730	1.54723	1.23543	1.14954	1.12475	1.12409	1.60616	2.60616

Source: Derived from Table 2.

The Type I multiplier is defined as the ratio of direct and indirect income effects associated with a producing sector's sale to final demand to the direct income coefficient for that sector. Column 2 of Table 11 gives the total of direct and indirect income effects associated with one dollar of sales to final demand by each producing sector. These figures were calculated in the following way. The figures for each column sector of Table 10 were multiplied by the corresponding household coefficients of Table 3. The individual results were summed to yield a measure of the total of direct and indirect effects for each producing sector selling to final demand. To illustrate this procedure, the Type I multiplier for agriculture will be developed. The procedure starts with the direct and indirect effects recorded in Table 10, more specifically the agriculture column of Table 10. For a brief review of the meaning of these figures, each row value is a measure of the gross output of that row sector associated with a dollar of sales to final demand by the agriculture sector in 1976. For instance, about 12 cents (0.12490) of the F.I.R.E. group's gross output was associated with one dollar of sales to final demand by the agriculture sector. Recall further that the figures in Table 10 do not include changes in sector outputs that are induced by changes in household incomes. The income effect associated with household expenditures is included in the Type II income multiplier. Next, the sector gross output figures in the agriculture column of Table 10 are converted to income, or household output, equivalents. This procedure is straightforward; each gross output figure recorded in the agriculture column of Table 10 is multiplied by the corresponding sector household input coefficient of Table 3. This procedure includes the following individual products: (<u>1.34141</u>) (.16314) + (<u>.10130</u>) (.15511) + (<u>.06327</u>) (.55993) + (<u>.03443</u>) (.59222) + (<u>.12490</u>) (.48222) + (<u>.03167</u>) (.37614) + (<u>.01165</u>) (.30443) + (<u>.00867</u>) (.00000). The underlined values are the agriculture column figures of Table 10. These figures are multiplied by the corresponding household coefficients of Table 3, which are reproduced as column 1 of Table 11. Notice that the above individual products are being summed. The objective is to arrive at a <u>total</u> of direct and indirect income effects. This total is recorded for agriculture in column 2 of Table 11. The totals of direct and indirect income effects for the other producing sectors were computed in a similar way, and their sums are recorded in column 2 of Table 11. Finally, to calculate the Type I income multiplier for the agriculture sector, the agriculture row figure in column 2 of Table 11 is divided by the agriculture row figure in column 1; that is, .36606/.16314 = 2.24384. This figure is recorded in column 3 of Table 11 along with the Type I multipliers for the other seven producing sectors.

In an input-output framework, the Type II income multiplier is the <u>ratio</u> of the direct, indirect, and induced income effects associated with a column sector's sale to final demand <u>to</u> the direct income coefficient for that sector. The first step in the derivation of the Type II multiplier is to set forth the figures in the household row of the total requirements table, which includes households as a producing sector, i.e., the household row of Table 4. These figures are recorded in column 4 of Table 11; these figures are then divided by the corresponding sector figures of column 1, which are the direct income coefficients from the

Table 11
Income Interactions for Nebraska, 1976

Sector	Direct Income Effects (1)	Direct and Indirect Income Effects (2)	Type I Income Multipliers (3)	Direct, Indirect and Induced Income Effects (4)	Type II Income Multipliers (5)
Agri.	.16314	.36606	2.24384	.54414	3.33542
Min. & Manuf.	.15311	.27909	1.79930	.41487	2.67468
Trade	.55993	.65506	1.16990	.97374	1.73904
Services	.59222	.65578	1.10732	.97480	1.64601
F.I.R.E.	.48222	.53709	1.11379	.79838	1.65563
T.C.U.	.37614	.43115	1.14625	.64090	1.70389
Constr.	.30443	.48154	1.58178	.71580	2.35128
Maint. & Repair	0	.48154	---	.71580	---

Source: Derived from Tables 3, 4 and 8.

household row of the direct requirements table of Table 3. The result yields Type II income multipliers which are recorded in column 5 of Table 11.

Income multipliers represent an alternative way of expressing economic effects associated with a change in a sector's sales to final demand. For a clear understanding of income multipliers, it is important to remember that sector changes in sales to final demand are being converted to income equivalents. To elaborate, the direct requirements table (Table 3) shows that for each producing sector, a change in one dollar of sector output results in a fractional change in household income. Expanding this relationship, a one dollar change in a sector's sales to final demand will also result directly in a fractional change in household income. Conversely, a direct change of one dollar in household income means that sales to final demand increased by more than one dollar. The exact amount of the change is not important in our interpretation. Realizing that a one dollar change in household income reflects some multiple change in sales to final demand, i.e., exports, the basic interpretation of Type I and Type II income multipliers is that a one dollar change in income paid directly to households by the exporting sector results in income changes in other producing sectors that directly and indirectly supply inputs to the exporting sectors. Therefore, there is a multiple income effect; hence the name income multiplier. From the previous discussion of the "household in/household out" treatment of the household sector, the technical distinction between the Type I and Type II income multipliers should be apparent.

Reliable Estimates

It must be remembered that the multipliers just discussed are couched in the assumptions used to convert the input-output transactions table to an analytical model. Consequently, the accuracy of these multipliers depends greatly on the validity of these assumptions. To review, these assumptions are: 1) that a proportional relationship exists between inputs and output; 2) that the input coefficients are average relationships; and 3) that there is no substitution of production factors. For discussion purposes, these related assumptions can be reduced to one basic assumption, that of fixed factor proportions.

The validity of the more general assumption of fixed factor proportions is related to the degree of industry aggregation used in the construction of the input-output transactions table. Industry aggregation, as used here, refers to the grouping of producing units, for example establishments, into producing industries or sectors. At one extreme, complete aggregation of all producing units would result in an input-output transactions table with one producing sector only. The sector row of the transactions table would show the distribution of final output to households, government, investment, and export. The sector column would show the way in which factor payments were distributed among wages, rent, depreciation, taxes, and profits. Such a table would not show interindustry transactions, and hence interindustry relations. At the other extreme, each producing unit of the region would be shown in the input-output transactions table as a separate producing sector. The number of rows and columns in the producing quadrant of the transactions table would equal the number of producing units in the region. It is true that this detailed input-output transactions table would give a complete picture of interindustry relations, but it would produce confusion by its sheer complexity. Obviously, neither extreme is used in the construction of an input-output transactions table. The first task in that construction is to determine the degree of aggregation which will make the best use of obtainable statistical information, on the one hand, and render validity to the assumption of fixed factor proportions on the other. While the availability and quality of data, along with industry aggregation, affect the accuracy of the results, it is our intent here to concentrate on the association between the validity of the assumptions and the degree of industry aggregation. To this end, we shall discuss the major conditions that need to be satisfied to render validity to the basic assumption of fixed factor proportions.

One condition is that the substitution of one input factor for another must be negligible. A very fine classification of industry groups may result in closely substitutable produced inputs being put into different industry categories. If input substitution occurs, because of, say, a price change, the interindustry relations after the substitution would differ from the industry relations before the price change. The possibility can be largely avoided by classifying closely substitutable inputs in the same industry category.

A second condition is that no significant excess capacity exists in the industry group. This is an important condition because with excess capacity or very large inventories of some inputs it may be possible for output to be increased without proportional increases in these inputs. A larger degree of industry aggregation would mean that excess stocks of inputs by some establishments would tend to be cancelled out by depleted stocks of other establishments.

A problem similar, but not identical, to excess stocks is input indivisibilities. An indivisible input is one where a unit of input suffices over a range of output, thus disproving the fixed factor proportions assumption. Sufficient industry aggregation will minimize this problem as some establishments in the industry group will purchase indivisible inputs to expand production while others will be able to expand output without an increase in such outputs. Thus the average input requirements for the industry group will tend to be more proportional to the increase in output if a large number of establishments are in the industry group.

As a fourth condition, changes in technology must not occur. Obviously, this is an unrealistic condition, but again the broader the industry classification, the more likely it is that the effects of different technologies will cancel out.

The fifth condition is that constant returns to scale exist for the industry group. This is a realistic condition because aggregation will tend to average out internal differences of economies of scale. Within the industry group, some establishments may be enjoying internal economies of scale, that is, lower average production costs with higher levels of output. The assumption of fixed factor proportions is not valid in this case. But other producers of the same industry group may be experiencing internal diseconomies of scale, that is, higher average production costs with higher levels of output. An aggregation of establishments with reversed average cost schedules would tend to cause a cancellation, and hence the average cost schedule for the industry group would approximate the fixed input-output relationship that is assumed in input-output analysis.

A final condition that underlies the basic assumption of fixed factor proportions is a constant interregional trade pattern. The degree of industry aggregation has, however, little effect upon the pattern of interregional trade. The constancy of interregional trade is mainly related to the size of the region under study. As said earlier, a county is likely to show a greater variation in its trade pattern than a multi-state region.

In summary, knowledge of how aggregation affects the validity of the basic assumption of fixed factor proportions is helpful in two ways. First, this knowledge aids the analyst in determining the degree of aggregation which best meets the above conditions that underlie the basic assumptions. Second, and equally important, such knowledge provides an awareness of how changes in, for instance, resource prices may affect input-output relations. Equipped with an understanding of what the basic input-output assumption implies, it is possible for the researcher to make adjustments in his final estimates where these adjustments reflect some known change in the region's economic structure.

Preparing a Regional Input-Output Transactions Table

A complete discussion of the preparation of a regional input-output transactions table is beyond the scope of this paper. The amount of technical detail involved in, and the number of alternative techniques available for, constructing a regional transactions table is substantial. In addition, a significant amount of judgement concerning interindustry relations, imports, exports, and the like plays an important role in the construction of a regional table. These matters are appropriately discussed in input-output manuals (see, for example, Isard, Walter, and Thomas W. Lanford, Jr., Regional Input-Output Study: Recollections, Reflections, and Diverse Notes on the Philadelphia Experience, Cambridge Massachusetts: MIT Press, 1971).

It should be briefly mentioned, however, that the tabular construction of interindustry relationships involves two parts: 1) the definition of sectors which includes the definitions of sector outputs, and 2) the calculation of interindustry transactions for the accounting period under study. These two parts are obviously related. The type of data required in the construction of the input-output table may depend on the degree of disaggregation of the region's economy into producing sectors. Much has been written on the subject of data requirements, more specifically survey techniques vs. nonsurvey techniques (see, for example, Edelstein, Robert H., Methodology of Regional and Subregional Input-Output Studies, Report No. 8, Cambridge, Massachusetts: Harvard Economic Research Project, June 1978; or McMenamin, David G., Constructing and Testing a Regional Minimum-Survey Input-Output Table, MR-182, Institute of Government and Public Affairs, University of California, Los Angeles, 1973).

Footnotes

1. The usual practice in the construction of a set of input-output tables is to calculate two basic total requirements tables, due to the treatment of the household sector. In the construction of one of the total requirements tables, the household sector is treated as a component of final demand. This means that the economic effects of changes in household incomes are not included in economic impact estimates. With the inclusion of households as a producing sector in the second total requirements table, any economic effects associated with household income changes are measured. The discussion that follows treats households as a producing sector.

2. By convention, the entries in a total requirements table are developed to reflect a one dollar sale to final demand. Hence, the unit of measurement is a dollar of sales to final demand by each individual producing sector. This means that the entries in the total requirements table can be easily applied to a producing sector's actual change in sales in final demand (increase/decrease) to determine the total economic impact of this change on the region's economy.

