A Systems Approach to U.S. Wheat Policy

By Leonard Brzozowski *

A system dynamics computer simulation model called GRAIN1 can be used to analyze public policy alternatives in the agricultural economy. American farm policy has been aimed at controlling commodity productions cyclic processes faced with many uncertainties. A systems approach such as GRAIN1, used to analyze six alternate future policies for wheat, can assist policymakers by assessing some of the critical trade offs and consequences of alternate policies.

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Simulation
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AN HISTORICAL FRAMEWORK FOR AMERICAN FARM POLICY

A serious problem in U.S. farming has been excess production. During the first half of this century, American agriculture advanced rapidly in efficiency and productivity. Mechanization, more intensive farming practices, and achievements in agricultural research made these advances possible. Yet these advances also resulted in food surpluses and reduced farm prices and incomes.

The efforts of farmers and agricultural researchers to reduce farm costs further through greater efficiency did not entirely succeed during the first third of this century. While some productivity gains were realized, they could not offset the depressed farm commodity prices experienced during that period. Because it was not economically favorable to produce wheat, farmers shifted to other crops yielding higher market prices.

The farmers' response to these economic forces caused cycles in commodity production. When wheat prices, for example, are high, farmers plan to produce more wheat. When half a million wheat farmers increase production, however, a large surplus sends the price down. Similarly, when wheat prices fall, farmers produce less wheat, inventories decline, and wheat prices rise once again. This cyclic behavior is inherent in the production of wheat, corn, and virtually all other commodities.

As a result, farm prices are volatile and difficult to control. They tend to move both upward and downward faster than prices in other sectors of the economy. As a result, agriculture has a visibility that causes politicians, consumers, and farmers to react strongly when prices change dramatically. Such reactions tend to coincide with the oscillations of the commodity production cycle for key commodities.

For example, when the wheat production cycle was at its low point (and prices were high) 3 years ago, consumers organized boycotts of meat products in several U.S. cities. In 1978, we experienced a nationwide farmers' strike at a time when the wheat production cycle was at its peak (prices were depressed).

THE ROLE OF AMERICAN FARM POLICY

With the passage of the Agricultural Adjustment Act of 1933, the Government made a firm commitment to stabilizing the agricultural economy. Since that time, American farm policy's role has been to control commodity production's cyclic processes in the face of uncertain weather variations, export demand, and, most importantly, conflicting consumer and farmer pricing goals. American farm policymakers try to introduce balance into the production and market systems and the divergent goals through three sets of programs: supply management, demand management, and income maintenance.

Supply Management Programs

Acreage controls, diversions, and set-aside programs have the aim of limiting and controlling production and balancing it with expected demand. Under these programs, the U.S. Department of Agriculture (USDA) administers farmer-held grain reserves to absorb random variations in supply and demand and to help insure that commodities are marketed with a minimum of disruption from harvest to harvest. Under provisions of the 1977 farm bill, farmers can take a nonrecourse loan from the Government at the prevailing loan rate, using their harvested crops as collateral. When prices are low, farmers can put part of their crop into Government-paid storage

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for 3 years. If prices rise above a predetermined level, farmers can sell their crop on the open market at a price above the loan rate. If prices continue to rise, the Government can encourage the sale of additional crops from the reserve by discontinuing the payment (subsidy) for crop storage. In extreme cases, the Government can call the loan due and acquire the remaining reserve crop for sale on the market.

Demand Management

Programs are also designed to stimulate demand for American commodities and to use supply excesses. In the past, these objectives were met by providing direct subsidies to foreign countries purchasing American crops, carrying out P.L. 480 (which provides food aid to needy foreign countries), and establishing long-term, grain buying agreements with other nations. Since the 1972 grain sale to the Soviets, which depleted U.S. inventories and contributed to a dramatic rise in prices, an elaborate export reporting system has been established. This system enables the Department of Agriculture to monitor grain exports and, when the market's stability may be threatened, to limit them.

Income Maintenance

Another major set of programs provides supplemental income payments to participating farmers when the supply and demand management programs alone cannot provide a profit-making market price for farm commodities. As farm costs continued to rise, the loan rate failed to guarantee farmers a break-even price for their production. Since increasing the loan rate would have increased the size and cost of Government inventories as well as farm revenues, a target price was established in 1973 to provide supplemental farm income payments. Participating farmers became eligible for a Government payment equivalent to the difference between the market price and the target price.

