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THE VALUE OF ENDOGENIZING AGRICULTURE IN A MULTI-SECTOR MACROECONOMIC MODEL

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ABSTRACT

Hughes, Dean W. and John B. Penson, Jr.--The Value of Endogenizing Agriculture in a Multi-Sector Macroeconomic Model

Several agricultural economists have suggested that agricultural models could be improved by capturing all of the linkages between agriculture and the rest of the economy. In this study, a new multi-sector macroeconomic model is used to compare the forecasting abilities of first, second, and third generation agricultural simulation models. This study finds that forecasting errors can be reduced and a wider range of questions can be addressed by models that simultaneously solve for the agricultural and nonagricultural sectors of the economy.

Key words: Agricultural modeling, macroeconomic models, endogenization

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THE VALUE OF ENDOGENIZING AGRICULTURE IN A MULTI-SECTOR MACROECONOMIC MODEL

Agricultural economists are increasingly recognizing that the linkages between agriculture and the general economy should not be ignored when modeling events in this sector. At issue is whether or not it is worth the time and expense required to endogenize these linkages in a model designed primarily to forecast agricultural sector outcomes. This paper initially groups existing agricultural sector models according to the manner in which they treat the linkages between this sector and the general economy. Representations of these alternative model configurations are then used to assess the value of endogenizing the interface between agriculture and the general economy when developing a model designed principally to forecast outcomes in this sector.

Generations of Sector Models

Agricultural sector models can be categorized according to how they treat the linkages between agriculture and the rest of the general economy. The first generation of agricultural sector models treat this sector as a separate entity. In these models, agriculture is affected by a few general economic variables, such as consumer disposable income, interest rates, and the level of agricultural exports. Disturbances in agriculture are assumed to have no impact on the rest of the economy. The second generation of agricultural sector models forecast outcomes in this sector recursively. General macroeconomic models are first used to forecast a set of relevant variables used to solve the agricultural equations.

The solution values for these agricultural sector variables are then transmitted back to the general economy through a set of definitional linkages. Examples of these linkages include the definition of the consumer price index and gross national product. While agriculture can have an impact on the general economy in second generation models, the effects are delayed one period. Thus, there are no first period multipliers for agricultural sector activities.

During the mid-1970s, agricultural economists began to realized the importance of more direct linkages between their models and the rest of the economy. As farm exports grew, the need to account for their impact on the balance of trade and exchange rates became obvious. The proportion of inputs purchased off the farm was rapidly increasing, making farmers and other production sectors more interdependent. The volatility of farm prices jumped sharply in the early 1970s, increasing general awareness of the impact that food prices have on the cost of living. Both real estate and nonreal estate farm debt rose rapidly over the last decade, making farm ownership and production activities more dependent on the availability and cost of credit. More recently, we have seen substantial changes in banking regulations which have made rural credit markets far more sensitive to changes in national money market conditions.

All of these linkages were discussed in papers presented by King, Popkin, Roop and Zeitner, Johnson, Just, Penson and Hughes, and Gardner at American Agricultural Economics Association (AAEA) meetings held in 1974, 1976, 1978, and 1981. Just, for example, summarized his concerns regarding partial equilibrium analysis with this comment

> "macroeconomic forecasters have done very poorly in predicting inflation rates, etc., for the general economy because they have failed to predict changes in exogenous prices, many of which pertain to the agricultural sector. However, agricultural forecasters have also done very poorly in predicting the recent large variations in agricultural prices, and again the reasons lie in the lack of inclusion or difficulty in prediction of exogenous variables, some of which pertain to the general economy. <u>Thus, both general and agricultural forecasters may benefit by pooling their models</u>." (p. 137, emphasis added)

Even those models designed to capture the interface between agriculture and the rest of the economy by recursively linking agricultural sector models to established macroeconomic models were criticized by Johnson for their approach.

> "Finally, for the linkages between the agricultural sector and the economy, it is not apparent that much progress has been made. Providing these links with a series of identities is possible and done by Chen and Roop and Zeitner, but there must be more to the connection between economic sectors of the economy." (p. 134)

In response to these calls for further endogenization, several econometric models of the entire economy have been developed which simultaneously solve for agriculture as one of a comprehensive set of sectors in the U.S. economy. The first of these models was discussed in a contributed paper by Shei and Thompson at the 1979 AAEA meetings. Shei's simulation model was extremely aggregate, capturing the entire economy in fewer than 40 equations. Lamm later provided an even more aggregate model of the economy, reducing the number of estimated equations to 28.