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VI. MEASURING REGIONAL ECONOMIC IMPACT ASSOCIATED WITH UNFAVORABLE CLIMATIC CONDITIONS DURING CROP PRODUCTION PERIODS: A CONCEPT PAPER

Charles Lamphear

A regional input-output model can be used to measure the economic impact associated with unfavorable crop growing conditions. Like any analytical model, however, various assumptions must be made to adapt a regional input-output model to this task. These assumptions are in addition to those discussed in the instructional paper entitled "Regional Input-Output Models: Understanding Their Application" which are common to all regional input-output models (Chapter V).

The procedure followed in this paper will be to conceptualize the mechanics involved in the use of a regional input-output model to measure climate-related economic impacts. Along with this discussion, various assumptions special to this task will be noted.

Model Formulation and Specification

Crop Selection

A variety of crops are typically grown in most agricultural regions - from field crops such as corn to garden crops such as potatoes. These various crops have different growing seasons, and they are affected by climatic conditions in quite different ways. Furthermore, there are substantial differences in the input requirements for the various crops. Theoretically speaking, these differences mean that each crop grown in the study region should be represented in the input-output transactions table as a separate producing sector. But to develop this degree of sector detail would be impractical. To keep the modeling effort manageable, it is reasonable to focus only on the major crops grown in the study region. For Nebraska, as an example, the major crops are corn, sorghum, wheat, soybeans, and hay. Each major crop can be identified in the transactions table as a separate producing sector. The remaining, less-important crops can be aggregated to form an "all other crops" sector.

Other Producing Sectors

As a general statement, the level of economic disaggregation followed in the definitions of non-agriculture sectors depends on the level of detail required in the assessment of economic impact. To partially address the issue here, it would seem important to identify, with some detail, those businesses that are most affected by climate-related crop production failures. Less detail could be used in defining non-agriculture related sectors. To be more specific, three-digit Standard Industrial Classification (SIC) level disaggregation would seem desirable for those activities that are a part of the agricultural industrial complex, for example food processing establishments and suppliers of agriculture's inputs for production purposes. Broad sector definitions could be used to aggregate business establishments that have little in common with agriculture. For example, manufacturers of furniture and fixtures, recreational vehicles, surgical instruments, and the like could be grouped into broad sector descriptions. A similar design could be followed for the non-manufacturing establishments (i.e., trade, services, utilities, and construction) that are only remotely associated with agriculture and its industrial complex.

Table 1

Classifying Producing Sectors: An Illustration

Crop Sectors	Agricultural Complex Sectors: Agriculture Suppliers	Agricultural Complex Sectors: Agriculture Processors	Other Producing Sectors
Corn	Agriculture Chemicals	Livestock & L.S. Products	Other Chemicals
Sorghum	Farm Machinery Manufacturers	Grain Mill Products	Printing and Publishing
Wheat	Agriculture Services	Dairy Products	Electrical Machinery
Soybeans	Transportation	All Other Food Products	-
Other Crops	Farm Implement Dealers	Wholesale of Farm Products	-
	Finance		Other Manufacturing
	Insurance		Eating and Drinking
	Hardware and Farm Supply Stores		-
	Motor Fuels and Electricity		Other Retail
			-
			Other Wholesale
			Business Services
			-
			Other Services
			Other Utilities
			Construction

Table 2
Regional Input-Output Transactions Table:
An Illustration

To / From	Crop Sectors	Agricultural Complex Sectors	Other Producing Sectors	Final Demand	Total Transactions
Crop Sectors					
Agriculture Complex Sectors					
Other Producing Sectors					
Other Products					
Total Purchases					

For illustrative purposes only, Table 1 shows a sector classification layout that provides considerable detail for assessing the kind of economic impact addressed in this paper. Limiting the number of sectors is desirable in input-output analysis for reasons discussed in the previously mentioned paper. Incidentally, to keep Table 1 brief, only a partial listing of "other sectors" is given.

Transactions Table Format

The list of producing sectors listed in Table 1 make-up the Quadrant I portion of a regional input-output transactions table. Disaggregating final demand (Quadrant II) into three sectors - households, exports, and other final demand - would seem appropriate for this study. Similarly, disaggregating other payments (Quadrant III) into households, imports, and rest-of-other payments would provide sufficient detail. Special attention needs to be made here to note that the household sector is treated as an exogenous sector. (See the paper entitled "Regional Input-Output Models: Understanding Their Application" for an extended discussion of the treatment of the household sector.) Recall that Quadrant IV is the intersection of the final demand column sectors with the other payments row sectors. Hence, Quadrant IV does not add any additional rows or columns to the table. Table 2 illustrates the kind of regional input-output transactions table being discussed here.

Identification and Measurement of Impact

Base-line Model

In order to measure the economic effect of adverse weather conditions on a region's economy, a base-line regional input-output transactions table is required. This table represents the region's economy under normal conditions, where normal conditions simply mean the absence of erratic economic situations. Unsteady situations are generally the rule for agriculture rather than the exception. Such factors as fluctuating farm prices, year-to-year crop carryovers which affect annual income from farm marketings, erratic weather conditions, and the like suggest that several years of production data should be used to estimate average input-output relations for the crop sectors. Generally, this erratic situation is limited to agriculture, and therefore single year production data can be used to determine average input-output relations for the non-agriculture producing sectors.

The base-line input-output transactions table, reflecting typical (or normal) economic relations, provides the basis for measuring so-called induced-by effects and stemming-from effects.

Induced-by Effects

The producing sectors listed in Table 1 under the general heading of Agriculture Complex are subdivided into two broad groups: suppliers and processors. Suppliers are involved in the various cropping operations, such as tilling, planting, cultivating, and harvesting. In an inter-industry framework, the inputs from these supplying sectors to the crop sectors represent "backward" transactions linkages, or viewed another way these inputs are induced-by the various operations associated with crop production. Since these inputs are required for crop production purposes, the induced-by effects are well-recognized.

However, an important point to consider in the measurement of induced-by effects is the time-stream of input requirements over the crop production season. To illustrate this point, consider the following comparative case. Imagine that a normal growing season prevails, and the crop is harvested, producing a normal yield. In contrast, imagine that the crop is completely destroyed by hail just prior to harvest time. The inter-industry transactions associated with tilling, planting, and cultivating would be the same in both situations. However, there would be no harvest cost in the second situation, resulting in a smaller total induced-by effect than that of the first situation, where the crop was harvested. In short, the economic extent of the induced-by effects depends on the time that the adverse climatic condition occurs during the growing season.

Turning to a more detailed discussion of the methodology to measure induced-by effects, crop production expenditures must be classified on the basis of cropping operations; for example, those costs associated with tilling must be kept separate from expenses associated with other crop operations, such as planting and harvesting. This detailed classification of crop production costs applies to each of the defined crop sectors in the regional input-output transactions table.

The use of detailed production cost information is in the construction of an adjusted regional input-output transactions table.[1] The kinds of crop expenditures that are entered in the adjusted transactions table will depend on the nature of the simulated weather condition.

Basically, the methodology being proposed here involves a comparison of interindustry activity exhibited in the base-line model for the crop sectors with comparable interindustry activity exhibited in an adjusted input-output transactions table, where these adjustments reflect the nature of some simulated climatic condition. For the moment, we will discuss how this adjusted table is developed. Later, we will discuss how the adjusted model is to be compared with the base-line table in order to estimate the induced-by effects of adverse climatic conditions.

To begin, the base-line input-output transactions for the crop sector rows and columns of the table are adjusted to reflect a particular climatic condition. Each crop's relative distribution of sales (the crop sector rows) is adjusted in order to maintain base-line levels of crop inputs to the region's crop processing sectors. This means that any decline in crop output, due to adverse climatic conditions, is shifted to a decline in sales to final demand. Base-line levels of regional crop processing are maintained in order to separate induced-by effects from stemming-from effects, which are discussed later. Next, the crop sector columns of the base-line transactions table are adjusted to reflect the relation between the nature of the simulated climatic condition and the time-stream of crop production expenses. It is reasonable to assume that alterations in interindustry relations due to adverse climatic conditions will be confined to the crop sector rows and columns. Except for some alterations in a few non-agriculture sectors, which will be discussed in a moment, the construction of the adjusted transactions table simply involves the above points.

The mechanics of the methodology can best be understood by illustrating a hypothetical situation. Imagine that Table 3 represents a base-line input-output transactions table for the region under study. To limit the technical detail, the base-line model exhibits a high level of industry aggregation. It displays only five producing sectors.

Table 3
Base-line Input-Output Transactions
Table: A Hypothetical Illustration

From \ To →	Crops	Manufac-turing	Trade	Utilities	Services	Final Demand	Total Transactions
Crops	20	40	0	0	10	70	140
Manufacturing	20	30	30	60	30	30	200
Trade	10	20	70	20	60	110	290
Utilities	20	50	60	40	50	80	300
Services	10	20	40	20	20	140	250
Other Payments	60	40	90	160	80	20	450
Total Purchases	140	200	290	300	250	450	1630

Now suppose that the input requirements for the crop sector column of Table 3 have been adjusted to reflect some adverse climatic condition. The adjusted figures are given in the crop sector column of Table 4, which is the adjusted transactions table. Suppose further that the adverse weather condition resulted in a reduction in crop output. The new crop output level is shown in Table 4 as the crop sector row/column sum, i.e., \$122. For the crop sector column of Tables 3 and 4, notice that direct input requirements are reduced by \$2 from manufacturing, \$1 from trade, \$5 from utilities, and \$10 for other payments. With the possible exception of the adjustment of \$10 for the other payments sector, these adjustments reflect reduced sales to the crop sector. This raises a critical question of how to handle these reduced sales in other parts of the transactions table. Table 4 shows that for the "goods" producing sectors, a reduction in sales to the crop sector means a corresponding increase in sales to final demand. This procedure is based on the argument that producers of material goods establish production levels on projected market conditions. Therefore, the occurrence of some unforeseen event, such as a drought, means an unexpected increase in the net inventory of finished goods, which is part of final demand.[2]

Devising reasonable procedures for adjusting the non-goods producing sectors is more difficult. It is unreasonable to assume that the output levels of the non-goods sectors will remain unchanged after a reduction in sales to the crop sector. Simply put, a "finished-goods-inventory" entry does not apply to, say, trade-and-service-type activity. In view of this, it seems reasonable to reduce the output levels of the non-goods sectors by the amount of reduction in sales to the crop sector. Notice

Table 4
Adjusted Input-Output Transactions
Table: A Hypothetical Illustration

From \ To →	Crops	Manufacturing	Trade	Utilities	Services	Final Demands	Total Transactions
Crops	20	40	0	0	10	52	122
Manufacturing	18	30	30	60	30	32	200
Trade	9	20	70	20	60	110	289
Utilities	15	50	60	40	50	80	295
Services	10	20	40	20	20	140	250
Other Payments	50	40	89	155	80	20	434
Total Purchases	122	200	289	295	250	434	1590

that in comparing Tables 3 and 4, the output levels for the trade and utilities sectors have been reduced by the amount of reduced sales to the crop sector - $1 and $5, respectively.[3]

Finally, notice that certain adjustments have been made in the other payments row of Table 4. Briefly, these adjustments reflect reductions in personal income and/or reductions in retained earnings.[4]

Once the adjusted input-output transactions table has been finalized, the next step is the computation of a crop output multiplier both for the base-line model and the adjusted model. The crop output multipliers for Tables 3 and 4 are 2.023 and 2.033, respectively.[5]

It is possible that the adjusted crop output multiplier will be larger than the base-line crop output multiplier. This means that the decline in crop output is greater than the associated decline in crop inputs. Again, this reflects the nature of the crop season and the associated time-stream of crop production expenses. Viewed somewhat differently, the purchase of, say, fertilizer becomes, in effect, a fixed expense once the crop is planted. The size of the input coefficient for fertilizer, measured in dollars, depends on the amount and value of the harvested crop.

