POLICY WORKING PAPER

MODELING THE INTERFACE BETWEEN AGRICULTURE AND THE GENERAL ECONOMY

AFPC POLICY WORKING PAPER NO. 90-13

Department of Agricultural Economics
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MODELING THE INTERFACE BETWEEN AGRICULTURE AND THE GENERAL ECONOMY

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MODELING THE INTERFACE BETWEEN AGRICULTURE AND THE GENERAL ECONOMY

Introduction

Models of the U.S. farm business sector typically assume specific trends in the macroeconomy when projecting future agricultural outcomes. Implicit in the use of exogenized macroeconomic variables is the assumption that events taking place on U.S. farms and ranches do not affect the macroeconomy over the solution horizon.

The assumed lack of annual interaction with the general economy in these partial equilibrium sector models is no doubt valid for certain analyses, such as projecting the impacts of relatively minor adjustments to federal farm program parameters over a short-term horizon. This assumption may ***not*** be valid, however, when projecting the impacts of major shocks to either the farm business sector or the general economy, particularly over a longer-term horizon. For example, restrictions on chemical use in crop production that lead to substantial reductions in crop yields and hence sharply higher commodity prices will likely have a significant impact on the level of ethanol production, the price of food, and the rate of inflation in the macroeconomy. The decade of the Eighties showed that farm financial stress can also have a major impact on government expenditures, both in the form of government payments to farmers as well as FDIC outlays caused by stress on many of the nation's rural banks.

This paper presents an overview of the linkages between the farm business sector and the general economy that underlie the newly developed AG+GEM econometric model. Section II describes the sectoring of the AG+GEM econometric model, while section III presents the theoretical approach taken to modeling the general economy in the model. Section IV describes the major structural properties that capture activities in the farm business and farm household sectors. Finally, section V describes the broad set of macroeconomic and federal farm program policies that can be evaluated by the AG+GEM econometric model, and the annual reports that provide a basis for policy analysis.

Sectoring The AG+GEM Econometric Model

Six different groups of transactors are specifically identified in the AG+GEM econometric model. These groups are: (1) farm operator families; (2) nonfarm households, which consists of non-operator landlord families, hired farm labor families, and other domestic consumers; (3) nonfarm businesses; (4) financial intermediaries; (5) government and (6) the rest-of-the-world sector. Farm operator families receive major attention in the AG+GEM econometric model; their business as well as household activities are endogenized. This transactor group produces farm products, owns a major share of farm business assets, consumes final products from other sectors, and is the residual claimant of farm profits.

The second transactor group in the AG+GEM econometric model is nonfarm households, which captures the activities of nonoperator landlord families, hired farm labor families, and other domestic consumers. These households account for the majority of total final demand for goods produced in the domestic economy, own a major share of nonfarm business assets, and offer labor services in the farm and nonfarm labor markets in the domestic economy.

Nonfarm businesses, the third transactor group in the AG+GEM econometric model, produce and supply manufactured farm inputs to farm businesses. These firms also supply all domestically-produced final consumer goods (including food and fiber), hire labor in nonfarm labor markets, and arrange for financing of their firms.

The fourth transactor group consists of domestic financial intermediaries which facilitate the use of private savings to meet the demand for loan funds in the economy. The government sector, another transactor group, purchases farm and nonfarm goods, hires labor, implements monetary, fiscal, trade and farm program policies, collects taxes, makes transfer payments and finances budget deficits by selling bonds.

The final transactor group is the "rest-of-the-world" sector, which imports goods purchased from U.S. nonfarm businesses in the final agricultural and nonagricultural products markets and exports intermediate goods to the U.S. nonfarm business sector. When the nonfarm business sector takes delivery of imported intermediate goods, it processes and distributes them in either the final agricultural or nonagricultural product markets.

Product flows

Business activity in the AG+GEM econometric model is sectored along product lines. The flows of goods and services in the economy are represented by the ***solid lines*** in Figure 1. All resources used to produce raw agricultural products are included in the farm business sector regardless of where their ownership lies. The same approach has been taken in the nonfarm business sector which, among other functions, processes and distributes intermediate goods acquired from the farm business sector. The farm and nonfarm business sectors are directly linked (see Figure 1) through three sets of markets: (1) domestic raw agricultural products markets, (2) domestic manufactured farm inputs markets, and (3) farm input rental markets, where the services provided by assets leased by farm operators from nonfarm businesses and nonoperator landlord families are acquired.

The farm and nonfarm business sectors are also linked through the farm real estate market, where nonfarm businesses purchase farmland for nonagricultural purposes from discontinuing proprietors. In addition to its linkages with the farm business sector, the nonfarm business sector is linked to a set of consumer groups through the markets for final agricultural and nonagricultural products and through a household asset rental market.

Table 1 illustrates the general approach taken to disaggregating the product markets in the AG+GEM econometric model. While this table gives an indication of how different sectors interact in the economy, the goods markets in the AG+GEM econometric model are actually much more disaggregated than shown here. The model, for example, includes commodity-level detail for the major crop, livestock and livestock products produced in this country. Quantities of raw agricultural products are marketed to nonfarm businesses by farm operator families and the "rest-of-the-world" group for further processing and distribution. The supply and demand equations suggested by Table 1 determine the quantities and relative prices required to calculate real GNP given the simultaneous solution for (1) interest rates in financial markets and (2) the general price level.

Financial flows

Seven specific types of financial instruments are captured in the AG+GEM econometric model. As shown in Table 2, demand deposits and time and savings deposits are assets held by farm operator families,

Figure 1. Physical and financial linkages between agriculture and the general economy