In compressing the economy to such small numbers of equations, both of the preceding models suffer from at least two problems. First, the goods in these models are be so highly aggregated that many useful behavioral relationships are hidden. For example, Lamm's model has only three "inputs" to agricultural production: (1) the real annual flow of capital into the agricultural sector, (2) the agricultural labor force, and (3) time. In light of the changes we have seen in the relative costs of fuel vs. capital, certainly further dissaggregation is necessary to capture the input substitution that has been underway for almost a decade. Second, both of the preceding models fail to account for the accumulation of wealth by different sectors. Thus, a major benefit of specifying multi-sector general equilibrium models is lost.

A third model, recently developed by Prentice, consists of over 100 equations and provides greater detail on many parts of the economy than is available in the models developed by Shei and Lamm. However, Prentice's model lacks reference to credit markets, thus ignoring the increasingly important financial linkages between agriculture and the rest of the economy.

A New Multi-sector Model

This study uses a new third generation model developed by Hughes and Penson.[1/] This model captures all of the linkages suggested by previous authors, including the linkages (1) between agricultural producers and the suppliers of inputs, (2) between agricultural output, wholesale purchases of food items, and the final consumption of agricultural goods at the retail level, (3) between agriculture and the U.S. balance of trade and exchange rates, (4) between agriculture and the government sector, and (5) between agriculture and national financial markets.

The model takes its name, "GEM," from its general equilibrium theoretical structure. General equilibrium models capture the demand by each consumer for each good and the supply of each good by each producer. Obviously, it is impossible with current data and technology to develop a completely dissaggregated general equilibrium model. Therefore, both transactors and goods must be aggregated.[2/]

GEM contains six economic sectors: farm operator families, the nonfarm production sector, other domestic consumers, government, financial intermediaries, and the rest of the world. While there are too many goods in the model to list individually, they can be categorized into two groups: physical goods and financial obligations. Physical goods include primary inputs such as land, labor, and crude petroleum; secondary inputs such as capital equipment, manufactured inputs to agriculture, and raw agricultural products; and final consumption goods such as consumer durables, food and, other consumer goods and services. Financial obligations include bank deposits, bonds, equities, and debt. In GEM, supplies of and demands for each of these goods by the sectors converge to the equilibrium prices and quantities (Table 1). All equations were estimated and are solved in constant dollars, and results are reported in both constant and current dollars.

Measuring the Value of Endogenization.

Now that we have a group of models which determine agricultural and nonagricultural economic outcomes simultaneously, one can question whether the effort was worth it? Gardner, while recognizing the need to simultaneously account for the interrelationships between agriculture and the rest of the economy, concludes that it is "preferable to use the macroeconomist's models for the economy-wide variables, and sectoral models with deflated prices for agricultural variables" (p. 16). Since it takes considerably more time, human effort, and money to develop third generation models, some benefits must occur to justify their construction and continued maintenance.

Benefits must come in achieving the goal of economic modeling in a "better" way than the less expensive approaches. We suggest

Table 1. The Structure of GEM

Goods/Sectors	Farm Operator Families	Other Domestic Consumers	Nonfarm Production Sector	Financial Inter-mediaries	Govern-ment	Rest of the World
Physical Goods						
Primary Inputs						
Land	D[1/]	D	D,S[2/]	D		
Labor	S,D	S	D		D	
Crude petroleum			D			S
Secondary Inputs						
Capital	D		D,S			
Manufactured Inputs to Agriculture	D		S			
Raw Agricultural Products	S		D		D	S
Final Products						
Consumer Durables	D	D	S			
Food	D	D	S		D	D
Other	D	D	S		D	D
Financial Obligations						
Bank Deposits	D	D	D	S		
Bonds						
Government		D	D	D	S	D
Private		D	D,S	D		
Equities		D	S	D		
Debt	D	D	D	S		

1/ Demand for goods.
2/ Supply of goods.

that the goal of economic modeling is to provide helpful information to decisionmakers that will improve the likelihood of their making a correct choice when confronted with a set of possible actions unknown to the researcher during construction of the model.

This goal can be discussed in three parts. First, while helpful information required by decisionmakers is an important aspect to be considered when specifying and implementing an economic model, it does not directly relate to the value of endogenization. Second, information provided by economic models should improve the likelihood of making correct choices. No economic model will perfectly forecast the impacts of a given choice. Yet modelers should strive to minimize errors in forecasting economic information. So one of the benefits that might be gained by endogenizing agriculture in a general macroeconomic model is the reduction of forecast error. Third, researchers cannot be aware of all of the possible uses for their models as they are being constructed. Thus, the scope of the questions that can be addressed by a model is also a measure of its value. We shall therefore evaluate the value of endogenization based on two measures: (1) the size of forecasting errors associated with the three generations of agricultural sector models and (2) the types of questions they can answer.