Multiplying the crop output multipliers by the corresponding crop outputs yields total induced-by effects. For the base-line model, the total induced-by effect is $283.22 (2.023 x $140). For the adjusted model, the total induced-by effect is $248.03 (2.033 X $122). The difference of $35.19 is an estimate of the induced-by effects associated with the adverse climatic condition modeled in the hypothetical situation of Tables 3 and 4.

The figure of \$35.19 does not include the economic effect associated with changes in household incomes. This figure represents a decline in total industry requirements due to a decline in the direct requirements of the crop sector.

The loss of interindustry transactions associated with the decline in crop activity, i.e., the \$35.19, will mean a change in household income for many or all of the producing sectors. However, much of this change will be confined to the agriculture sector. But the extent of this change is not known. For instance, it is quite possible that a climatic condition which affects crop yields over a large portion of a major agricultural region will result in an increase in the market prices of farm crops. This could result in an increase in farm income. Assuming for the moment that this situation occurs, it is most difficult to predict how this increase in farm income will be expended. Much of the increase may be used to purchase capital items that tend to reduce the influence of adverse climatic conditions on crop output, such as irrigation equipment. Alternatively, much of the increase in farm income may be used to purchase desired household items. Consequently, the appropriate input-output multiplier(s) to use in order to pick-up the induced-by effects operating through the household sector depends largely on (a) the association between adverse climatic conditions and farm income, and (b) the capital investment/household consumption decisions of farmers. The suggested way to treat this cloudy issue is to make several induced-by estimates based on reasonable alternative assumptions on (a) the nature of changes in household income and (b) how each assumed change in household income will affect household consumption/capital investment patterns. A detailed discussion of appropriate alternative assumptions and associated methodology is outside the scope of this concept paper.

As a final comment, it is important to note that the difficult manner of handling household income is not an indication of any basic limitation of input-output analysis. In fact, the detailed interindustry framework of input-output analysis helps one to be aware of all the various kinds of economic impact.

Stemming-from Effects

Stemming-from effects pertain to the activity of users, or in this paper processors, of the output(s) of the sector(s) under study. This returns us to Table 1 for an illustrated list of users of crop output; that is, crop processors.[6] The interindustry transactions between crop producing sectors and crop processing sectors are called "forward linkages." Interindustry transactions associated with crop processing therefore stem-from crop production.

However, in regards to estimating economic impact, it is much more difficult to identify the stemming-from impacts than the induced-by impacts. Consider, for illustrative purposes, that a region's crop output has been substantially reduced because of some adverse weather condition. It is difficult to say that this situation will, in turn, result in a corresponding decline in crop processing for the region. The adverse weather condition may simply result in a reduction in the volume of crop exports. In fact, it is possible that the region's crop processing sectors may even expand their operations, reflecting an expected increase in national/world markets for their products. On the other hand, the local availability of crops for regional processing may be reduced because of adverse weather conditions. To adjust to this situation, regional processors may simply import a greater volume of crops, and therefore maintain planned levels of crop processing. These few illustrations simply point out the fact that any estimate of so-called stemming-from effects is generally open to appropriate criticism, meaning that it is not the basic model that is open to criticism, but rather only the appropriateness of the assumed changes in the forward linkages.

Once it has been determined how changes in regional crop production will affect the level of crop processing within the region, the procedures for estimating stemming-from effects are similar to those used to measure induced-by effects. The similarity in methodologies can be illustrated by returning to the hypothetical case of Tables 3 and 4. Recall from the earlier discussion that the adverse climatic condition modeled in Table 4 resulted in a decline in crop output of \$18. Recall further that in order to estimate the induced-by effects this decline in crop output of \$18 was treated in the adjusted input-output transactions table as a decline in sales to final demand. It is now to be assumed that this decline results in a corresponding decline in regional crop processing, suggesting a definite cause-and-effect relationship between crop production and crop processing. Based upon the proportionality assumption of input-output analysis, this means that the level of crop processing will decline from \$200 to \$110, or result in a net reduction in crop processing of \$90 ($40/200 = 22/x$; $x = \$110$).[7] This reduction means that fewer non-crop inputs will be purchased by the crop processing sector and also by related sectors, and industry workers will be laid off, resulting in a decline in aggregate household income. A decline in household income, in turn, means a further reduction in regional economic activity. The household income portion of the stemming-from effects will be discussed at the close of this section. Multiplying the output multiplier of 2.143 for this sector by the net reduction in the output of crop processing yields an estimate of the stemming-from effects without households associated with the adverse climatic condition modeled in Table 4. This estimate is \$172.87 (2.143 x \$90).

As already indicated, the figure of \$192.87 does not include the effects of reduced household incomes. To capture the stemming-from effects on the household side requires the calculation of a total requirements table that includes the household sector as a producing sector. With households included, the output multiplier for the crop processing sector is 2.857. (The total requirements table used to obtain this multiplier is not given in this paper.) Multiplying the change in crop output of \$90 times the output multiplier of 2.857, with households in, yields a total stemming-from effect of \$257.13. The difference of \$64.26 (\$257.13 - \$192.87 = \$64.26) estimates the decline in regional economic activity due to a reduction in household incomes and hence a reduction in household consumption.

Summary

Economic impact assessment includes 1) induced-by effects, including household income effects, and 2) stemming-from effects, including household income effects. Analytical procedures for estimating these kinds of economic effects have been discussed in this paper. It is realized that there are numerous places in the methodology that need further articulation and refinement.

There is an important final point to be made here. Once various impacts have been defined in tidy numeric (cardinal) terms, common belief has it that their numbers can then be added to arrive at a total impact estimate. It is hoped that the emphasis given to assumptions in this paper provides, however indirect, an opposite view to the belief that these numbers are additive.

Direct Requirements Table:
Base-line Model

From \ To →	Crops	Manufac-turing	Trade	Utilities	Services
Crops	0.1429	0.2000	0.0	0.0	0.0400
Manufacturing	0.1429	0.1500	0.1034	0.2000	0.1200
Trade	0.0714	0.1000	0.2414	0.0667	0.2400
Utilities	0.1429	0.2500	0.2069	0.1333	0.2000
Services	0.0714	0.1000	0.1379	0.0667	0.0800

Total Requirements Table:
Base-line Model

From \ To →	Crops	Manufac-turing	Trade	Utilities	Services
Crops	1.2646	0.3576	0.1040	0.1021	0.1510
Manufacturing	0.3772	1.4743	0.3819	0.4000	0.3953
Trade	0.2736	0.3764	1.5293	0.2440	0.5130
Utilities	0.4314	0.6412	0.5662	1.3878	0.5518
Services	0.2114	0.2909	0.3199	0.1886	1.2585
Final Demand Multiplier	2.5582	3.1404	2.9013	2.3225	2.8696
Output Multiplier	2.0229	2.1301	1.8971	1.6735	2.2802

Direct Requirements Table:
Adjusted Model

From \ To →	Crops	Manufacturing	Trade	Utilities	Services
Crops	0.1639	0.2000	0.0	0.0	0.0400
Manufacturing	0.1475	0.1500	0.1038	0.2034	0.1200
Trade	0.0738	0.1000	0.2422	0.0678	0.2400
Utilities	0.1230	0.2500	0.2076	0.1356	0.2000
Services	0.0820	0.1000	0.1384	0.0678	0.0800

Total Requirements Table:
Adjusted Model

From \ To →	Crops	Manufacturing	Trade	Utilities	Services
Crops	1.3019	0.3692	0.1087	0.1077	0.1565
Manufacturing	0.3960	1.4836	0.3892	0.4111	0.4016
Trade	0.2911	0.3841	1.5357	0.2515	0.5180
Utilities	0.4239	0.6431	0.5721	1.3966	0.5552
Services	0.2341	0.2993	0.3252	0.1950	1.2634
Final Demand Multiplier	2.6470	3.1793	2.9309	2.3619	2.8947
Output Multiplier	2.0332	2.1430	1.9085	1.6912	2.2912

Footnotes

1. It should be noted here that the base-line and adjusted transactions tables exclude the household sector from the group of producing sectors. The reason for this is to measure household income effects separately. This matter will be discussed later.

2. This is a critical assumption, and therefore its practical relevance should be thoroughly debated.

3. Technically speaking, a producing sector's change in output will exceed its change in sales by some multiple of the change in sales. In terms of the adjusted levels for the trade and utility sectors of Table 4, this means that each sector's output should be reduced by more than the reduction in sales to the crop sector. This greatly complicates the adjustment procedure because a change in one sector's sales triggers the need to adjust the output levels of related producing sectors, and so on across all the various rounds of transaction effects. The practical relevance for making these more refined adjustments needs to be questioned.

4. Throughout the foregoing discussion on adjusting the base-line input-output transactions table to estimate the induced-by effects, it was assumed that the simulated adverse climatic condition was region specific. This is an important assumption because any reduction in crop output due to, say, a localized drought is insignificant in terms of the nation's total crop production. Therefore, market prices for farm crops will not be significantly affected by region-specific adverse climatic conditions. The relevance of this basic assumption needs to be discussed. There are procedures available to alter relative price relationships for the adjusted input-output transactions table, providing it is possible to estimate the effects that various adverse climatic conditions have on the market prices for farm crops.

5. See the Appendix for the total requirements tables that were used to derive these output multipliers. For a discussion of how output multipliers are computed, see "Regional Input-Output Models: Understanding Their Application." (See Chapter V)

6. As a technical point, users are being defined here as producing sectors that purchase inputs from regional producers for their own production purposes. Thus we are focusing on intermediate demands vs. final demands.

7. Since the hypothetical base-line input-output transactions table of Table 3 (and the corresponding adjusted Table 4) does not contain a separate crop processing sector, the manufacturing sector of Tables 3 and 4 is being used here as the crop processing sector. Therefore, the crop-to-manufacturing transactions figure of $40 (Table 3) represents the purchase of crops for crop processing.

VII. POSSIBLE APPLICATIONS OF INPUT-OUTPUT MODELS IN CLIMATIC IMPACT ASSESSMENTS

William Cooter

Regional Input-Output Analysis

Regional Models Driven by Demand

The most commonly used form of input-output analysis involves a set of matrix materials for a specified region where predictions of levels of final demand for the output of various economic sectors is used to generate estimates of interindustry purchases and sales involving all the sectors of the economy. Analysis begins from a comprehensive tabulation of transactions giving dollar values for intersectoral inputs and outputs for a given base year. A hypothetical transactions table for a three sector economy is given below in Figure 1.

Input \ Output		Sectors: 1 Ag.	2 Util.	3 Const.	Final Demand	Total Output
	1 Agriculture	x_{11}	x_{12}	x_{13}	y_1	x_1
Sectors	2 Utilities	x_{21}	x_{22}	x_{23}	y_2	x_2
	3 Construction	x_{31}	x_{32}	x_{33}	y_3	x_3
Primary Inputs		v_1	v_2	v_3	0	
Total Inputs		x_1	x_2	x_3		

Figure 1. Hypothetical Transactions Table

For illustrative purposes, consider the three economic sectors, or industries, as agriculture, utilities, and construction. If a given column is considered, for instance, sector 1 or agriculture, the transactions table can be interpreted to mean that to produce its output, agriculture must buy dollar inputs of x_{11} from other agricultural enterprises, x_{21} from utilities, and x_{31} from construction. Agriculture must also buy primary inputs of value v_1. These primary inputs would include expenditures for wages paid out to labor, profits to agribusiness shareholders, payments for items imported from outside the region, and so forth. The total inputs would be of value x_1, which is the sum of $x_{11} + x_{21} + x_{31} + v_1$. The value of all the outputs of agriculture available for purchase is obtained by reading across the sector 1 row. Agriculture produces a value x_{11} which it purchases itself, a value x_{12} purchased by utilities, and a value x_{13} purchased by construction. A value y_1 is sold for ultimate consumption or final demand. These ultimate consumers would include households buying food and fiber products for their sustenance or enjoyment. Purchases by governments, additions to inventories, and export sales would also figure in the final demand category. The total value of agricultural outputs would be x_1, the sum of $x_{11} + x_{12} + x_{13} + y_1$.