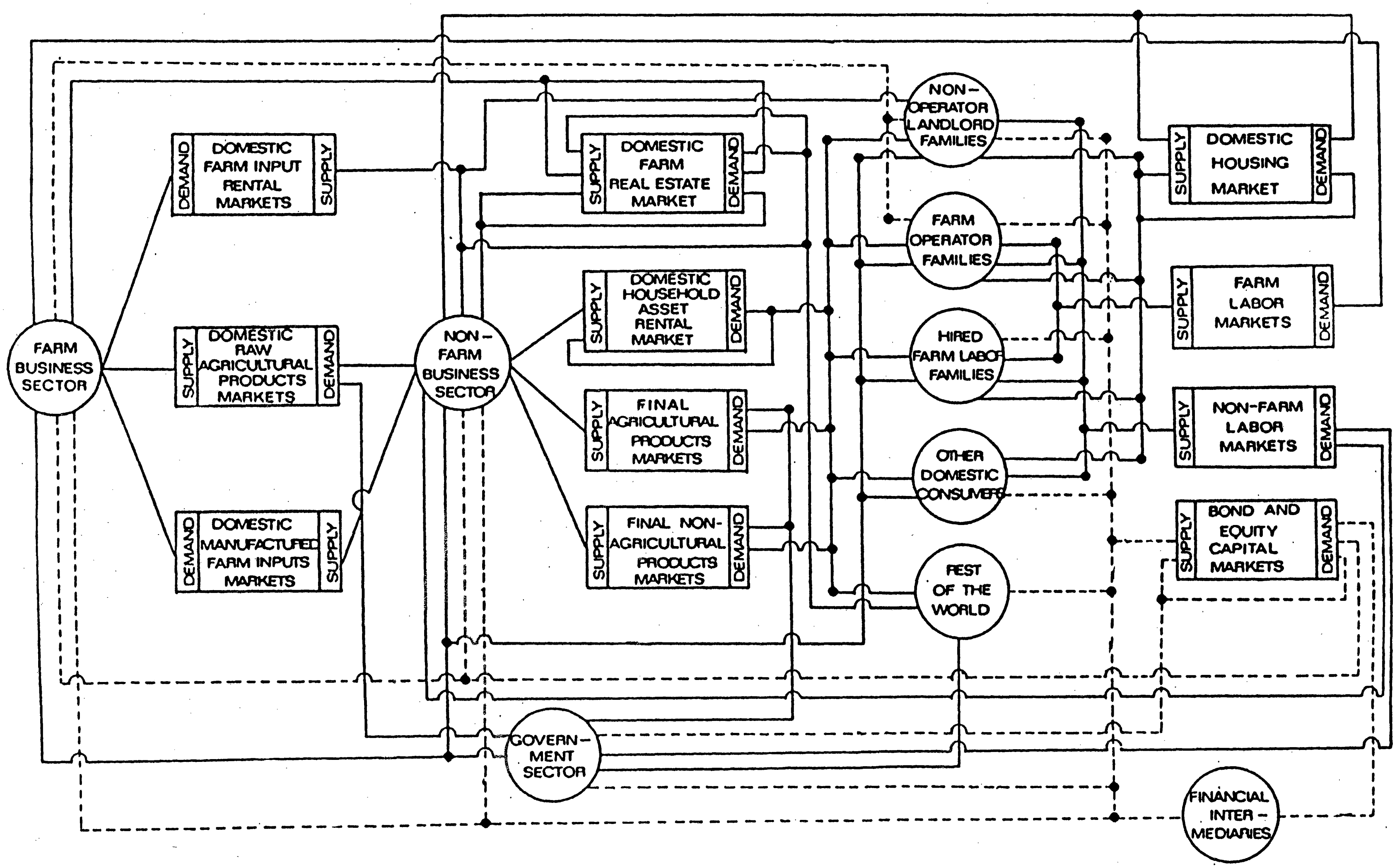

Table 1 Disaggregation of Product Markets in the AG+GEM Model.

Good or service	Farm Operator Families[1]	Nonfarm households	Nonfarm Businesses	Financial Intermediaries	Government	Rest of the World
Primary Inputs:						
Land	D,S[2]	D	D,S	D		
Labor	D,S	S	D		D	
Petroleum			D			S
Secondary Inputs:						
Durable Farm Inputs	D		D,S			
Nondurable Farm Inputs	D		S			
Raw agricultural products	S		D		D	S
Final Products:						
Food	D	D	S		D	D
Consumer Durables	D	D	S			
Other	D	D	S		D	D

[1]Includes both farm business and farm household activities.

[2]D and S represent demand and supply of goods and services, respectively.

Table 2 Disaggregation of Financial Markets in the AG+GEM Model.

Financial Instrument	Farm Operator Families[1]	Nonfarm households	Nonfarm Businesses	Financial Intermediaries	Government	Rest of the World
Bank deposits:						
Demand deposits	D[2]	D	D	S[2]		
Time deposits	D	D	D	S		
Bond market:						
Commercial bonds		D	D,S	D		
Government bonds		D	D	D	S	D
Stock market:						
Equities		D	S	D		
Loans funds market:						
Farm loans:						
Real estate	D			S		
Non-real estate	D			S		
Nonfarm loans		D	D	S		

[1]Includes both farm business and farm household activities.

[2]D and S represent demand and supply of financial instruments, respectively.

nonfarm households, nonfarm businesses and the "rest-of-the-world" group. These deposits also represent liabilities of financial intermediaries. Commercial bonds, bank loans and equities (stocks) finance the activities of nonfarm businesses. Government bond markets capture the financial implications of monetary and fiscal policies. Farm and nonfarm loan funds markets are modeled separately.

To better understand the need to endogenize these financial interfaces in modeling the farm business sector, let us examine the linkage between savers in the economy and the financing of farm business operating expenses and capital accumulation. The channels through which these funds flow are indicated by the ***dashed lines*** in Figure 1. For example, each of the domestic consumer groups and the "rest-of-the-world" sector either invests funds in the bond and equity capital markets or places funds on deposit at commercial banks and other deposit-based financial intermediaries. These consumer groups also repay their existing loans and borrow new loan funds. One of the reasons nonoperator landlord families and farm operator families borrow is to supplement their internal equity capital when financing the purchase of farm business assets in either the manufactured farm input markets or the farm real estate market. Merchants and dealers also provide debt financing to farm businesses who purchase manufactured farm inputs. A relatively small number of incorporated farm businesses also acquire external financing by selling debt and equity instruments in bond and equity capital markets as well as by borrowing directly from financial intermediaries. Some financial intermediaries, such as the Farm Credit System, obtain their new loanable funds by issuing debt instruments in the bond markets. The government sector, principally the Farmers Home Administration, also provides loan funds to farm businesses. The Farmers Home Administration, in turn, receives its loanable funds either directly from government appropriations financed by tax revenues or from the issuance of debt in the bond markets. Other items also flow through this and other selected linkages in Figure 1. Transfer payments and government loans to businesses and consumers as well as government tax receipts, all government securities transactions are also captured.

Modeling the Macroeconomy

The purpose of this section is to describe the scope and design of the macroeconomic component of the AG+GEM econometric model. We will begin by explaining how the structure of the general economy in the AG+GEM econometric model differs from the standard textbook macroeconomic model. We will then discuss the sectoring of a multi-sector macroeconomic model and the conventions adopted in this study.