Forecasting Errors of Three Generations of Agricultural Sector Models

To be completely fair in comparing the forecasting errors associated with the three generations of agricultural sector models, we would have to start with three separate representative models, specify some common set of endogenous variables to be used as measurement criteria, project to a common set of exogenous information, forecast a given future time horizon, and then wait for the future to unfold. Yet even this fair test of the properties of the three generations of sector models has many problems in implementation. First generation models have many exogenous macroeconomic variables that are endogenous to the other generations. How can these general economic variables be forecast so as to not bias the test in one direction or another? In addition, three different agricultural sector models would have innumerable differences in their scope and in the specification of individual equations. To overcome many of these problems, we have used GEM to recreate what might have happened if the three generations of models had been asked to forecast a historic time period.

Design of Experiment

The equations in GEM were first partitioned into one set representing an agricultural sector model (89 equations) and the rest (60 equations) representing a nonagricultural macroeconomic model. Conceptually, to simulate a first generation model, the nonagricultural sector equations could be solved for a given number of years and the results could then be fed into the agricultural sector equations to forecast the same time period.3/ Second generation models could be simulated by solving the nonagricultural model, followed recursively by solving the agricultural sector model for each time period. Third generation results can be obtained by solving all of GEM's equations simultaneously.

Unfortunately, the methodology cannot be quite that simplistic. Because GEM contains numerous linkages between the agricultural and nonagricultural sectors, assumptions have to be made regarding agricultural sector outcomes to solve the nonagricultural equations. Simply exogenizing the agricultural sector variables has the effect of using actual agricultural sector outcomes when forecasting nonagricultural variables. This would artificially reduce forecast errors in the nonagricultural equations and bias the results in favor of first and second generation models. Solving the agricultural sector equations first would also bias the conclusions since the nonagricultural variables would be set at their actual values.

We resolved these problems by introducing information from another model. The Federal Reserve-MIT-Penn quarterly econometric model was used to forecast proxies for the nonagricultural variables to initiate a solution algorithm that: (1) solved GEM's agriculture sector equations, (2) fed the results into the nonagricultural equations, and (3) finally solved the agricultural sector equations again. In this way, the impact of the quality of the proxies was reduced in forecasting agriculture sector results and the biases of GEM are included in all comparisons across generations.

The forecasted time period, 1971 through 1975, was chosen to capture a time of unusually high variations in agricultural sector outcomes. Both the Russian wheat deal and the first OPEC oil embargo occurred during this time, causing agricultural input and output prices to be extremely volatile. If it has ever been important to capture agriculture in a macroeconomic model, the early 1970s should point to its importance.

Because individuals differ in their ability to conceptualize large numbers of unspecified economic relationships, the quality of a model's forecasts is not merely a function of its specification and estimation. In fact, the artistry of incorporating relationships among exogenous variables may be the most important aspect of forecasting. For this reason, the forecasts made in this paper were based on actual observations of the exogenous variables.

Comparison of Forecast Errors

Table 2 presents the forecast results for the three generations of models. Three conclusions seem evident: (1) forecasting errors are reduced by increasing endogenization, (2) the importance of endogenization increases over the forecast horizon, and (3) the reduction in forecast errors between the third and second generation models seems to be even greater than that gained by moving from first to second generation models.

Mean absolute percentage forecasting errors (MAPE) decline in almost every case as endogenization was increased. The only significant exception was nominal farm production expenses where errors

Table 2. Percentage Errors of the Projections of Selected Variables from Three Generations of Agricultural Sector Models, 1971-75.