A similar logic would apply to the other sectors. With allowance for factors like imports and exports, the column sum $y_1 + y_2 + y_3$ represents a major constituent of the gross regional product, GNP for a nation. The column sum $x_1 + x_2 + x_3$ represents the total output of the regional economy. Input-output analysis assumes a state of economic equilibrium where each sector's total inputs equal that same sector's total outputs.

Ordinarily a fixed technological recipe is assumed for each sector, whereby purchases by each sector are set at a fixed ratio to total sectoral outputs. If a transactions matrix is defined as

$$T = \begin{bmatrix} x_{11} & x_{12} & x_{13} \\ x_{21} & x_{22} & x_{23} \\ x_{31} & x_{32} & x_{33} \end{bmatrix}$$

then a matrix A of technical coefficients can be defined in terms of sectoral outputs x_1, x_2 and x_3 as follows:

$$T = A \begin{bmatrix} x_1 & 0 & 0 \\ 0 & x_2 & 0 \\ 0 & 0 & x_3 \end{bmatrix} .$$

In other words,

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} = T \begin{bmatrix} x_1 & 0 & 0 \\ 0 & x_2 & 0 \\ 0 & 0 & x_3 \end{bmatrix}^{-1} = T \begin{bmatrix} 1/x_1 & 0 & 0 \\ 0 & 1/x_2 & 0 \\ 0 & 0 & 1/x_3 \end{bmatrix} .$$

If a vector of final demands is defined where

$$Y = \begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix}$$

and

$$X = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

it can be shown that the following matrix equation represents row by row sums of information in the original transactions table:

$$\underbrace{AX}_{\text{intermediate output}} + \underbrace{Y}_{\text{final demand}} = \underbrace{X.}_{\text{total output}}$$

If

$$B = (I - A)^{-1}$$

then

$$X = BY.$$

Given any set of values for a final demand vector $\hat{Y} = (\hat{y}_1, \hat{y}_2, \hat{y}_3)^T$, the values of an output vector $\hat{X}$ can be determined. Using the matrix A of technical coefficients and the values of the vector $\hat{X} = (\hat{x}_1, \hat{x}_2, \hat{x}_3)^T$, a new matrix of interindustry transactions can be determined from the relation

$$T_{new} = A \begin{bmatrix} \hat{x}_1 & 0 & 0 \\ 0 & \hat{x}_2 & 0 \\ 0 & 0 & \hat{x}_3 \end{bmatrix} .$$

This provides most of the information needed to fill in a new transactions table. The only missing information concerns values for the primary inputs $\hat{v}_1$, $\hat{v}_2$ and $\hat{v}_3$. These can be determined from the following bookkeeping expressions:

$$\hat{v}_1 = \hat{x}_1 - (\hat{x}_{11} + \hat{x}_{21} + \hat{x}_{31}),$$
$$\hat{v}_2 = \hat{x}_2 - (\hat{x}_{12} + \hat{x}_{22} + \hat{x}_{32}),$$
and
$$\hat{v}_3 = \hat{x}_3 - (\hat{x}_{13} + \hat{x}_{23} + \hat{x}_{33}).$$

The new transactions table would now be represented as in Figure 2 below.

	Input \ Output	Sectors 1	Sectors 2	Sectors 3	Final Demand	Total Output
Sectors	1	$\hat{x}_{11}$	$\hat{x}_{12}$	$\hat{x}_{13}$	$\hat{y}_1$	$\hat{x}_1$
	2	$\hat{x}_{21}$	$\hat{x}_{22}$	$\hat{x}_{23}$	$\hat{y}_2$	$\hat{x}_2$
	3	$\hat{x}_{31}$	$\hat{x}_{32}$	$\hat{x}_{33}$	$\hat{y}_3$	$\hat{x}_3$
	Primary Inputs	$\hat{v}_1$	$\hat{v}_2$	$\hat{v}_3$		
	Total Inputs	$\hat{x}_1$	$\hat{x}_2$	$\hat{x}_3$		

Figure 2. New Transactions Table

Variations in this basic approach can be obtained by adding or deleting rows and columns from the transactions matrix. For instance, sectoral salaries and wages in the primary input category along with sectoral consumption values by households in the final demand category are often separately determined to create a household row and column. In the original transactions table (Figure 1), the primary input row and column were as follows:

				Final Demand
				y_1
				y_2
				y_3
Primary Inputs	v_1	v_2	v_3	0

Figure 3. Original Primary Input Row and Final Demand Column

Specifying a household row and column would yield the following:

				Households	Other Final Demand
				x_{14}	y_1
				x_{24}	y_2
				x_{34}	y_3
Households	x_{41}	x_{42}	x_{43}	x_{44}	y_4
Other Inputs	v_1	v_2	v_3	0	0

Figure 4. Household Row and Column Specified

Given the values in our original transactions table, it can be seen that in this case x_{44} and y_4 have values of zero. For analytical purposes, though, the algebraic identity of these two values is preserved.

An enlarged matrix of technical coefficients may now be defined. If the value x_4 is taken to be the total output of the household sector, a value equal either to the total wages paid to households, $x_{41} + x_{42} + x_{43} + x_{44}$, or the total of household expenditures for final demand, $x_{14} + x_{24} + x_{34} + x_{44}$, then

$$A_{enlarged} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix}$$

$$= \begin{bmatrix} x_{11} & x_{12} & x_{13} & x_{14} \\ x_{21} & x_{22} & x_{23} & x_{24} \\ x_{31} & x_{32} & x_{33} & x_{34} \\ x_{41} & x_{42} & x_{43} & x_{44} \end{bmatrix} \begin{bmatrix} x_1 & 0 & 0 & 0 \\ 0 & x_2 & 0 & 0 \\ 0 & 0 & x_3 & 0 \\ 0 & 0 & 0 & x_4 \end{bmatrix}^{-1}$$

$$= T_{enlarged} \begin{bmatrix} 1/x_1 & 0 & 0 & 0 \\ 0 & 1/x_2 & 0 & 0 \\ 0 & 0 & 1/x_3 & 0 \\ 0 & 0 & 0 & 1/x_4 \end{bmatrix} .$$

Adding entries for households,

$$Y_{enlarged} = \begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix} \quad \text{and} \quad X_{enlarged} = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix}$$

so that

$$X_{enlarged} = (I - A_{enlarged})^{-1} \; Y_{enlarged}.$$

This formulation can be used to estimate output effects for economic sectors (sectors 1-3) and income effects for households (sector 4) resulting from changes in final demand patterns. This formed a central feature in the author's recent report to NOAA/CEAS. In this report, extra income to farmers from weather modification activities was placed as the household sector entry in the enlarged final demand vector. The resultant output vector then contained information on output for economic sectors and income effects. In essence, it was assumed that

$$\begin{bmatrix} \hat{x}_1 \\ \hat{x}_2 \\ \hat{x}_3 \\ \hat{x}_4 \end{bmatrix} = (I - A_{enlarged})^{-1} \begin{bmatrix} 0 \\ 0 \\ 0 \\ \hat{y}_4 \end{bmatrix} .$$

In the output vector, the total impact on industrial sectoral output was $x_1 + x_2 + x_3$, with x_4 being an income effect for households.

In a similar manner, the size of the transactions matrix could be decreased. In our original transactions table (see Figure 1), sector 3 was taken to be construction. Consider the following transactions matrix

$$T_{decreased} = \begin{bmatrix} x_{11} & x_{12} \\ x_{21} & x_{22} \end{bmatrix} ,$$

from which a matrix of technical coefficients could be defined as

$$A_{decreased} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} ,$$

the two matrices being related through the expression

$$T_{decreased} = A_{decreased} \begin{bmatrix} x_1 & 0 \\ 0 & x_2 \end{bmatrix} .$$

Having defined $A_{decreased}$, then

$$X_{decreased} = (I - A_{decreased})^{-1} D.$$

The vector D is defined as

$$D = \begin{bmatrix} d_1 \\ d_2 \end{bmatrix}.$$

It includes the ordinary final demand for sectors 1 and 2 and, in addition, the demand for the construction sector (sector 3) for the output of the other industrial sectors. Recall that the present formulation of the input-output analysis has assumed a fixed technical recipe for the way the construction industry purchases its inputs in order to carry out its production. Consider a situation where bad weather conditions have reduced the construction industry's ability to purchase its inputs by 10% across the board.

Within the context of input-output analysis, this would mean that all the entries in the original transactions table in the column for construction have been reduced by 10%. This change can be summarized in the following column of values:

Changes in Construction Sector Inputs

$-.1x_{13}$

$-.1x_{23}$

$-.1x_{33}$

$-.1v_3$

$-.1x_3$ (Total Inputs = Total Outputs)

These changed values will be accepted as givens. It will be noted that two of these values, namely $-.1x_{13}$ and $-.1x_{23}$, can be considered as entries in the column vector of demands, D, defined above. From this observation, it is possible to determine the change in output for sectors 1 and 2. Then these output changes are represented in the following expression:

$$\begin{bmatrix} \hat{x}_1 \\ \hat{x}_2 \end{bmatrix} = (I - A_{decreased})^{-1} \begin{bmatrix} -.1x_{13} \\ -.1x_{23} \end{bmatrix} .$$

(Note: the outputs $\hat{x}_1$ and $\hat{x}_2$ will have negative values.)

Values for the change in total output for sectors 1 and 2 are now known, and the values for $T_{decreased}$ can be recovered from the expression

$$T_{decreased} = A_{decreased} \begin{bmatrix} \hat{x}_1 & 0 \\ 0 & \hat{x}_2 \end{bmatrix} = \begin{bmatrix} \hat{x}_{11} & \hat{x}_{12} \\ \hat{x}_{21} & \hat{x}_{22} \end{bmatrix} .$$

(Note: the entries $\hat{x}_{11}$, $\hat{x}_{12}$, $\hat{x}_{21}$ and $\hat{x}_{22}$ will have negative values.)

The values for a transactions table showing expected changes in inter-industry inputs and outputs resulting from the 10% across the board decrease in the construction sector's ability to absorb inputs have now been determined. At this stage, assuming conditions of economic equilibrium, the known values are given in the figure below.

Input \ Output		Sectors 1	2	3	Final Demand	Total Output
Sectors	1	$\hat{x}_{11}$	$\hat{x}_{12}$	$-.1x_{13}$	0	$\hat{x}_1$
	2	$\hat{x}_{21}$	$\hat{x}_{22}$	$-.1x_{23}$	0	$\hat{x}_2$
	3	?	?	$-.1x_{33}$	0	$-.1x_3$
	Primary Inputs	?	?	$-.1v_3$		
	Total Inputs	$\hat{x}_1$	$\hat{x}_2$	$-.1x_3$		

Figure 5. Changes in Interindustry Transactions

The remaining unknown values (indicated by question marks in the figure above) can be determined since a fixed technological recipe for all the sectors, including sectors 1 and 2, is assumed. Knowing the total output level changes for these two sectors, it can be said that

$$\hat{x}_{31} = a_{31}\hat{x}_1$$

and

$$\hat{x}_{32} = a_{32}\hat{x}_2 \quad .$$

It is then possible to determine $\hat{v}_1$ and $\hat{v}_2$ from the following bookkeeping identities for columns 1 and 2:

$$\hat{v}_1 = \hat{x}_1 - (\hat{x}_{11} + \hat{x}_{21} + \hat{x}_{31})$$

and

$$\hat{v}_2 = \hat{x}_2 - (\hat{x}_{12} + \hat{x}_{22} + \hat{x}_{32}) \quad .$$

(Note: $\hat{x}_{31}$, $\hat{x}_{32}$, $\hat{v}_1$ and $\hat{v}_2$ should also be interpreted as negative values.