Modifying a textbook model

The standard textbook macroeconomic model typically accounts for the equilibrium in the nation's product markets (the IS curve), money market (the LM curve) and labor market (the aggregate supply or AS curve). Such a model can be stated in mathematical terms as follows:

(1) $Y_t/P_t = c(Y_t/P_t, r_t, W_t/P_t) + i(Y_t/P_t, r_t) + g_t + xm_t$ (IS curve)

(2) $M_t/P_t = l(Y_t/P_t, r_t, W_t/P_t)$ (LM curve)

(3) $\dot{P}_t = \dot{P}^e_t + a(Y_t - Y_{pt})/Y_{pt}$ (AS curve)

where Y represents nominal gross national income, P is a measure of the overall price level (i.e., the numeraire), r is a real interest rate, W is the nominal value of wealth (which includes the capital stock (K), money (M) and government bonds (B)), c represents real consumption expenditures, i represents real investment expenditures, g is real government expenditures, xm represents real net exports, $\dot{P}$ is the rate of change in the general price level, $\dot{P}^e$ is the expected rate of change in the general price level, Y_p represents potential output and the t subscript denotes period t.[1]

Replacing the LM curve

At first glance, there appear to be three endogenous variables in this three-equation model (i.e., Y/P, r and $\dot{P}$). However, there are five variables imbedded in this simple model (the three above plus the quantity and interest rate on government bonds), making the system incomplete. To define wealth, government bonds must be included. Yet, equations detailing the demand for and supply of these bonds are omitted in most standard textbook models. Instead, most authors implicitly use Walras Law and the government budget constraint to remove references to government bonds.

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[1]Many of the simplifying assumptions reflected in these equations are *not* embodied in the AG-GEM model. For example, the model *does* capture the tax rate effects on consumption and investment expenditures, and money is *not* assumed to be neutral in the short run. These simplifying assumptions were made here to facilitate the presentation.

A simplistic interpretation of Walras Law is that every dollar of income is used in some way. Thus, dollars not spent on consumption or taxes (savings) are used to increase wealth. This statement can be expressed algebraically in nominal terms as follows:

$$(4) \quad S_t = \Delta W_t = \Delta M_t + \Delta B_t + I_t \qquad \text{(total savings)}$$

where S represents savings, ΔW is the change in wealth, ΔM is the change in base money, ΔB is the change in the value of government bonds owned by the public and I represents nominal gross investment.[2] Through algebraic manipulation, equation (4) can be solved to give the residual demand for bonds as shown below:

$$(5) \quad \Delta B_t = S_t - \Delta M_t - I_t \qquad \text{(change in government bonds)}$$

The government budget constraint expressed in nominal terms states that the federal budget deficit must be financed either by "printing money" or by issuing government bonds. This constraint is expressed as follows:

$$(6) \quad G_t - T_t = \Delta M_t + \Delta B_t \qquad \text{(government budget constraint)}$$

where G represents government expenditures and T represents tax revenues. Rearranging equation (6) to solve for the residual supply of bonds, we see that:

$$(7) \quad \Delta B_t = G_t - T_t - \Delta M_t \qquad \text{(change in government bonds)}$$

which simply states that the supply of bonds is equal to the size of the budget deficit minus any change in base money. In most macroeconomic textbook models, equations similar to equations (5) and (7) are used as the basis for omitting explicit references to the quantity and interest rate on government bonds.

The decision to exclude the bond market in standard textbook presentations is generally made for ease of exposition. Since the supply of money is one of the government's principal policy instruments, its inclusion in textbook models facilitates the development of macroeconomic multipliers and the analysis of policy

[2]Total gross investment does not necessarily represent an increase in wealth since part of gross investment constitutes replacement investment. Savings, however, must cover both replacement investment and any increases in the capital stock.

options. Patinkin argues, however, that the exclusion of the bond market is not necessarily a good choice in practice. He has shown that, while the choice of market to exclude does not influence final market equilibriums, the choice does have implications for dynamics of the system. In his comparison of the dynamics of models including the money market with an LM curve versus models including the bond market with a BB curve, Patinkin concludes that the dynamics make more sense when the bond market is included.[3]

Given Patinkin's arguments, the bond market rather than the money market is included in the AG+GEM model. Walras Law and the government budget constraint are used to residually solve for the demand and supply of money. Equations (5) and (7) thus must be respecified to solve for the change in money rather than the change in bonds. If we use these two new equations to eliminate the quantity of money (M) and the return on money (r), the LM curve given by equation (2) can be replaced by:

(8) $B_t/P_t = b(Y_t/P_t, r_{bt}, W_t/P_t)$ (BB curve)

Monetary policy in this model is transmitted through changes in government bonds held by the public. The Federal Reserve controls the growth in money by deciding how many government bonds to buy. This differs from models with an LM curve which requires the user to assume how much to add to bank reserves.[4] Fiscal policy is reflected in this model by the level of government expenditures and tax rates.

Respecifying the AS curve

The aggregate supply (AS) curve presented in equation (3) has been widely adopted in macroeconomic textbooks (see Gordon). It has many of the important properties deemed necessary in such a function. The

[3]Patinkin's arguments relate to the direction of change in interest rates implied by the two curves whenever there is excess supply for both bonds and money. If there is excess supply in these two financial markets, there must be excess demand in the goods markets. Excess supply of bonds implies decreasing bond prices and higher interest rates. Excess supply of money implies declining interest rates. During a period of excess demand for goods, Patinkin argues that rising interest rates are more likely and thus inclusion of the bond market is more appropriate. A symmetric argument can be made for times when there is excess demand in both the bond and money markets.

[4]Purchases of government bonds account for only the nonborrowed reserves component of the monetary base. Two other exogenous variables are used - the discount rate and the level of currency - to control growth in other components of base money. The monetary base is then converted into maximum levels of deposits and bank loans based upon reserve requirements. These maximums help determine interest rates charged and paid by financial intermediaries.

first term on the right-hand side of equation (3) can be interpreted as representing ***cost push*** inflationary pressures. Workers expecting a given inflation rate will bargain for increases in their wages. Producers also expecting the same level of inflation will likely grant such wage requests. The second term in equation (3) reflects ***demand pull*** inflationary pressures. As actual GNP grows relative to the nation's potential GNP, inflation will increase.

Equilibrium is achieved in the long run only when there are no surprises (i.e., when actual inflation equals expected inflation). This can only be true in equation (3) when actual GNP equals the nation's potential GNP. So, while equation (3) allows for a short term dynamic trade-off between inflation and the unemployment of labor and capital, long run equilibrium satisfies the classical requirement of full employment.

Equation (3) cannot be estimated in its present form since reliable data on general price expectations are unavailable. Assumptions therefore must be made regarding the formation of inflationary expectations. One approach is to assume that the expected level of inflation is directly related to current and past rates of change in the money supply. In the AG+GEM econometric model, however, the elimination of the money market requires further substitution before estimation. Solving equation (7) for ΔM and partitioning the budget deficit from bond financing, the AS curve specified for the AG+GEM econometric model takes the form:[5]

$$(9) \quad \overset{*}{P}_t = \theta_n(G_t - T_t) + \theta_m(\overset{*}{B}_t) + a(Y_t - Y_{pt})/Y_{pt} \qquad \text{(revised AS curve)}$$

where θ_m represents an m-period distributed lag and $\overset{*}{B}$ is the growth rate for government bonds owned by the private sectors. Equations (1), (8) and (9) form the theoretical basis of the AG+GEM econometric model's macroeconomic structure.