Variable	Units	-----1971-----			-----1972-----			-----1973-----			-----1974-----			-----1975-----			Mean Absolute Percent Error		
		I[1/]	II[2/]	III[3/]	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
FARM																			
Gross Farm Income	Constant Dollars	7.41	7.41	3.61	2.19	2.01	-6.52	2.84	2.53	-7.95	20.74	19.98	3.85	27.93	27.17	1.52	12.17	11.80	4.69
	Nominal Dollars	8.58	8.58	4.95	1.57	1.43	-6.99	3.04	2.61	-8.80	12.30	11.15	-4.50	30.44	29.21	1.34	11.19	10.60	5.32
Farm Production Expenses	Constant Dollars	1.65	1.65	0.18	0.16	-0.39	-5.13	-8.35	-9.22	-16.10	6.32	5.06	-2.91	18.66	18.42	8.34	7.03	6.95	6.53
	Nominal Dollars	1.06	0.85	-0.64	-0.77	-1.34	-6.13	-10.26	-11.18	-18.38	0.83	-0.69	-9.29	13.32	12.93	1.45	5.25	5.40	7.18
Total Farm Assets	Constant Dollars	5.88	5.88	6.07	5.41	5.03	4.41	0.22	-0.44	-2.04	18.40	17.71	15.93	43.57	40.61	26.26	14.70	13.94	10.94
	Nominal Dollars	8.02	8.02	8.30	3.24	2.87	2.08	-3.83	-4.63	-7.08	15.23	14.41	10.95	40.32	37.81	21.96	14.13	13.55	10.07
Total Farm Debt	Constant Dollars	2.51	2.51	2.23	-0.23	-0.63	-2.53	-6.80	-7.78	-12.29	6.25	4.59	-1.97	30.94	28.42	15.12	9.34	8.79	6.83
	Nominal Dollars	2.20	2.20	2.20	0.31	-0.15	-1.53	-7.15	-8.23	-12.42	1.22	-0.73	-7.09	31.94	28.63	14.10	8.56	7.99	7.47
NONFARM																			
Gross National Product	Constant Dollars	2.39	2.39	2.14	-2.19	-2.35	-4.05	-0.30	-0.82	-2.36	11.57	11.59	10.58	10.63	10.90	9.09	5.42	5.61	5.64
	Nominal Dollars	2.22	2.22	1.97	-2.54	-2.70	-4.49	-1.94	-2.50	-4.77	6.45	6.17	3.74	8.50	8.47	4.82	4.33	4.41	3.96
Consumer Price Index	Index 1967=100	1.74	1.74	1.47	3.45	3.40	2.56	1.92	2.07	-0.28	-1.00	-0.78	-4.57	6.38	7.08	1.92	2.90	3.01	2.16
Gross National Product Deflator	Index 1967=100	0.24	0.24	-0.17	-0.67	-0.67	-0.46	-3.93	-4.00	-2.47	-7.12	-7.37	-6.19	-4.75	-5.00	-3.91	3.34	3.46	2.64
Exchange Rate	Index 1967=100	-3.13	-3.13	-3.09	6.09	6.12	6.53	4.28	4.48	5.87	-2.26	-1.93	-0.72	-11.29	-11.34	-10.35	5.41	5.40	5.31

1/ First generation agricultural sector model.
2/ Second generation agricultural sector model.
3/ Third generation agricultural sector model.

in forecasting the gross national product deflator and constant dollar farm production expenses were positively correlated. In some cases, the reduction in forecast errors was substantial. For example, the MAPE of constant dollar gross farm income for the third generation model was only 39 and 40 per cent of that associated with the first and second generation models, respectively. The value of endoganizing agriculture on nonfarm variables seemed to be most important in the price indices. The MAPE for the consumer price index showed a decrease of almost a full percentage point. And MAPE for the gross national product price deflator declined about three-fourths of a percentage point when we moved to the third generation model.

The results shown in Table 2 suggest that the value of endogenization increases as one forecasts further into the future. While the third generation provided some minor improvements in forecasting one year into the future for some variables, percentage errors in most variables were roughly comparable until the fourth and fifth years of the forecast period.

It should not be surprising that increased endogenization enables a model to more accurately forecast further into the future. As feedback loops between different sectors are more completely incorporated into a model, more of the constraints on the activities of decisionmakers are included, leading to more realistic forecasts. Acknowledgement of these feedback mechanisms is extremely important since they determine a greater and greater share of the impact of decisions as time passes. Additionally, given a stable economy, second-round effects must not reinforce initial impacts. Thus, the impact of any decision modeled in a partial equilibrium framework will have a bias toward overstating the decision's impact.

Finally, it was somewhat surprising that moving to a fully simultaneous macroeconomic model would provide greater improvement in forecasting than the move from a first generation model to a second generation model. Yet, as shown in to Table 2, such is the case. Only marginal improvements were found in the MAPE between the first and second generation models. Most of the reductions came in the move to the third generation model. To further test this conclusion, we counted the number of equations in the whole model which showed improvement between generations. Lower MAPE's were found in 73 of the equations in the second generation model when compared with the first generation model. In the same comparison, generation one had 46 equations with a lower MAPE than generation two. Three equations had identical MAPE to the fourth decimal place.[4/] In comparing the MAPE of the third generation model to the second generation model, 80 equations were lower in the third generation model, 41 were lower in the second generation model, and one equation had an identical MAPE between generations. Thus, counting equations also seems to confirm that the improvements were greater in moving from second generation models to third generation models as opposed to moving from first generation models to second generation models.