Thus an entire transactions table of changes in inputs and outputs is completed.

It is probably safe to say that current capabilities will allow the development of models that can predict changes in the ability of various construction sub-sectors like building construction or road construction to absorb inputs in the face of changes in suitably defined weather variations. A heavily aggregated input-output table with a single construction sector may very well need to be replaced with a more disaggregated table specifying the appropriate subsectors to enhance quantitative accuracy in impact projections. One would obviously expect differences in response to weather variations by significantly different subsectors. By using a level of disaggregation appropriate to the problem at hand, useful predictions can probably be obtained without violating the assumptions of linearity in sectoral response underlying input-output analysis.

Now consider another example. Going back to the original 3-sector system where sector 2 is taken to be utilities, say a severe winter storm has increased final demand on the part of residential consumers by an amount with dollar value C. The output effects would be

$$\begin{bmatrix} \hat{x}_1 \\ \hat{x}_2 \\ \hat{x}_3 \end{bmatrix} = B \begin{bmatrix} 0 \\ C \\ 0 \end{bmatrix} \quad .$$

This increased spending by households for their utility bills would likely be offset by decreased spending on final demand for other sectors. A rough estimate of these counterbalancing output effects can be made by using the input-output formulation including households as a row and column. Following the procedure outlined before, the counterbalancing output effects could be expressed as:

$$\begin{bmatrix} -\bar{x}_1 \\ -\bar{x}_2 \\ -\bar{x}_3 \\ -\bar{x}_4 \end{bmatrix} = (I - A_{enlarged})^{-1} \begin{bmatrix} 0 \\ 0 \\ 0 \\ -C \end{bmatrix}$$

The total output effect on industrial output would be

$$(\hat{x}_1 + \hat{x}_2 + \hat{x}_3) - (\bar{x}_1 + \bar{x}_2 + \bar{x}_3) \quad .$$

A negative impact on incomes of $(-x_4)$ would also be predicted.

Better estimates of the positive and negative effects on industrial outputs and incomes could be obtained if better information were available for showing how an increase in consumer spending for one sector like utilities affected spending on other economic sectors. In the absence of such information, the approach just outlined provides a working approximation.

Regional Models Driven by Input Levels

Mathematically, there is no reason why the input-output approach cannot be revised to show sensitivity to levels of primary inputs rather than levels of final demand. In concrete terms, this amounts to revising the technological recipe assumed for each sector. Previously, a characteristic pattern for the manner in which each sector requires its inputs relative to the level of total sectoral output was assumed. As will be seen below, the present formulation will assume a characteristic pattern for the manner in which each sector disposes of its output relative to the level of total sectoral output. To begin, an expresssion for a matrix of output coefficients is derived where

$$A = \begin{bmatrix} \bar{a}_{11} & \bar{a}_{12} & \bar{a}_{13} \\ \bar{a}_{21} & \bar{a}_{22} & \bar{a}_{23} \\ \bar{a}_{31} & \bar{a}_{32} & \bar{a}_{33} \end{bmatrix} .$$

In terms of the transactions matrix, T, and the total outputs x_1, x_2 and x_3

$$T = \begin{bmatrix} x_1 & 0 & 0 \\ 0 & x_2 & 0 \\ 0 & 0 & x_3 \end{bmatrix} \bar{A}$$

or

$$\bar{A} = \begin{bmatrix} 1/x_1 & 0 & 0 \\ 0 & 1/x_2 & 0 \\ 0 & 0 & 1/x_3 \end{bmatrix} T .$$

If a vector of primary inputs is

$$V = (v_1, v_2, v_3)$$

and a vector of outputs

$$X^T = (x_1, x_2, x_3),$$

then summing by columns in the original transactions table is identical to the matrix equation

$$X^T\bar{A} + V = X^T .$$

If

$$Q = (I - \bar{A})^{-1},$$

then

$$X^T = VQ.$$

Given any set of entries for a vector of primary inputs, then, a vector of total outputs can be determined. By procedures analogous to the input-output formulations where total output was a linear transformation of final demand, a revised transactions table can be constructed.

An example of a weather-sensitive application could be the decline in wages paid to workers due to widespread and severe winter storms. This should reduce one or more entries in the primary input vector V and hence reduce the possible output vector values of X^T under conditions of economic equilibrium. This would in turn set a limit to equilibrium levels of final demand. If the primary input formulation of the input-output model predicted a level of output of

$$\hat{X} = \begin{bmatrix} \hat{x}_1 \\ \hat{x}_2 \\ \hat{x}_3 \end{bmatrix} ,$$

then since

$$\hat{X} = (I - A)^{-1} \hat{Y} ,$$

it would follow that

$$\hat{Y} = (I - A) \hat{X} .$$

Knowledge of this permitted equilibrium vector of final demand, $\hat{Y}$, would be valuable for planning purposes. Government action might well be required to maintain final demand at these levels. The alternative would be to throw the economy out of equilibrium, creating inflationary pressures if demands exceeded supplies.

Comparing with previous examples, a decreased output coefficient matrix could be defined. This could be used to derive models where weather-related bottlenecks in the inputs of sectors like construction or transportation to the rest of the economy could set limits to permissible equilibrium output. Care should be exercised in the interpretation of the mathematical frameworks outlined above. Still, these two types of formulations of the regional input-output model covered in the previous sections suggest numerous applications in the area of climatic impact assessment.

Multiregional (Interregional) Input-Output Analysis

The logic underlying input-output analysis can be extended to handle, in a remarkably detailed and explicit fashion, the flow of commodities not only between economic sectors but also between economic sectors located in specific regions, for example not only the buying and selling of bricks, but the buying and selling of bricks from Missouri, Kansas, Oklahoma, and so forth.

From \ To		Region I Sector 1	Region I Sector 2		Region II Sector 1	Region II Sector 2	Final Demand	Total Outputs
Region I	Sector 1	x_{11}^{11}	x_{12}^{11}		x_{11}^{12}	x_{12}^{12}	y_1^1	x_1^1
	Sector 2	x_{21}^{11}	x_{22}^{11}		x_{21}^{12}	x_{22}^{12}	y_2^1	x_2^1
Region II	Sector 1	x_{11}^{21}	x_{12}^{21}		x_{11}^{22}	x_{12}^{22}	y_1^2	x_1^2
	Sector 2	x_{21}^{21}	x_{22}^{21}		x_{21}^{22}	x_{22}^{22}	y_2^2	x_2^2
	Primary Inputs	v_1^1	v_2^1		v_1^2	v_2^2		
	Total Inputs	x_1^1	x_2^1		x_1^2	x_2^2		

Figure 6. Two-Region, Two-Sector Interregional Input-Output Transactions Table

To consider a typical representation of a multiregional transactions table, assume a hypothetical economy composed of only two regions where each region has only two economic sectors. The transactions table would resemble Figure 6. From this table, a transactions matrix with a typical entry x_{ij}^{rs} could be defined. This typical entry would represent the value of commodities produced by the ith sector in region r for use by the jth sector in region s. From such a transactions matrix, a matrix C of interregional coefficients could be obtained where a typical entry would be

$$C_{ij}^{rs} = x_{ij}^{rs} / x_j^s \quad .$$

The value x_j^s is the total output value of the jth sector in region s.

Similarly, a typical entry in the final demand column would be y_j^s, which would represent all sales of commodity j sold anywhere to final demand which have been produced in region s. If a vector of outputs is defined where

$$X = \begin{bmatrix} x_1^1 \\ x_2^1 \\ x_1^2 \\ x_2^2 \end{bmatrix}$$

and a vector of final demands where

$$Y = \begin{bmatrix} y_1^1 \\ y_2^1 \\ y_1^2 \\ y_2^2 \end{bmatrix}$$

then row-wise summations from the transactions table would yield the following vector equation:

$$CX + Y = X$$

or

$$X = (I - C)^{-1}Y.$$

The mathematical similarity of the expressions above to the regional formulation is apparent. The implications to be derived from the multi-regional model, however, have an extra dimension lacking from ordinary regional formulations. If some change in the value of y_1^1 in our vector Y of final demands could be predicted, this change could take the form of an increase in region I's residential demand for utility output (considering utilities as sector 1) due to a severe winter. Such an increase in regional consumer demand would definitely increase the value of y_1^1 by some amount, for example Δy_1^1. The following expression would then be true:

$$(I - C)^{-1} \begin{bmatrix} \Delta y_1^1 \\ 0 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} \Delta x_1^1 \\ \Delta x_2^1 \\ \Delta x_1^2 \\ \Delta x_2^2 \end{bmatrix} .$$

Note that a direct impact originating in one region and for one sector can be expected to affect the output levels for all sectors in all regions. This predictive capability of a multiregional input-output model has intriguing implications that are of obvious interest and relevance to anyone concerned with climatic impact assessment.

The present simplified discussion has, to be sure, not addressed some of the difficultuies encountered in actually implementing a multiregional model. Still, research beginning at Harvard and continuing at M.I.T. has resulted in the implementation of a multiregional model for the United States. Exploration of possible applications of this MRIO model are certainly worth consideration.

Combining Input-Output Models and Econometric Models

In the previous discussion, the existence of or the possibility for the development of direct impact models that can predict one or more entries in a vector of inputs or demands was assumed. Input-output analysis can then be applied to yield estimates of output effects. In the main, the types of models envisioned have been regression models predicting demand or primary input response for single sectors only. It would also be possible to develop models that could predict many, or even all, the entries in the required driving vectors. The types of models commonly called econometric models would often have this capability.

The goal of an econometric model is to relate, usually through methods of statistical estimation, a set of independent, or exogenous, variables to a set of dependent, or endogenous, variables. Given m endogenous variables and n exogenous variables, the form of an econometric model would be

$$\underbrace{{}_mB_m \begin{bmatrix} f_1 \\ f_2 \\ \cdot \\ \cdot \\ \cdot \\ f_m \end{bmatrix}}_{\text{endogenous variables}} = \underbrace{{}_mA_n \begin{bmatrix} x_1 \\ x_2 \\ \cdot \\ \cdot \\ \cdot \\ x_n \end{bmatrix}}_{\text{exogenous variables}} + \underbrace{\varepsilon}_{\text{error terms}}$$

or

$$BF = AX + \varepsilon.$$

The matrices of coefficients B and A are estimated using a variety of statistical techniques. The model is then solved for the endogenous variables and placed in so-called reduced form. Assuming a linear system,

$$F = B^{-1} AX + \mu.$$

The types of endogenous variables predicted by econometric models are often similar to the final demand or primary input categories of the vectors needed to drive an input-output model. This is especially true in the case of models like the Brookings or Wharton Annual models that try to estimate major components of national income and consumption. If the variables predicted by an econometric model are exactly the same as those required to drive an input-output model, the potential for combining the two models is obvious. Often, though, there are significant differences in the types of variables predicted by an econometric model and those required to articulate with input-output analysis. For instance, while an input-output model may require a vector of sectoral final demands for its implementation, an econometric model may generate a set of values for various types of final demand categories, e.g., automobiles or durable goods, that are not the same as the sectoral classification scheme used in input-output analysis.