The AG+GEM econometric model, however, is a ***commodity-specific*** macroeconomic model. The model is still general equilibrium in nature, since it captures the interactions between transactor groups taking place annually in specific markets in a fully simultaneous fashion over the life of the simulation period. Changes in farm product prices, for example, show up in the food component of the Consumer Price Index

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[5]Separation of the deficit from bond financing in this equation is done to accommodate the fact that the government budget constraint is not an exact identity (see footnote 3).

(CPI) and the rate of inflation. The rate of inflation, in turn, affects real interest rates, and hence a broad range of variables, such as foreign exchange rates.

The contribution of the individual transactor groups to the nation's output in the AG+GEM model can be seen by examining the calculation of the nation's GNP. Actual GNP expressed in constant dollars reflects expenditures by these groups summed over all products, or:

$$(10) \quad y = \sum_{i=1}^{nc} \sum_{k=1}^{mc} c_{ikt} + \sum_{j=1}^{ni} \sum_{h=1}^{mi} i_{jht} + g_t \qquad \text{(multi-sectored IS curve)}$$

where y represents real GNP, c_{ik} represents real consumption expenditures for the k^{th} good by the i^{th} transactor group, i_{jh} represents real investment expenditures for the h^{th} good by the j^{th} transactor group, g represents total real government expenditures, nc represents the number of consumer groups, mc represents the number of consumer goods and services, ni represents the number of investor groups and mi represents the number of investor groups. In other words, the AG+GEM econometric model sums over the goods and services purchased by consumers (including foreigners), producers and government. Equation (10) above represents a disaggregation of equation (1), where the determinants of consumption and investment behavior by the individual transactor groups are discussed below.

Product market disaggregation

Demand and supply equations for ***consumer goods and services*** take the following general forms in the AG+GEM econometric model:

$$(11) \quad q^d_{ikt} = d(p_{kt}, \Phi p_{ot}, r_{bt}, c_{it}) \qquad \text{(demand for consumer goods)}$$

$$(12) \quad q^s_{kt} = s(p_{kt}, \Phi p_{ot}, r_{bt}, \Phi p_{ut}) \qquad \text{(supply of consumer goods)}$$

where the market clearing equation takes the form:

$$(13) \quad \sum_{i=1}^{nc} q^d_{ikt} = q^s_{kt} \qquad \text{(market equilibrium)}$$

and where q_{ij}^d represents the quantity of the j^{th} good demanded by the i^{th} group, p_k is the own price of the k^{th} good, c_i represents the total expenditures by the i^{th} transactor group (which acts as a budget constraint), q_k^s is the quantity of the k^{th} good supplied, Φp_o represents a vector of the prices of all other consumer goods, r_b represents the real market interest rate, and Φp_u represents a vector of the prices of all the inputs used in the production of the k^{th} good.

Forcing equilibrium using the market clearing equation allows us to solve one of the demand or supply equations for the price of the k^{th} good. Consumption for each transactor group and for each good can be calculated based upon these prices and quantities and aggregated to determine total consumption, which represents the ***first*** term in equation (10).

The demand and supply equations for ***capital goods*** in the AG+GEM econometric model take the following general forms:

(14) $q_{jht}^d = d(p_{ht}, r_{bt}, \Phi p_{ot}, O_{jt}, tx_t, K_{jht-1})$ (demand for producer capital)

(15) $q_{ht}^s = s(p_{ht}, \Phi p_{ot}, r_{bt}, \Phi p_{ut})$ (supply of producer capital)

where the market clearing equation takes the form:

(16) $q_{ht}^s = \sum_{j=1}^{ni} (q_{jht}^d + D_{jht})$ (market equilibrium)

and where q_{jh} is the quantity of the h^{th} capital good added to the capital stock of the j^{th} group, p_h is the real price of the capital good, r_b represents real market interest rate, Φp_o is a vector of prices of all other capital goods, O_j represents expected output, t is the effective tax rate, K_{t-1} is the lagged capital stock, Φp_u is a vector of the prices of all inputs used to produce the h^{th} capital good, and D_{jh} is the depreciation of the h^{th} capital stock owned by the j^{th} group.

Total investment expenditures in the h^{th} capital good by the j^{th} investor group is therefore given by the following general form:

(17) $i_{jht} = p_h(q_{jht} + D_{jht})$ (gross private domestic investment)

$$D_{jht} = e(\sum_{i=1}^{\infty} q_{jht-i}). \quad \text{(capital consumption)} \tag{18}$$

Thus, equations (14) through (18) solve for the price of capital goods, the net increase in capital stocks, depreciation and the quantity supplied for each capital good. Equation (17) summed across all goods for all transactor groups gives us gross private domestic investment, which represents the ***second term*** in both equation (1) and equation (10).

The traditional determinants of investment - income and the interest rate - are included in equation (14), but with some extra detail. Income is represented by the prices and quantities of outputs. The interest rate is incorporated in an implicit rental cost of capital which also accounts for the price of capital, the method of financing and taxes (see Penson, Romain and Hughes). The lagged capital stock is included to reflect the base from which stock adjustments are made.

The disaggregated demand and supply equations for consumer goods and services as well as capital goods provide a direct linkage between specific transactor groups through primary and secondary input markets as well as final goods markets. Farm businesses, for example, create raw agricultural commodities by using primary inputs such as land and labor in combination with intermediate goods such as machinery and chemicals supplied by other transactor groups. Derived demand functions for inputs used in farm production as well as the supply of these inputs are included in the AG+GEM econometric model.

Financial market disaggregation

Financial markets in the AG+GEM econometric model are disaggregated to capture the financial flows between farm operator families and the rest of the economy and to determine the financial condition of this transactor group as indicated earlier in Table 2. Unlike the disaggregation of the product markets, however, expanding beyond the money market to account for government bonds is not sufficient. With the exception of money and government bonds, all financial assets cancel out in the standard textbook macroeconomic model. Once sectors are partitioned, however, one must account for ***each*** sector's financial instruments, since the liabilities of one group are no longer canceled by the assets of another group. This expansion of the number of financial instruments is one of the principal differences between aggregate macroeconomic analysis and standard microeconomic theory. Those who have an understanding of the standard textbook macroeconomic model may feel that many of the financial asset equations appearing in a multi-sectored general equilibrium model are included on an ad hoc basis. Their inclusion, of course, is ***not ad hoc***. In microeconomic theory, the demands and supplies of financial instruments can be developed using portfolio balancing theory (see Tobin, Penson).

The general form of the demand equations for financial instruments in the AG+GEM econometric model is described in the following equation:

(19) $S^d_{ijt} = d(r_{jt}, \Phi Spa_{it}, \Phi Sfa_{it}, \Phi Sdt_{it})$ (demand for financial assets)

where S^d_{ij} represents the demand for the j^{th} financial instrument by the i^{th} sector, r_j is the rate of return on the j^{th} asset or interest rate on the j^{th} liability, and ΦSpa_i, ΦSfa_i and ΦSdt_i represent vectors of the stocks of physical assets, ***other*** financial assets (i.e., where $k \neq j$) and ***other*** liabilities in the i^{th} sector, respectively (Tobin, Penson).