Management Programs Interlinked

These three sets of programs are closely interrelated and must operate simultaneously to be effective. Some critics argue, for example, that income maintenance programs keep some marginal producers in business and generate excess production. The additional output in turn creates a surplus that tends to reduce prices, creating the need to expand our export demand to reduce excess supplies and return prices to more reasonable levels. To effectively manage these complex interactions, policymakers need a broad "systems" view of agriculture.

A SYSTEMS APPROACH TO FARM POLICY ANALYSIS

A system is a collection of components that interact with each other to perform a function. A farm is a component that interacts with markets, distribution networks, consumers, the environment, labor, machinery, and the Federal Government to produce food and fiber in the system known as the agricultural economy.

Most scientific and economic training focuses on taking complicated systems apart before analyzing them, an extremely useful strategy in increasing the understanding of each component. Effective policies, however, must be based on analytical syntheses of major components' interactions. One cannot design farm policy to act on the commodity market without considering the impact on prices, demand for exports, farm incomes and investment decisions, barriers to entry, and annual production planning. A policy that attempts to reduce prices in the short run will shift future investment and production patterns, which results in much higher future prices to consumers. The long-term effect of a policy that focuses on only one component of the total system will likely be completely different from the desired policy goal or objective.

Thus, we must take an integrated systems approach to farm policy analysis to understand true cause and effect relationships and to understand trade offs between the short and the long term. To understand the farmer and his problems, one must also understand the commodity markets, distribution networks, consumer behavior, capital markets, and export trade in a global context. Current farm policies and market conditions are alteady influencing future farm investment planning and farm structure. The planning and structural changes, in turn, will influence market conditions farther into the future.

THE GRAIN1 MODEL

To study the interactions among components of the agricultural economy, computer programmers developed a computer simulation model of the U.S. wheat production system. The model, GRAIN1, uses the system dynamics method to simulate the behavior of complex systems. In system dynamics, information feedback and control concepts are extended to nonlinear social systems. The system dynamics computer language, DYNAMO, allows the user to represent real-world decision mechanisms as simple mathematical equations.

This method has been used to model such processes as inventory control and production planning in industrial organizations,[1] capital investment decisions giving rise to commodity production cycles,[2] and the policy and market forces that will govern the energy transition of the United States from oil and gas to alternate sources.[3]

Figure 1, the basic structure of the GRAIN1 model, illustrates some major relationships in the U.S. wheat production system. The arrows point from causes to effects; whether the arrowhead is open or closed indicates the nature of the influence. A closed arrowhead (plus) indicates that a change in the influential variable causes a change in the same direction of the influenced variable, when all other elements of the system are assumed to remain constant. An open arrowhead (minus) indicates that the influenced variable will move in the opposite direction.

Analysts developed the model's basic structure by examining the direct cause-effect relationships within the wheat sector, through interviews with wheat farmers, bankers, equipment dealers, Government policymakers, farmers, and co-op managers. The analysts combined the responses with conventional economic theory and historical statistics to obtain the major causal relationships between each of the major model sectors.

The wheat *production and market sector* examines the existing complement of land and equipment and the application of inputs. It calculates annual production, sets the season's average price, and determines the year's consumption, both domestic and export.

The *farm program sector* models the effect of Government programs on wheat farming. In addition to the supply and demand management and the income maintenance programs described earlier, this sector represents the effects of programs designed to conserve the land base from decay caused by erosion or by the extraction of key soil nutrients. It includes Federal Government expenditures on research and development directed at increasing the yield potential of American farmland. These programs are explicitly included under such headings as wheat allotments, parity payments, marketing certificates, disaster payments, deficiency payments, Commodity Credit Corporation reserve stocks, research and development, and conservation programs.

The *goal formulation sector* sets objectives for farmers during the coming year. In this sector, farmers are assumed to compare performance, as defined by annual income per farm, with performance of those not pursuing a career in farming. Based on this comparison, the sector formulates income and production goals for the coming year.

Once an output goal is established, the *factor allocation sector* calculates the investment necessary to meet it. On occasion, when the annual cash flow is insufficient to warrant new debt acquisitions, as determined in the finance sector (described below), the required level of investment will not be met. The factor allocation sector divides the annual investment between two strategic alternatives. Farmers can increase their output by expanding farm size and purchasing the additional capital equipment, or they can farm their existing land more intensively through increased use of current inputs.