In many instances, a solution to this apparent incompatibility may be forthcoming by estimating the coefficients for a "bridge matrix" that serves as a linear transformation from the econometric to the input-output categories. If such a matrix, H, can be obtained, then a vector, F, of spending categories from an econometric model can be transformed to a vector Y of input-output final demand categories as follows:

$$Y = HF$$

or

$$\begin{bmatrix} y_1 \\ y_2 \\ \cdot \\ \cdot \\ \cdot \\ y_k \end{bmatrix} = {}_kH_m \begin{bmatrix} f_1 \\ f_2 \\ \cdot \\ \cdot \\ \cdot \\ f_m \end{bmatrix} .$$

This is exactly the approach taken in the Brookings and Wharton Annual models. Interest in developing similar combined econometric and input-output models at the state level has also grown in recent years. Where climate-sensitive features can be built into an econometric model, the possibility for combining its predictions with input-output models deserves serious consideration.

Conclusions

In and of itself, a set of input-output matrices does not automatically constitute a weather or climate sensitive modeling tool. The input-output matrices become useful for climatic impact analysis only when other techniques (e.g., single-sector regression models, multi-sector econometric models, or mere educated guesses) provide sectoral entries in the vectors of demand or inputs that drive the input-output models. One great potential of input-output analysis for climatic impact assessment lies in the fact that input-output models already exist in abundance. Input-output analysis is such a widespread tool for impact analyses of all sorts that matrix materials have been developed for all manner of geographical units: counties, cities, regions within states, states, regions composed of several states, and the nation as a whole. A review of the literature would also disclose a fairly impressive variety of models that can supply information for the exogenous-vector variables of demands or inputs needed to drive an input-output model. Input-output analysis, then, should allow us to capitalize on our body of current techniques and expertise, using existing models and existing climate-sensitive direct impact models to derive overall economic impact assessments of broad regional or national scope.

Initially, the nature of these predictions may be crude. Nevertheless, even extremely crude approaches may be more than adequate to pinpoint which sectors show the greatest economic sensitivity to climatic variability and which climate-sensitive sectors in turn trigger the greatest secondary impacts on the rest of the economy. Even rough "ballpark" estimates may prove invaluable in showing the relative magnitude and significance of climate impacts on economic activity. Such knowledge would help define promising topics for research and would also help in setting funding priorities in the area of climatic impact assessment.

In time, the quantitative rigor of the predictions should increase. The information provided would be of obvious use to planners and policy makers as well as to the informed public at large. Detailed quantitative knowledge of the sectoral and regional impacts of climate variations could be used to frame governmental or business programs to counteract adverse climate-related consequences working within the current strictures of our economic system. For instance, a fuller appreciation of the economic implications of harsh winters, droughts, or widespread damage from severe tropical storms could help in the design of programs to redress the associated economic hardships. A fuller appreciation of climate impacts would also point out areas in which basic restructurings of our technologies are in order. This could take the form of revising features of, for instance, transportation systems or construction practices to make them more immune to climate variability. It could also take the form of working with climate instead of against it, a good case in point being the relationship between climate-conscious building design and utility demands. Through these and other ways, the development of applied climate-sensitive economic models could broaden our understanding of the interactions between climate and the economy and hence provide the basis for informed control of these interactions for our greater safety, security, and well-being.

VIII. ASPECTS OF INPUT-OUTPUT ANALYSIS PERTINENT TO CLIMATE-ECONOMIC MODELING THREE SHORT NOTES

William Cooter

Conjoining Input-Output and Econometric Models

Introduction

Econometric models are commonly used to estimate the values of variables such as employment or wage levels and hence income, and levels of final demand consumption for various categories of industrial output (Klein and Glickman, 1977; Glickman, 1977). Variables of this sort are central to the estimation of Gross Regional Product (GRP), which may be measured with certain refinements either as the value of final demand purchases or as the level of gross income. The two conceptualizations are complementary, with the proceeds from commodity sales in the last analysis providing the source of money income and income and wages in turn underwriting the purchase of goods and services. If econometric models provide sufficient disaggregation as to the sectors supplying the income and the values of final demand sales for these sectors, then there is the possibility of coupling the estimates of income or final demand consumption from an econometric model with an input-output model showing a comparable scheme of sectoral disaggregation.

Such combined models have been available for a number of years at the national level. Most of them trace their inspiration to research associated with the Brookings Model (Fisher, Klein, and Shinkai, 1965).

The ideas underlying the Brookings Model form the basis for the highly regarded Wharton Annual Model (Preston, 1972; Schink, 1979) and the Long Term Interindustry Transactions Model developed by Edward Hudson and Dale Jorgenson (1974) for Data Resources Inc. Both these models have seen extensive use in energy-related forecasting and policy simulation (Hughes, 1979).

In recent years, interest has grown in developing state-level combined models, a good example being the pioneering work conducted for the state of Ohio (L'Esperance, 1977; L'Esperance, King, and Sines, 1977). State and other regional-level combined models involve geographic scales that should prove amenable to the introduction of climatic variables in the econometric models.

A general discussion of the features of a combined econometric/ input-output model will now be attempted. The national-level Wharton Annual Model forms the basis for much of this exposition. The types of models envisioned here, however, would probably be of a regional nature, say, involving a state. A fuller discussion and debate over data or other difficulties likely to be encountered in conjoining input-output and econometric models will, it is hoped, be initiated as a result of responses to the remarks that follow.

Relating Income to Sectoral Output and Final Demand

Consider the following input-output transactions table for a hypothetical two sector regional economy:

	Sector 1	Sector 2	Final Demand	Total Outputs
Sector 1	x_{11}	x_{12}	y_1	x_1
Sector 2	x_{21}	x_{22}	y_2	x_2
Primary Inputs (Income)	v_1	v_2		
Total Inputs	x_1	x_2		

Figure 1. Hypothetical Transactions Table

The total income generated in this economy is the sum of the primary inputs, i.e., $v_1 + v_2$. The total final demand is given by the sum $y_1 + y_2$. These two sums are alternative measures of the Gross Regional Product (GRP), so that

$$y_1 + y_2 = v_1 + v_2 = \text{GRP}.$$

Reasonably good series for employment, wage rates, and other measures of income originating by economic sector are available at both the national and regional levels. Econometric models often try to incorporate projections of income, or employment and wage rates, from which income could be estimated. Such projections can then be used in conjunction with aspects of input-output analysis to estimate the total outputs for each economic sector. If a stable production recipe for each sector is assumed, then from the following column summations (to verify, refer to transactions table),

$$x_{11} + x_{21} + v_1 = x_1 \quad \text{and}$$
$$x_{12} + x_{22} + v_2 = x_2 \ ,$$

then it can be said that

$$x_{11}/x_1 + x_{21}/x_1 + v_1/x_1 = 1 \quad \text{and}$$
$$x_{12}/x_2 + x_{22}/x_2 + v_2/x_2 = 1 \ .$$

If the following definitions are assumed

$$a_{11} = x_{11}/x_1 \ , \qquad a_{12} = x_{12}/x_2 \ ,$$
$$a_{21} = x_{21}/x_1 \ , \text{ and } \ a_{22} = x_{22}/x_2 \ ,$$

then

$$v_1/x_1 = 1 - (a_{11} + a_{21}) \quad \text{and}$$
$$v_2/x_2 = 1 - (a_{12} + a_{22}) \ .$$

If the following matrix is defined as:

$$M = \begin{bmatrix} 1 - (a_{11} + a_{21}) & 0 \\ 0 & 1 - (a_{12} + a_{22}) \end{bmatrix} = \begin{bmatrix} v_1/x_1 & 0 \\ 0 & v_2/x_2 \end{bmatrix}$$

and the vectors

$$V = \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} \qquad \text{and} \qquad X = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} ,$$

it is obvious that

$$MX = V \quad \text{or}$$

$$X = M^{-1} V.$$

In the customary input-output formulation where

$$A = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \quad \text{and}$$

$$Y = \begin{bmatrix} y_1 \\ y_2 \end{bmatrix}$$

we have $AX + Y = X$, i.e.,

$$a_{11}x_1 + a_{12}x_2 + y_1 = x_1$$
$$a_{21}x_1 + a_{22}x_2 + y_2 = x_2 \quad \text{or}$$

$$x_{11} + x_{12} + y_1 = x_1$$
$$x_{21} + x_{22} + y_2 = x_2$$

as can be verified by reference to the original transactions table.

It has been shown that sectoral incomes and outputs can be related through the expression

$$X = M^{-1}V.$$

Substituting this expression for X in the fundamental input-output accounting identity $AX + Y = X$,

$$A(M^{-1}V) + Y = M^{-1}V \quad \text{or}$$
$$Y = (I - A)M^{-1}V.$$

Given an initial set of predictions generated by an econometric model for sectoral incomes, sectoral outputs and final demands can then be estimated using input-output analysis.

Converting Spending Category Values to Sectoral Final Demands

Frequently, econometric models use a system of national income accounting different from the sectoral breakdown of final demand required for input-output analysis. Input-output analysis involves final demand associated with particular industries such as mining, manufacturing, agriculture, etc. Econometric models often use data series based on spending categories broken down into classifications like business capital formation spending, consumer purchases of durable goods, nondurable goods and services, public spending, etc. The grand totals of these two ways of looking at expenditures should both sum to the same amount. If we assume "n" spending categories, each category associated with an expenditure value g_i, then in terms of our hypothetical two sector economy,

$$y_1 + y_2 = \sum_{i=1}^{n} g_i = GRP.$$

In the Wharton model, this difficulty is solved by developing a "bridge matrix" that transforms a matrix G of spending category amounts into the required vector F of final demands. If we call the rectangular bridge matrix H and let

$$G = \begin{bmatrix} g_1 \\ g_2 \\ \cdot \\ \cdot \\ \cdot \\ g_n \end{bmatrix} ,$$

then

$$Y = HG.$$

Recall that in the previous section it was shown that

$$Y = (I - A)M^{-1}V.$$

Substituting for Y,

$$HG = (I-A)M^{-1}V \quad \text{or}$$

$$V = M(I - A)^{-1}HG.$$

If

$$C = M(I - A)^{-1}H,$$

then

$$V = CG.$$

The following expressions summarize the results as

$$V = MX \quad (\text{or } X = M^{-1}V)$$

$$Y = (I - A)M^{-1}V$$

$$Y = HG$$

$$V = CG.$$

These various identities allow use of the econometric and input-output models as cross-checks on the predictions of both. Serious discrepancies would indicate that one or both of the models are in need of revision. This could entail statistical respecification of the coefficient matrices for an econometric model or reestimation of the technical coefficient matrix A and the bridge matrix H associated with the input-output model.

As noted previously, regional (state or SMSA) estimates of wages, employment and other data bearing on income are generally available. Regional data of spending category amounts vary in their quality and may be available only at a limited degree of disaggregation. This could hinder development of a meaningful bridge matrix. An alternative would be the use of time series of sectoral final demands in the construction of the econometric model. Unfortunately, sectoral final demand data per se have not been traditionally collected or estimated other than at the national level. Techniques have been proposed, however, to use state income data in conjunction with proportionality constants derived from national materials to estimate Gross State Product by industry (see Kendrick and Jaycox, 1965). Such GSP series have been used, for instance, in the development of the Ohio econometric model (L'Esperance, 1977; L'Esperance, King, and Sines, 1977). Such a procedure allows articulation with an input-output model in a direct and obvious fashion.