The rates of return (interest) on assets (liabilities) are determined within the AG+GEM econometric model according to the following general relationship:

(20) $r_{jt} = s(\sum_{i=1}^{m} S^d_{ijt}, \Phi r_{ot})$ (supply of financial assets)

where ΣS^d_{ij} represents the total stock of the i^{th} financial instrument demanded by all groups and Φr_o represents a vector of rates of return (interest) on ***other*** assets (liabilities) relevant to the supplying sector. The yields on government bonds, however, are influenced by the supply rather than demand, as this is where the Federal Reserve influences the money supply and market rates of interest.

International trade linkages

Allowances have been made in the AG+GEM econometric model for the linkages between the domestic and foreign economies. The existence of linkages through the supply of raw agricultural products, demands for food and nonfood consumer goods, and the purchase of government bonds by the "rest-of-the-world" group was already identified in Tables 1 and 2. Rather than having an IS curve with net exports listed as a separate item in calculating gross national product, the components of net exports have been identified and included as demands and supplies in individual markets (see equations (11) and (14)). The real Federal Reserve trade-weighted exchange rate for the ten major U.S. trading partners is a function, in part, of real U.S. and foreign real interest rates. The net export demand for specific farm commodities is discussed in the following section.

Modeling Farm Sector Activity

The general forms of the demand and supply equations for consumer goods and services as well as producer capital goods in the AG+GEM econometric model were described in the previous section. The purpose of this section is to provide further insight to the farm business component of this econometric model. Some of these equations are behavioral in nature, reflecting events taking place in agriculture as well as the general economy. Others are definitional in nature; they sum together selected commodity level outcomes and compute net relationships. Farm commodity-specific components are presented in more detail below.

Crop supply component

The crop supply component of the AG+GEM econometric model is based on a set of supply equations for each of the U.S. Department of Agriculture's ten farm production regions. Crops included in the model are corn, grain sorghum, barley, oats, wheat, soybeans, cotton and hay, with cultivated summer fallow treated as another land use in semi-arid regions. Acreage idled under government programs is also treated as a competing land use in the model.

The regional crop supply component is comprised of a set of econometric equations which include: (1) the total cropland in the region for crops endogenous to the model, including cultivated summer fallow and land idled under government programs; (2) a set of share equations that give the fraction of the total acreage devoted to individual crops, to summer fallow, or idled under government programs; (3) yield equations for each crop that depends on input and crop prices, time, and (in some instances) the acreage harvested and acreage fallowed the previous year; (4) a machinery power index equation that reflects the use of non-land capital; (5) a set of equations for the participation rate in farm programs for individual crops; and

(6) identities for per-acre return expectations.

Specification of the total acreage equation in the AG+GEM econometric model takes the following general form:

$$A_{rt} = \alpha_0 + \alpha_1 RENT_{rt} + \alpha_2 PART_{rt} \bullet SA_{rt} + \alpha_3 A_{rt-1} + \alpha_4 A_{rt-2} \quad (21) \quad \text{(total acreage)}$$

where A_r is total acreage (planted + idled + fallowed) in region r; $PART_r$ is the weighted average participation rate for program crops; and SA_r is the weighted average set-aside rate for program crops.

Individual crop acreage response was modeled by a set of equations that allocate the total acreage to individual crops on the basis of expected returns for individual crops, to cultivated summer fallow, or to land idled under government programs. Land allocation is made on the basis of expected returns for individual crops, farm program variables, and other factors. This set of equations can be denoted in general terms as follows:

$$a_{irt} = f_{ir}(Z_{irt}) \quad (22) \quad \text{(acreage share equations)}$$

where a_{ir} is the fraction (or share) of the total acreage, A_r, devoted to crop i, to summer fallow, or idled in region r; and Z_{ir} is a set of explanatory variables. A zero-one constraint on the range of values for a_{ir} takes the form:

$$0 \leq a_{irt} \leq 1 \quad \text{for all i, r, and t} \quad (23) \quad \text{(zero-one restriction)}$$

which is constrained by the adding-up restriction that:

$$\sum_i a_{irt} = 1. \quad (24) \quad \text{(adding up restriction)}$$

The mathematical form selected for the share equations in the AG+GEM econometric model takes the following exponential form:

$$a_{irt} = 1 - EXP\{\beta_{iro} + \sum_j \beta_{ijrt} R_{jrt} + \gamma_{0ir} a_{ir,t-1} + \gamma_{1ir} edp_{irt} + \gamma_{2ir} part_{irt} sa_{irt} + \epsilon_{irt}\} \quad (25) \quad \text{(share equations)}$$

where edp_{ir} is the per-acre effective diversion (not set-aside) payment rate, $part_{ir}$ is the participation rate, and sa_{ir} is the set-aside rate for crop i in region r. Equations for the fraction of the total acreage in cultivated summer fallow and equations for the fraction of the total acreage idled under government programs were specified to have the same form as equation (25). However, returns and government program variables were weighted averages over all crops rather than individual crop variables.

The exponential form imposes an upper limit of one on the fraction of the acreage devoted to an individual crop, but does not impose a lower limit of zero nor necessarily satisfy the adding-up restriction in equation (25). However, the form is appealing because the dependent variable can be transformed to result in equations that are linear in parameters if Z is linear. The transformed equation is,

(26) $$w_{irt} = -\log(1 - a_{irt}) = \beta_{ir0} + \sum_j \beta_{jrt} R_{jrt} + \gamma_{0ir} a_{ir,t-1} + \gamma_1 edp_{irt} + \gamma_2 part_{irt} sa_{irt} + \epsilon_{irt}$$ (transformed share equations)

The set of all equations for all crops, summer fallow, and idled acreage in each region was estimated by the seeming-related estimator to account for plausible correlation of the errors, ϵ_{ir}.

Expected per-acre returns for program crops was defined to be the maximum of lagged regional market price and target price (assuming full deficiency payments) times expected per-acre yield minus variable production costs. Individual crop acreage equations were specified to depend on expected per-acre returns over variable costs for the own-crop and major competing crops in that region, while the total acreage equation was specified to depend on per-acre returns over non-land fixed and variable costs. Fixed costs were considered in the total acreage equation but not in the individual crop acreage equations because they influence long-run acreage expansion or contraction decisions, but should not influence annual decisions about what fraction of an existing cropland base to plant to individual crops. Expectations of returns over variable costs for a specific crop at the regional level in the AG+GEM econometric model are given by:

(27) $$R_{irt} = MAX\,[P_{ir,t-1}, TP_{irt}] \cdot \hat{Y}_{irt} - VC_{irt}$$ (per-acre return expectations)

where R_{ir} is expected per-acre returns over variables costs for the i^{th} crop in the r^{th} region, TP_{ir} is the target price for that crop, $\hat{Y}_{ir}$ is expected yield, and VC_{ir} is the variable cost of producing that crop.