One caveat to this conclusion should be mentioned. Most of the currently used second generation models are solved quarterly, while GEM is an annual model. Since feedback from agriculture to nonagricultural sectors of the economy is more frequent in many second generation models, it may be argued that their recursiveness is less of a limitation than would be implied by the results shown in Table 2. Offsetting this problem, to some extent, are questions regarding the reliability of quarterly agricultural data. For example, the USDA collects production expense data on an annual basis only. Quarterly forecasts of production expenses or net farm income, therefore, will not yield better forecasts of other variables than those produced by an annual model.

The Value of Questions That Can Be Answered By Different Generations of Agricultural Sector Models

It is almost a tautology that larger econometric models can properly respond to more questions than smaller ones. However, it probably is not generally recognized just how restricted the set of questions that can be responsibly analyzed with first and second generation agricultural models should be.

Researchers, in identifying the ability of an economic model to respond to specific questions, must assume that there is no feedback from the endogenous variables in their models to those that are considered exogenous. In addition, all exogenous relationships, which by definition have been excluded from models, must be subjectively identified and included by researchers in developing a forecast.

Concern regarding relationships between exogenous variables can be overcome to some extent by the skills and commitment of an individual researcher. However, the lack of feedback between agriculture and the rest of the economy embodied in first and second generation models strictly prohibits them from dealing with questions that might substantially alter the general economy.

Take, for example, a question that might concern farm policymakers in the USDA: What is the impact of a major drought on the financial condition of farmers? Researchers may well start out with a consistent baseline forecast of the general economy which specifies consumer incomes, interest rates, and the prices of farm inputs. Yet drought would mean increased prices of farm products. As these price increases work their way through the U.S. economy, their effects will likely include: increases in the relative price of food in domestic retail and export markets, decreases in the purchases of nonfood consumer goods (since the demand for food is inelastic), increases in government expenditures (through ASCS disaster payments), decreases in the value of the dollar in foreign exchange markets, pressure to increase the money supply to finance a growing deficit, and therefore, the possibility of an increase in the overall inflation rate. In future periods, higher inflation would lead to faster increases in the costs of farm inputs, a rise in nominal interest rates, and an increase in the proportion of returns to farming captured in the form of capital gains (Melichar).

First generation agricultural sector models would be at a total loss in capturing these feedback effects. Even second generation agricultural sector models would miss much of the impact of higher current food prices on the current price level. Simply including higher food prices in the definition of the consumer price index overlooks the impact of this change on consumers' decisions to purchase other goods. Thus, forecasts of the impacts of even such a basic change in agricultural sector outcomes would be biased when made by models which are not fully simultaneous.

Conclusions

Agricultural economists who hope to successfully deal with the increasingly integrated economy of the 1980s will have to expand their horizons. Macroeconomics and general equilibrium systems of equations will become the basis for testing economic relationships that have, in the past, been considered specific to farming. As shown in this paper, the benefits of taking a holistic view of the national economy are both measurable and substantial. And the benefits of including agriculture in more general macroeconomic models are becoming evident. As U.S. agriculture leaves the problems of overcapacity in the past, and as world markets for agricultural commodities continue to evolve, variations in the production of food and fiber will be harder to ignore.

FOOTNOTES

1/ Some changes have been made to GEM since the technical report was issued. These changes include redefining the numeraire to be the GNP deflator instead of the CPI, reestimating all of the equations using data through the end of 1979, respecifying the markets for raw agricultural to make demand price dependent and supply quantity dependent, including the CPI in a definition relationship, and adapting the crop production function to account for government set aside programs. These changes have improved the convergence properties of the model and have extended the forecasting horizon. While work is still underway in testing the model, it does solve in a forecasting mode for up to 20 years and seems to have a forecasting horizon of up to 10 years for most variables.

2/ The need to aggregate by assumption has directly led to the proliferation of macroeconomic models. As researchers focus their attention on different aspects of the overall economy, the importance of dealing with individual economic actors and goods changes with the perspective of the work being done. There is, therefore, no "true" economic forecasting model, but a large number of models, each with its own strengths and weaknesses.

3/ The USDA's General-Analytical-Simulation-Solution-Program (Kite) used to solve GEM, allows the researcher to exogenize (turn-off) endogenous relationships. Some minor modifications were required to the SOLV subroutine to allow solutions of one set of endogenous equations to be based on previous solutions of other endogenous equations. The senior author would be pleased to share these adaptations with other users of the USDA's program.

4/ There were 27 equations excluded from the analysis. In each case, the dependent variable was small in absolute terms and ranged between positive and negative numbers. Thus, percentage errors for these variables were meaningless. Most of these variables were real interest rates, but net import and export equations were also excluded.

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