Desirable Features of an Econometric Model

The general form of a (linear) econometric model would be

$$DW = EZ + \varepsilon ,$$

where D is an invertible square matrix of statistically derived coefficients, E a rectangular matrix of coefficients, W a column vector of endogenous variables, Z a column vector of exogenous variables, and ε a column vector of error terms. A new vector, μ, of error terms can be defined to solve for W:

$$W = D^{-1}EZ + \mu .$$

In Z, lagged values of variables that could appear in W would be included, instrumental variables such as levels of government spending, and weather variables. In W, values for sectoral income and final demands would be desired. From W, therefore, values for the vectors V and Y (or G) described above could be taken. Using input-output analysis, cross-checks on expected values of X, V, Y, and G could be performed. In addition, input-output analysis can provide estimates for all the interindustry transactions (e.g., numerical values for x_{11}, x_{12}, x_{21}, and x_{22} in our hypothetical two sector transactions table). A combination of econometric with input-output models, then, provides a built-in means of checking the adequacies of the separate models and adds predictive capabilities impossible when using an econometric model alone.

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Effects of Technological Changes In Input-Output Analysis

The following examples are designed to illustrate the impacts on an economy of changes in technology affecting one or more sectors. It will be argued that these impacts result in a recognizable pattern of changes in sectoral income levels and distributions. The impacts are spread over the whole fabric of interindustry transactions as well, but regional data series for these transactions are usually incomplete or lacking. Regional data series, though, on employment, salaries, and wages are usually available and provide a convenient means of bringing possible technological alterations to our attention. The impacts of technological change will often be significant enough so that no reasonable set of sectoral final demands could have produced a given set of sectoral incomes unless technological change is taken into account. Regional data series for final demand must usually be estimated from other data series, but even allowing for the poorer quality of the resultant estimates, they can be used to further underscore a hypothesis that significant technological change has taken place.

To begin, specify a set of initial conditions for a hypothetical 4 sector economy as embodied in the following transactions table:

	Sectors 1	2	3	4	Final Demand	Total Outputs
Sectors 1	10	20	10	10	10	60
2	15	10	25	10	10	70
3	10	15	5	10	30	70
4	15	10	10	20	5	60
Income	10	15	20	10		
Total Inputs	60	70	70	60		

Figure 1. Original Transactions Table

For purposes of illustration, sector 1 will serve as agriculture. This identification will help in visualizing real world analogues of the first example to be explored below.

In the conceptual framework of input-output analysis, this initial state of the economy is associated with the following matrix of technical coefficients;

$$A = \begin{bmatrix} 0.1667 & 0.2857 & 0.1429 & 0.1667 \\ 0.2500 & 0.1429 & 0.3571 & 0.1667 \\ 0.1667 & 0.2143 & 0.0714 & 0.1667 \\ 0.2500 & 0.1429 & 0.1429 & 0.3333 \end{bmatrix}$$

For a vector of final demands, $Y = (y_1, y_2, y_3, y_4)^T$, and a vector of sectoral outputs, $X = (x_1, x_2, x_3, x_4)^T$, the following equation results:

$$AX + Y = X,$$

from which

$$X = (I - A)^{-1}Y.$$

It is also convenient to define the following rectangular matrix:

$$AA = \begin{bmatrix} 0.1667 & 0.2857 & 0.1429 & 0.1667 \\ 0.2500 & 0.1429 & 0.3571 & 0.1667 \\ 0.1667 & 0.2143 & 0.0714 & 0.1667 \\ 0.2500 & 0.1429 & 0.1429 & 0.3333 \\ 0.1666 & 0.2142 & 0.2857 & 0.1666 \end{bmatrix}$$

This matrix, AA, differs from the matrix A by the addition of the last row, which includes the sectoral fraction of total inputs going to incomes. If a diagonal matrix is defined as

$$D = \begin{bmatrix} x_1 & 0 & 0 & 0 \\ 0 & x_2 & 0 & 0 \\ 0 & 0 & x_3 & 0 \\ 0 & 0 & 0 & x_4 \end{bmatrix},$$

where the elements on the diagonal are the same as in the output vector, $X = (x_1, x_2, x_3, x_4)^T$, then values for the bulk of the entries in a transactions table can be calculated from the expression

$$T = (AA)\ (D).$$

Given the matrix T along with a vector of final demands and the associated vectors of outputs and total sectoral inputs, the ingredients needed for a complete transactions table are complete.

Now consider two types of technological change affecting sector 1 (agriculture). Imagine a situation where some combination of economic and climatic factors have made agriculture more dependent on its own resources and less dependent on inputs from other industrial sectors. Agriculture could be viewed as having become less capital intensive, i.e., more capital extensive. Concomitant with this, agriculture might well come to rely on a greater proportion of its inputs being supplied by labor or, put in other words, would have to outlay for inputs. In terms of the input-output matrix of technical coefficients, such a change is reflected by changing the first column of the AA matrix from

SHARES TO SECTORS	1:	0.1667	ORIGINAL TECHNOLOGY
	2:	0.2500	
	3:	0.1667	FOR SECTOR 1
	4:	0.2500	
INCOME SHARE	:	0.1666	

to

SHARES TO SECTORS	1:	0.2500	MORE EXTENSIVE
	2:	0.1500	
	3:	0.1500	TECHNOLOGY FOR
	4:	0.1500	
INCOME SHARE	:	0.3000	SECTOR 1

In addition, consider a situation where economic and climatic factors have encouraged agriculture to become less dependent on its own inputs, more dependent on inputs from other industrial sectors, and less dependent on labor inputs. In this case, agriculture would have become more capital intensive. In terms of the input-output matrix of technical coefficients, such a change is reflected by changing the first column of the AA matrix from

SHARES TO SECTORS	1:	0.1667	ORIGINAL TECHNOLOGY
	2:	0.2500	
	3:	0.1667	FOR SECTOR 1
	4:	0.2500	
INCOME SHARE	:	0.1666	

to

SHARES TO SECTORS	1:	0.1000	MORE INTENSIVE
	2:	0.3000	
	3:	0.2500	TECHNOLOGY FOR
	4:	0.2500	
INCOME SHARE	:	0.1000	SECTOR 1

Assume no changes in the technologies of the other three sectors.

For the same levels of final demand, i.e., $Y = (10, 10, 30, 5)^T$, as in the original conditions, input-output analysis can be used to construct transactions tables showing the performance for the total economy for the extensive and intensive alterations in sector 1 technology. These changes are summarized in figures 2a, 2b, and 2c.

Sectors		1	2	3	4	Final Demand	Total Outputs
	1	10	20	10	10	10	60
	2	15	10	25	10	10	70
	3	10	15	5	10	30	70
	4	15	10	10	20	5	60
	Income	10	15	20	10		
	Total Inputs	60	70	70	60		

Figure 2a. Original Transactions Table

Sectors		1	2	3	4	Final Demand	Total Outputs
	1	14.30	16.24	8.99	7.67	10	57.21
	2	8.58	8.12	22.48	7.67	10	56.85
	3	8.58	12.18	4.50	7.67	30	62.93
	4	8.58	8.12	8.99	15.35	5	46.04
	Income	17.16	12.18	17.98	7.67		
	Total Inputs	57.21	56.85	62.93	46.04		

Figure 2b. Transactions Table for More Extensive Sector 1 Technology

		Sectors 1	2	3	4	Final Demand	Total Outputs
Sectors	1	5.94	21.98	11.05	10.47	10	59.45
	2	17.83	10.99	27.62	10.47	10	76.92
	3	14.86	16.48	5.52	10.47	30	77.34
	4	14.86	10.99	11.05	20.95	5	62.85
	Income	5.94	16.48	22.10	10.47		
	Total Inputs	59.45	76.92	77.34	62.85		

Figure 2c. Transactions Table for More Intensive Sector 1 Technology

For the same levels of final demand, changes in technology have resulted in significant alterations in the transactions tables. The value of total outputs for the extensive case have declined (from 260 to 223.04) while the value of total outputs for the intensive case have increased (from 260 to 276.56). The levels of outputs, assuming economic equilibrium, are identical to the levels of inputs. It should be noted that an increase in total outputs can be brought about by increases in final demand for one or more sectors. In such a case, though, sectoral outputs, and inputs, would be increased across the board. Similarly, for decreases in final demands, sectoral outputs, and inputs, would all decline.

For our output changes associated with changes in technology, sectoral outputs, and inputs, show an uneven pattern of increases and decreases. This results in an uneven pattern of sectoral income changes. For closer scrutiny, isolate the income changes as follows:

	SECTOR				
	1	2	3	4	Total
ORIGINAL INCOME	10.00	15.00	20.00	10.00	55
EXTENSIVE CASE	↑17.16	↓12.18	↓17.98	↓ 7.67	55
INTENSIVE CASE	↓ 5.94	↑16.48	↑22.10	↑10.47	55

↑ or ↓ indicates increase or decrease relative to original income levels

Since the total income for all sectors must equal the total amount spent on final demand, note that total final demand and total incomes in all the cases equal 55. Within sectors, though, note that relative to the original levels, incomes have not changed uniformly in the extensive and intensive cases. In the extensive case, even while the total inputs for agriculture have declined (from 60 to 57.21), agricultural income has actually risen (from 10 to 17.16). All the other sectors show decreases in income. For the intensive case, even though the total inputs for agriculture have not changed appreciably (from 60 to 59.45), agricultural income has fallen (from 10 to 5.94) while incomes for all the other sectors have risen. These uneven redistributions of income are the results of the changes in technology. Sector 1, where the technological change originated, has obviously undergone changes in its patterns of input-output flows, but so have all the other sectors of the economy.

To help clarify these points, another set of examples will be presented. No attempt will be made to conceptualize these changes in concrete terms, and the sectoral technological changes imposed will purposefully avoid changing the percentage share of sectoral income out of total sectoral input expenditures. As will be seen, this still produces an uneven pattern of total income redistribution among the various sectors.

Once again, consider a change in sector 1 technology alone. Let this change (Case II) be represented by exchanging two non-income components in the first column of the AA matrix as follows:

SHARES TO SECTORS	1:	0.1667	ORIGINAL TECHNOLOGY FOR SECTOR 1
	2:	0.2500	
	3:	0.1667	
	4:	0.2500	
INCOME SHARE	:	0.1666	

becomes

SHARES TO SECTORS	1:	0.1667	CHANGED TECHNOLOGY FOR SECTOR 1 (CASE II)
	2:	0.2500	
	3:	0.2500	
	4:	0.1667	
INCOME SHARE	:	0.1666	

As another case (III), consider changing the technology for both sectors 1 and 2. To the sector 1 change from Case II (above) will be added an interchange of two non-income components in the second column of the AA matrix. The changes are summarized as follows:

		SECTOR 1	SECTOR 2	
SHARES TO SECTORS	1:	0.1667	0.2857	ORIGINAL TECHNOLOGY FOR SECTOR 1 AND SECTOR 2
	2:	0.2500	0.1429	
	3:	0.1667	0.2143	
	4:	0.2500	0.1429	
INCOME SHARE	:	0.1666	0.2142	

		SECTOR 1	SECTOR 2	
SHARES TO SECTORS	1:	0.1667	0.2857	CHANGED TECHNOLOGY FOR SECTOR 1 AND SECTOR 2 (CASE III)
	2:	0.2500	0.2143	
	3:	0.2500	0.1429	
	4:	0.1667	0.1429	
INCOME SHARE	:	0.1666	0.2142	

Assuming the original level of final demands, i.e., $Y = (10, 10, 30, 5)^T$, input-output analysis can be used to estimate levels of sectoral outputs, and inputs, and hence sectoral incomes. The pertinent income information is summarized below:

	SECTOR 1	SECTOR 2	SECTOR 3	SECTOR 4	Total
ORIGINAL INCOME	10.00	15.00	20.00	10.00	55
CASE II	↓ 9.90	↑15.05	↑21.17	↓ 8.88	55
CASE III	↑10.07	↑16.07	↓19.92	↓ 8.94	55

As in previous examples, the uneven sectoral redistributions of income resulting from the technological changes can be noted. These uneven patterns could neither have been produced by increases in one or more sectoral final demands nor by decreases in one or more sectoral final demands.