Yield equations in the AG+GEM econometric model were specified to be a function of the ratio of an input price index to the maximum of the lagged market price and the target price. A chemical price index was used for cotton and soybeans, and a fertilizer price index was used for the other crops in the model. The general functional form used is as follows:

$$(28) \quad Y_{irt} = a_0 + a_1 t + a_2(PF_t/MAX(P_{ir,t-1}, TP_{irt}))^2 \qquad \text{(yield equations)}$$

where PF is the input price index previously referenced. This functional form is consistent with a quadratic production function, but because of potential aggregation biases the regional yield equations should be interpreted only as an aggregate behavioral relationship.

Regional participation in government farm programs was endogenized into the econometric model and thus the simulation model with a set of equations that show the participation rate as a function of economic and program variables. This set of equations was specified to take the following form:

$$(29) \quad part_{irt} = 1 - EXP\{ -(c_0 + c_1 RM_{irt} + c_2 RTP_{irt}(1 - sa_{irt}) + c_3 edp_{irt})\} \qquad \text{(participation rate equations)}$$

where $part_{ir}$ is the participation rate in the program for crop i in region r; RM_{ir} is expected returns based on lagged market price; TRP_{ir} is expected returns based on target price; sa_{ir} is set-aside rate; and edp_{ir} is effective diversion payment rate. Returns based on target price reduced for the set-aside requirement is a parsimonious way of showing the impacts of both target price and set-aside requirements on participation, and as such is conceptually similar to the notion of an effective support price proposed by Houck and Subotnik.

Crop demand component

Commodities included in the crop demand sector are corn, grain sorghum, barley, oats, wheat, soybeans, cotton lint and cottonseed, hay, and cottonseed and soybean meal and oil. Crop demand was further broken down into seed use, food, fiber or crushing use, feed use, net export and ending stocks categories. The following discussion will highlight specification of these model components, especially as they relate to endogenous variables in the AG+GEM econometric model. Selected econometric equations include additional explanatory variables (that are too numerous to mention in this article) to explain historical shifts in demand. All demand functions were specified to be homogeneous of degree zero in real prices and income.

Food demand for corn, sorghum, barley, oats, and wheat was specified to be of the form:

$$(30) \quad \ln(QFO_{it}) = \alpha_i + \Sigma\beta_{ij}\ln(p_{jt}) + g_i\ln(YFO_t) \qquad \text{(food demand)}$$

where QFO_i is the per-capita domestic food demand for the i_{th} commodity (corn, sorghum, barley, oats, wheat, cottonseed oil and soybean oil), p_j is price of the j_{th} commodity, and YFO is per-capita expenditures on food. Symmetry of cross-price effects was imposed on the system of food demand equations given by equation (30).[6]

Domestic livestock feed demand was specified to be proportional to endogenous animal units (grain, roughage or protein consuming animal units, depending on feed type), and exponentionally related to feed price:

$$(31) \quad \ln(QFE_{it}) = \ln(AU_t) + \alpha_i + \Sigma\beta_{ij}\ln(p_j) \qquad \text{(feed demand)}$$

where QFE_i is the quantity of feed type i (corn, sorghum, barley, oats, wheat, hay, cottonseed meal and soybean meal) consumed, and AU is (grain, roughage or protein) consuming animal units. Animal units were endogenously computed from livestock numbers and production; therefore, feed demands depend on livestock as well as crop prices in the model.

Stocks of nonperishable agricultural commodities were treated conceptually the same as other components of demand; namely, stocks were specified to depend on prices because firms hold stocks for speculative purposes as well as for pipeline inventories. Econometric specification of the stock equations allowed for the influence of farm programs on stocks, but under the 1985 Food Security Act, the loan rate for program crops (i.e. feed grains, wheat, soybeans and cotton lint) does not establish a floor on market price. Under the current farm program, total stocks were specified to depend on market price and beginning stocks:

$$(32) \quad \ln(QS_{it}) = \alpha_i + \beta i\ln(p_{it}) + \gamma i\ln(QS_{i,t-1}) \qquad \text{(stock holding behavior)}$$

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[6]See Taylor for additional discussion of symmetry.

where QS_i is total (Government plus private) stocks of the i_{th} commodity.

Domestic oilseed (cottonseed and soybeans) crushing demand was specified to depend on the raw material price and on the prices of oil and meal:

(33) $\ln(QCR_{it}) = \alpha_i + \beta_i \ln(p_{it}) + \gamma_i \ln(po_{it}) + \eta_i \ln(pm_{it})$ (oilseed crushing demand)

where p_i is raw material price, po_i is the price of oil, and pm_i is the price of meal (i = soybeans, cottonseed).

The crop-specific international component of AG+GEM is modeled by a set of equations for: (a) production of agricultural commodities in the rest of the world as related to world price and relevant exchange rates; (b) world prices as related to domestic prices and exchange rates; and (c) net export demand (for the United States) as related to domestic prices, exchange rates, and production of that crop in the rest of the world. Rest-of-world production is specified as follows:

(34) $\ln(QROW_{it}) = \alpha_i + \beta_i \ln(cp_{it-1} * cxrate_{it})$ (rest-of-world production)

where cp_i is the weighted price (in U.S. dollars) of the i^{th} commodity in major competing countries, and $cxrate_i$ is the crop specific real weighted exchange rate for competing countries. The weighted price in competing countries is related to the domestic price in the AG+GEM econometric model as follows:

(35) $\ln(cp_{i,t}) = \alpha_i + \beta_i \ln(p_{it})$ (rest-of-world price)

where p_i is the domestic price of the i^{th} commodity.

Net export demand for commodities produced in the United States is specified in the AG+GEM econometric model as follows:

(36) $\ln(QEX_{it}) = \alpha_i + \Sigma\beta_{ij} \ln(p_{jt} * xrate_{it}) + \gamma_i \ln(QROW_{it}) + \eta_i \ln(QEX_{i,t-1})$ (net export demand)

where $xrate_i$ is the crop-specific real weighted exchange for countries which import the i^{th} commodity produced in the U.S. Symmetry was imposed for the non-zero cross-price effects in equation (36).

The specification of the international agricultural sector and the net export demand for U.S. agricultural products given by equations (34), (35) and (36) shows how foreign producers react to world prices, how the domestic share of world exports react to foreign production, and how foreign consumers react to domestic prices expressed in terms of their own currency. Commodity trade-weighted exchange rate indices are also endogenized in the AG+GEM econometric model, reflecting trends, in part, in the Federal Reserve's trade-weighted exchange rate index discussed previously.

Finally, seed demand in the AG+GEM econometric model was assumed proportional to crop acreage, or:

(37) $QSD_{it} = \alpha_i A_{it}$ (seed demand)

where QSD_i is the quantity of seed used for the i^{th} crop, and A_i is the total planted acreage of the i^{th} crop.

Livestock component

The livestock component of the AG+GEM econometric model is comprised of national-level production and inverse demand equations for beef, veal, milk, pork and chickens. Prices at the farm and retail level are endogenized with a system of margin or farm price relationships.

The livestock component is linked to the crop component of the AG+GEM econometric model because feed costs are an explanatory variable in specific livestock supply equations. Furthermore, the crop component is linked to the livestock model because animal units are explanatory variables in the domestic feed demand equations. A detailed specification of the livestock component of the AG+GEM econometric model is given by Peel and Taylor.

Agricultural commodity prices

The AG+GEM econometric model is solved by numerically finding the set of prices that simultaneously clear all markets. In the crop and livestock components, aggregate supply, which is largely predetermined in a given year, is equated with aggregate demand when determining the set of national average crop and livestock market prices. The set of crop and livestock prices that simultaneously clear all crop and all livestock markets is obtained in each year over the simulation period. Numerical solution is required because the demand functions and supply functions related to current prices are highly nonlinear and cannot the algebraically obtained.

Farm capital expenditures

The desired stock of specific categories of durable capital goods in agriculture (i.e., tractors, trucks, autos, other machinery, real estate improvements and breeding livestock) adopted in the AG+GEM econometric model are given by:

(38) $K_{jt}^* = \beta_j(p_tX_t/c_{jt})^*$ (desired stock of durable agricultural goods)

where β_j is the partial production elasticity associated with the j^{th} input, pX^* is the expected revenue generated by another unit of capital and c_j^* is the expected implicit rental price of the j^{th} capital good. The desired expansion of the j^{th} durable capital good in period t would therefore be given by:

(39) $N_{jt}^* = \beta_j(p_tX_t/c_{jt})^* - K_{jt-i}$. (desired expansion of capital goods)

Penson, Romain and Hughes define the implicit rental price of capital adopted in the AG+GEM econometric model as follows:

(40) $c_j = [(q_j\rho)/(1 - F_j)][\alpha - i_c - i_\pi\{\delta/(\delta + \rho)\}]/(1 - i_\pi) + (Z - i_\pi r\psi)/(1 - i_\pi)$ (implicit rental price)

where:

(41) $F_j = \sum_{i=1}^{\infty} h_{ji}(1 + \rho)^{-i}$,

(42) $1/(1 - F_j) = 1 + \sum_{t=1}^{\infty} (\partial R_{jt}/\partial K_j)(1 + \rho)^{-t}$,

(43) $\delta/(\delta + \rho) = \sum_{t=1}^{\infty} \delta(1 - \delta)^{t-1}(1 + \rho)^{-t}$,

and where r is the real rate of interest on debt capital, ρ is the real after-tax opportunity rate of return on equity capital desired by farmers, q_j is the real price paid for the j^{th} capital good at the retail level, α is the proportion of the investment financed with equity capital, i_c is the investment tax credit rate, R_{jt} represents the real level of replacement investment required in period t, i_π is the income tax rate, δ represents the tax depreciation rate given by 2/n where n is the service life of the tractor, Z represents the value of the periodic loan payment (principal plus interest), ψ is the fraction of the purchase price financed with debt capital (i.e., $\psi = 1 - \alpha$), F_j is the present value of the stream of capacity depreciation associated with the j^{th} capital good, and h_{ji} is the fraction of the tractor's original productive capacity lost in the i^{th} year of its service life.

Equation (40) suggests that the implicit rental price of tractors will increase if their purchase price, the cost of debt and equity capital, capacity depreciation, or income tax rates increase. These effects will be offset to some extent by an increase in the investment tax credit rate and the deductibility of tax depreciation allowances and interest payments. The implicit rental price of tractors presented in equation (40) is a sharp contrast to the measures of the marginal factor cost specified in previous studies.

Farm production expenses

The demand equations for nondurable capital goods used to produce crops and livestock in the AG+GEM econometric model take much the same form adopted for durable capital goods expressed in equation (40). The major difference is in the specification of the implicit cost of durable versus nondurable capital goods. Several of the terms in equation (40) "drop out" of the implicit cost of nondurable goods adopted in the AG+GEM econometric model, including the present value of the stream of capacity depreciation (F_j) and the tax depreciation rate (δ).

Other significant features of equations addressing farm production expenses in the AG+GEM econometric model include the means by which interest expenses and depreciation are modeled. Interest expenses are modeled by accounting for both the average interest rates on real estate and non-real estate farm loans and the levels of these categories of farm debt outstanding. This requires an explicit modeling of the demand for farm debt capital. The demand and supply of farm debt capital is usually omitted in agricultural sector models. Depreciation expenses are modeled in the AG+GEM econometric model by accounting for stocks of durable capital goods, which is given in general form by a transformation of equation (38), as well as tax depreciation rates.

Net farm income

The most closely watched statistic projected by the AG+GEM econometric model is net farm income, which is found by subtracting farm production expenses from gross farm income. Gross farm income is determined by totaling cash receipts for the individual crop and livestock commodities as well as other sources of income, including direct government payments associated with program crops and livestock. While not included in net farm income, the AG+GEM econometric model also captures off-farm income of farm operator families as well as farm household expenditures.

Balance sheet entries

In addition to modeling the income statement for the farm business sector as well as farm household income, the AG+GEM econometric model captures the factors influencing the values of physical assets on farms and the financial assets of farm businesses and households. The model also captures farm debt outstanding owed by farm operator families and nonoperator landlords. The demands for financial assets and farm debt by farm operator families are modeled based upon the general form expressed in equation (19). Stocks of durable capital goods on farms are influenced by capital expenditures, which were captured in equation (38). Farm business and nonoperator landlord demand for farm land and farm real estate prices specified by Hughes, Penson and Bednarz are adopted in the AG+GEM econometric model. The optimal quantity of a durable input such as land can be expressed in the following form:

(44) $K_{fl,FOFt^*} = \beta(RE_{FOFt}/(P_{fl}C_{flt})$ (optimal level of durable inputs)

where K_{fl,FOF^*} is the optimal quantity of land owned by farmers, β is the partial elasticity of production for land, RE_{FOF} is expected gross revenues from farm production, P_{fl} is the price of farm land, and C is the nonprice implicit rental cost of land, an adjusted marginal factor cost. Interest rates on debt enter into the demand for land through the rental cost (C_{fl}), a complex function much like equation (40) where the cost of using a capital input was related to the price of the item, the required return on equity, the item's physical depreciation, income taxes, property taxes, debt financing decisions, and the interest rate on debt.