It is conceivable that some combination of increases and decreases in final demands could produce such uneven income patterns given a constant technology. As we shall see, however, such presumed final demand changes would usually be distinctive enough that it could be decided rather easily whether final demand changes alone or technological changes are more likely to be responsible for a given set of sectoral incomes. To demonstrate this point requires the introduction of some additional matrix equations.

If a vector of sectoral incomes is defined as $V = (v_1, v_2, v_3, v_4)^T$, and the following diagonal matrix as,

$$M = \begin{bmatrix} v_1/x_1 & 0 & 0 & 0 \\ 0 & v_2/x_2 & 0 & 0 \\ 0 & 0 & v_3/x_3 & 0 \\ 0 & 0 & 0 & v_4/x_4 \end{bmatrix},$$

then recalling that a vector of total sectoral outputs has been defined as $X = (x_1, x_2, x_3, x_4)^T$, then

$$MX = V \quad \text{or}$$

$$X = M^{-1}V \ .$$

Previously the fundamental input-output accounting identity was defined as

$$AX + Y = X.$$

Substituting for X and solving for Y,

$$Y = (I - A)M^{-1}V .$$

An equation of this form may be used to relate sectoral incomes to final demands. Using this relationship, the following final demands are anticipated assuming the original technology but employing the sectoral income levels from Case II and Case III above:

		ORIGINAL TECHNOLOGY: FINAL DEMANDS FROM CASE II INCOMES		ORIGINAL TECHNOLOGY: FINAL DEMANDS FROM CASE III INCOMES
SECTORS	1:	10.00	1:	10.00
	2:	10.00	2:	15.36
	3:	34.95	3.	29.67
	4:	0.05	4:	- 0.03

Recall that under the initial conditions (see Figure 1 above), sectoral final demands were $Y = (10, 10, 30, 5)^T$. Under the original technology, Case III incomes presuppose a rise in final demand for sector 3 and a fall in final demand to near zero levels for sector 4. Similarly, to have Case III incomes under the original technology would require a sizeable increase in final demand for sector 2 and a decline to a small <u>negative</u> final demand for the output of sector 4. These changes are drastic and, in the latter instance, perhaps physically impossible. While regional data series for sectoral final demands are not of the best quality, changes of major magnitudes would be discernable. If such changes were not observed, then the only alternative would be to consider changes in sectoral technology.

The foregoing examples should suffice to provide an appreciation of the types of impacts that can stem from technological changes. Data series on sectoral incomes and estimates of regional final demands should suffice to indicate whether discrepancies between the real economy and estimates provided by input-output materials geared to a particular base-year technology warrant attention to the possibility of technological change. In a variety of real-world applications, such discrepancies should be minor enough to allow use of a given set of technical coefficients. Discrepancies of major magnitude should obviously direct our attention to the ways in which sectoral technologies may have changed. Recognition of the presence of technological change does not necessarily give clear cut indications as to the exact nature of the sectoral alterations. The exploration of methods to respecify tables of technical coefficients will be considered in future installments.

A Method for Estimating Changes in Technical Coefficients

In previous discussion, the general nature of changes in sectoral technology was outlined, and the point was made that the presence of significant technological changes should be recognizable through comparisons with data series for incomes and final demand levels. If discrepancies between actual data series and the estimates derived using a given set of technological coefficients are minor, then the given set of input-output matrix materials may be used for a span of years over and beyond the base year for which they were derived. If, on the other hand, technological changes seem evident, then methods for estimating new sets of technical coefficients are obviously called for.

The most straightforward approach would be to conduct a new survey of a region and develop a revised set of input-output materials from the survey data. Such an approach, however, can be very expensive. Completely revised input-output tables have only been prepared at the national level at five to ten year intervals, and few states can boast a more prolific rate of production.

As an alternative, matrix materials for a given base year can be used in conjunction with data on total and primary sectoral inputs and total sectoral outputs and sectoral final demands to estimate technical coefficients for years in the neighborhood of the base year study. This approach is central to such widely used methodologies as the so-called RAS technique (see the discussion in O'Connor and Henry, 1975; McMenamin, 1973). An example of this methodology will be presented for a hypothetical three sector economy.

Assume that a transactions table is available for a given base year as in Figure 1 below. The matrix of technical coefficients associated with this transactions table is

$$A = \begin{bmatrix} .1 & .2 & .1 \\ .5 & .1 & .3 \\ .2 & .3 & .1 \end{bmatrix} .$$

	Input \ Output (Sectors)	1	2	3	Final Demand	Total Output
Sectors	1	10	20	10	60	100
	2	50	10	30	10	100
	3	20	30	10	40	100
	Primary Inputs	20	40	50		
	Total Inputs	100	100	100		

Figure 1. Original Transactions Table

Now assume that for some other year data is available, or can be estimated, for sectoral final demands and outputs and for sectoral primary and total inputs. This would allow calculation of the total intermediate outputs and inputs for each sector since for each ith sector (i = 1, 2, 3)

$$(\text{Intermediate Output})_i = (\text{Total Output})_i - (\text{Final Demand})_i$$

and for each jth sector (j = 1, 2, 3)

$$(\text{Intermediate Input})_j = (\text{Total Input})_j - (\text{Primary Input})_j .$$

The nine individual interindustry transactions for the regional economy remain unknown. Once these are estimated, a new matrix of technical coefficients, $A_{(New)}$, can be calculated. The known information is summarized in Figure 2.

		Sectors 1	2	3	Intermediate Output	Final Demand	Total Output
Sectors	1				30	50	80
	2	UNKNOWN			80	20	100
	3				60	30	90
	Intermediate Inputs	65	55	50			
	Primary Inputs	15	45	40			
	Total Inputs	80	100	90			

Figure 2. Known Information To Be Used in Estimating Unknown Interindustry Transactions

Using the base year matrix A of technical coefficients, the unknown interindustry transactions may be estimated by an iterative approach. An initial set of interindustry transaction values may be computed using the A matrix and the known set of sectoral outputs. If the outputs are placed as the main diagonal in a diagonal matrix D, then

$$T_{(\text{Initial})} = AD$$

or

$$\begin{bmatrix} 8 & 20 & 9 \\ 40 & 10 & 27 \\ 16 & 30 & 9 \end{bmatrix} = \begin{bmatrix} .1 & .2 & .1 \\ .5 & .1 & .3 \\ .2 & .3 & .1 \end{bmatrix} \begin{bmatrix} 80 & 0 & 0 \\ 0 & 100 & 0 \\ 0 & 0 & 90 \end{bmatrix} .$$

The iterative procedure involves manipulations of the values in $T_{(\text{Initial})}$, constraining the row and column sums to converge to the values of the sectoral intermediate outputs and inputs. To begin, consider the row sum for $T_{(\text{Initial})}$ as compared with the actually required levels of intermediate outputs:

	Actual Row Sum		Required Value
ROW (SECTOR) 1:	8 + 20 + 9 = 37	vs.	30
ROW (SECTOR) 2:	40 + 10 +27 = 77	vs.	80
ROW (SECTOR) 3:	16 + 30 + 9 = 55	vs.	60 .

To preserve the constraints, define the following three row adjustment factors:

$$RQ_1 = 30/37$$

$$RQ_2 = 80/77$$

$$RQ_3 = 60/55 .$$

If each element in row 1 is multiplied by RQ_1, the row constraint is preserved. A similar adjustment is carried out for the other two rows. This procedure produces the following set of interindustry transactions:

$$T_{(\text{Row Revised})} = \begin{bmatrix} 6.49 & 16.21 & 7.30 \\ 41.56 & 10.39 & 28.05 \\ 17.45 & 32.73 & 9.82 \end{bmatrix} .$$

These values, however, now violate the column constraints, as can be seen below.

	Actual Column Sum		Required Value
COLUMN (SECTOR) 1:	6.49 + 41.56 + 17.45 = 65.5	vs.	65
COLUMN (SECTOR) 2:	16.21 + 10.39 + 32.73 = 59.33	vs.	55
COLUMN (SECTOR) 3:	7.30 + 28.05 + 9.82 = 45.17	vs.	50 .

To preserve the constraints, define the following three column adjustment factors:

$$CQ_1 = 65/65.5$$

$$CQ_2 = 55/59.33$$

$$CQ_3 = 50/45.17 .$$

If each element in column 1 is multiplied by CQ_1, the column constraint is preserved. A similar adjustment is carried out for the other columns. This procedure produces the following revised set of interindustry transactions:

$$T_{(\text{Column Revised})} = \begin{bmatrix} 6.44 & 15.03 & 8.08 \\ 41.24 & 9.63 & 31.05 \\ 17.32 & 30.34 & 10.87 \end{bmatrix} .$$

If a complete iteration is viewed as a series of row revisions followed by a series of column revisions, then the result of successive iterations will yield a set of interindustry transactions whose row and column sums will converge to ever smaller deviations from the sectoral row and column constraint values.

One such iteration has been shown in detail above. After five such iterations, the following set of values for $T_{(New)}$ was obtained, where the resultant row and column sums were all within 0.01 units of their constrained values:

$$T_{(New)} = \begin{bmatrix} 6.6188 & 15.0761 & 8.3050 \\ 40.3913 & 9.2001 & 30.4085 \\ 17.9873 & 30.7280 & 11.2847 \end{bmatrix} .$$

From $T_{(New)}$ and the new sectoral total output levels (sector 1, 80; sector 2, 100; sector 3, 90), the following component values for $A_{(New)}$ are computed:

$$A_{(New)} = \begin{bmatrix} 0.0827 & 0.1508 & 0.0923 \\ 0.5049 & 0.0920 & 0.3379 \\ 0.2248 & 0.3073 & 0.1254 \end{bmatrix} .$$

The original technical coefficient values are given below for comparison:

$$A = \begin{bmatrix} 0.1 & 0.2 & 0.1 \\ 0.5 & 0.1 & 0.3 \\ 0.2 & 0.3 & 0.1 \end{bmatrix} .$$

Such a process could be repeated for years preceeding or following a base year for which an A matrix was available. In such a fashion, a time series could be developed for technical coefficients. Changes in specific intersectoral coefficients could then be subjected, say, to regression analysis, using weather variables to explain a portion of the variations in the coefficients.

An approach of this sort has obvious attractions for climate-economic modeling. Two potential drawbacks, though, should be borne in mind. To begin with, the number of years in a data series would be limited if a very small number of base year technical coefficient matrices were available. If one estimated coefficients for much more than, say, five years prior or subsequent to a given base year, the validity of the coefficient values for the years most remote from the base year might be questioned. For regions that have available only a single set of input-output materials, the coefficient series would be limited in duration to ten or so years. The small sample size could very well hinder significant regression analysis. A more fundamental problem involves the availability of year-by-year estimates for final demands, total outputs, primary inputs, and total inputs. As has been noted in previous discussions, sectoral final demand series for regions like states often leave much to be desired. Even greater difficulties surround estimates for sectoral primary inputs. Good quality data are generally available for household incomes. The primary input category also includes, however, profits and imports into the region. Information for these matters is often extremely hard to come by or even to estimate. Without adequate data series in these areas, there is no basis for the column and row constraints in the iterative procedure.

While the problems outlined above need careful investigation, the methodology itself offers a means of addressing in an explicit fashion the detailed intersectoral patterns of technological change over time. A groundwork is then provided for modeling aspects of these changes as functions of weather and climate variations.

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