The nonprice implicit rental cost reflects all of these factors, except the price of the item. Since land does not depreciate and is not subject to investment tax credit, its ***nonprice*** implicit rental cost is significantly simplified in the AG+GEM econometric model as follows:

$$C_{fl} \equiv \rho \frac{[1 - \alpha + (1 - i_{\pi})\alpha U + \alpha V]}{(1 - t_{i\pi})} \tag{45}$$

(nonprice implicit rental cost)

where ρ is the required return on equity, α is the fraction of land purchased using debt financing, i_{π} is the tax rate on profits, U is the present value of the real interest payments on a loan of one dollar, and V is the present value of the real principal payments on a one dollar loan. Both U and V are discounted using the investor's required return on equity. The discounted present value of the loan, therefore, need not be equal to its starting principal balance.

Nonoperator landlord demand for land is assumed to be made on the basis of their desires to balance portfolios of assets and liabilities (Tobin, Penson). This means that their demand function can be expressed as follows:

$$K_{fl,NOLt}^{d} = f(r_{landt}, SOPA_{NOLt}, SFA_{NOLt}, SDT_{NOLt}, Y_{NOLt}) \tag{46}$$

(landlord demand for land)

where $K_{fl,NOLt}^{d}$ stands for the amount of farm land demanded, r_{land} is the total return on land ownership, $SOPA_{NOL}$ is a vector of other physical assets owned, SFA_{NOL} is a vector of the stocks of debt owed by nonoperator landlords and Y_{NOL} represents their current income.

Farm operator families, in addition to wanting land for production purposes, may also desire land as part of their portfolios. The demand for land by farmers in the AG+GEM econometric model is, therefore, a combination of equations (44) and (46), or:

$$K_{fl,NOLt}^{d} = f(RE_{FOF}/(P_{fl}C), SOPA_{FOF}, SFA_{FOF}, SDT_{FOF}). \tag{47}$$

(farmers' demand for land)

Farmers' demands for other assets and debt are also simultaneously accounted for by the AG+GEM econometric model as discussed earlier.

The total supply of farm land is not fixed. Price increases for land can lead to land improvements, while price declines can lead to removal of farm land for other uses. It can be expected, therefore, that the supply of farm land in the United States has a small positive slope.

To complete the specification of the farm land equations, a supply function and a market clearing equation are needed. The supply of farm land is given by:

$$(48) \quad K_{flt}^{s} = f(P_{flt}, P_{labt}, P_{buildt}) \qquad \text{(supply of farm land)}$$

where K_{fls} is the supply of farm land, P_{fl} is the price of farm land, P_{lab} is the wage rate for labor and P_{build} is the price of buildings; P_{lab} and P_{build} reflect the costs of transforming farm land to other uses or improving the quality of the land. The market clearing equation is therefore given by:

$$(49) \quad K_{flt}^{s} = K_{fl,FOFt}^{d} + K_{fl,NOLt}^{d} \,. \qquad \text{(market clearing land price)}$$

The farm land market in the AG+GEM econometric model is therefore captured by equations (44), (46), (47), (48), and (49).

Because farmers purchase most of the farm land sold in the United States each year, it seems reasonable that the principal factors used in explaining changes in the price of farm land are those describing the economic conditions of farmers. Equation (48) was, therefore, solved for the price of farm land. Price thus became a function of the returns to farming, the nonprice components of the implicit rental cost of land, and the per unit costs of real estate improvements.

Remarks on the Model and Software

The AG+GEM econometric model was developed as self-contained FORTRAN code that can be run on a portable 386-based PC. Operation of this model is facilitated by its menu-driven programming. The user designs the nature of the run to be made by responding to a series of menu options. A run of the model based upon the user's assumptions of what farm program policies, macroeconomic policies and other exogenous variables will "most likely" be over the life of the solution horizon is referred to as a ***baseline run***, and comes as close as we come to forecasting. A baseline run and a run reflecting the effects of an ***alternative policy*** can be completed in less than five minutes, thereby allowing the user to provide estimates of the effects that an alternative policy would have to policy makers within a very short time span. These alternative policy runs may focus on the characteristics of a wide variety of policy options associated with farm program policies, macroeconomic policies, or environmental regulations.

A fairly exhaustive menu of farm policy alternatives for which the AG+GEM econometric model is suitable for include: (1) changes in target prices and/or loan rates, (2) an exogenous or endogenous determination of set-aside rates under the Acreage Reduction Program, (3) a soybean marketing loan, (4) changes in paid land diversion rates, (5) changes in Conservation Reserve Program acreage, (6) an endogenous or exogenous determination of farmer participation in the farm program, (7) the use of grain to produce ethanol, (8) changes in technology (introducing new technology or removing old technology such as a pesticide ban) as reflected in per-acre crop yields and variable production costs, (9) crop yield deviates to simulate consequences of a particular weather pattern in combination with a particular policy, and (10) the adoption of dairy growth hormones. Among the broad list of macroeconomic policy options that can be evaluated with this model are: (1) changes in Federal Reserve discount rates, reserve requirement ratios and holdings of government bonds, and (2) changes in personal and business income tax rates, depreciation allowance rates and other fiscal policies.

Reports Provided by AG+GEM

The AG+GEM econometric model described in general terms in this paper projects both economy-wide outcomes as well as sector-level outcomes. Not surprisingly, therefore, the AG+GEM model provides a broad series of reports that reflect economy-wide aggregates as well as sector-level details. The various reports generated by the model ***if requested*** include:

- Nominal and real GNP, including its major components
- Nominal and real federal budgetary information on tax revenue, government expenditures and the budget deficit
- Nominal and real interest rates on a broad range of debt and equity financial instruments
- Implicit GNP price deflator and the components of the CPI, including food
- Balance sheets for farm businesses, farm operator families, nonfarm households, nonfarm businesses and financial intermediaries
- Regional crop production statistics, including acres devoted to major crops, current production levels and carryover stocks
- National commodity balance sheets for major crops, which include information on carrying stocks, production, and imports as well as domestic use, exports and carryout stocks
- Commodity prices received, prices paid for specific production inputs and farm interest rates

- Detailed farm income statement which reports components of gross farm income and total production expenses as well as nominal and real net farm income
- Changes in economic surpluses computed from a policy run compared to a baseline run of the model
- Detailed breakdown of government costs associated with farm programs

Selected output is automatically written to DOS files, which can then be printed. A screen graphics interface allows the user to quickly view the time paths of many of the endogenous variables.

Concluding Remarks

Interdependencies within the agricultural sector and between the agricultural sector and the rest of the United States and world economy are highly complex. The AG+GEM econometric model represents a large-scale effort to model this complexity in a way that will be useful in analyzing the aggregate economic consequences of a wide variety of agricultural and macroeconomic policies. In addition to providing quantitative results, models of this type can provide qualitative results that assist policy in thinking through the complex interdependencies and paradoxical effects. Currently available microcomputer hardware and software now allow us to provide policy impact information to decision makers in a timely way, often in a matter of minutes, rather than after decisions have already been made.

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