The *farm population and land sector* measures the profitability and attractiveness of wheat farming. It determines the number of farmers who wish to enter

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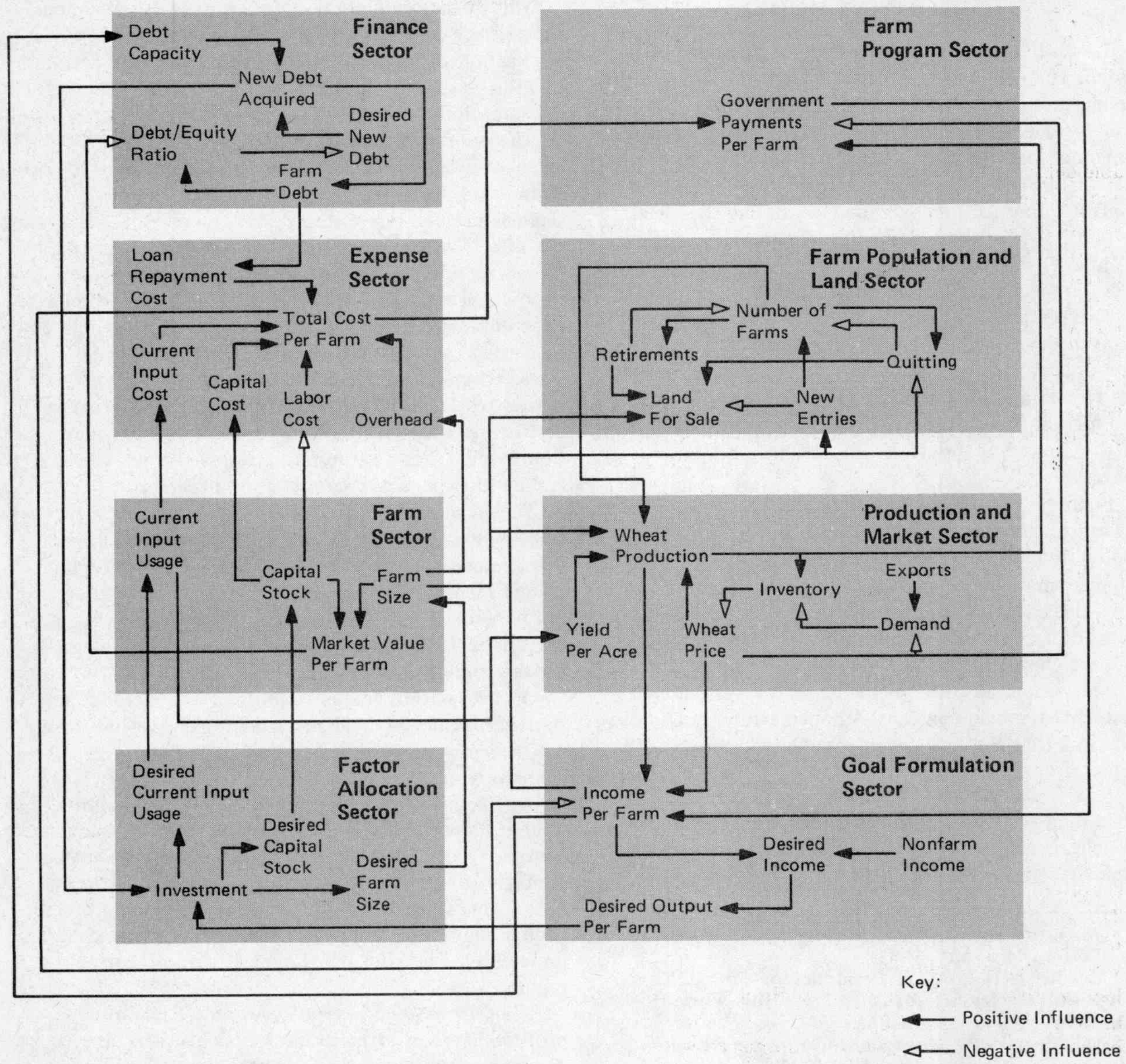
[1] Forrester, Jay W., *Industrial Dynamics*, The MIT Press, Cambridge, MA, 1961.

[2] Meadows, Dennis L., *Dynamics of Commodity Production Cycles*, Wright-Allen Press, Inc., Cambridge, MA, 1970.

[3] Naill, Roger F., *Managing the Energy Transition*, Ballinger Pub. Co., Cambridge, MA, 1977.

FIGURE 1
Major Causal Relationships in Wheat Production



the industry and the number of established farmers who quit for economic reasons. This sector records the natural maturation process of established farmers, calculates the number of normal retirements that occur each year, and records transfers of property. The sector also measures the total demand for farmland, by both established and potential farmers, and apportions the available land between the two groups.

The *finance sector* measures wheat farmers' annual cash flow and determines the total amount of supportable debt. It also performs an accounting of annual debt acquisition and repayments, and records the total level of farm debt.

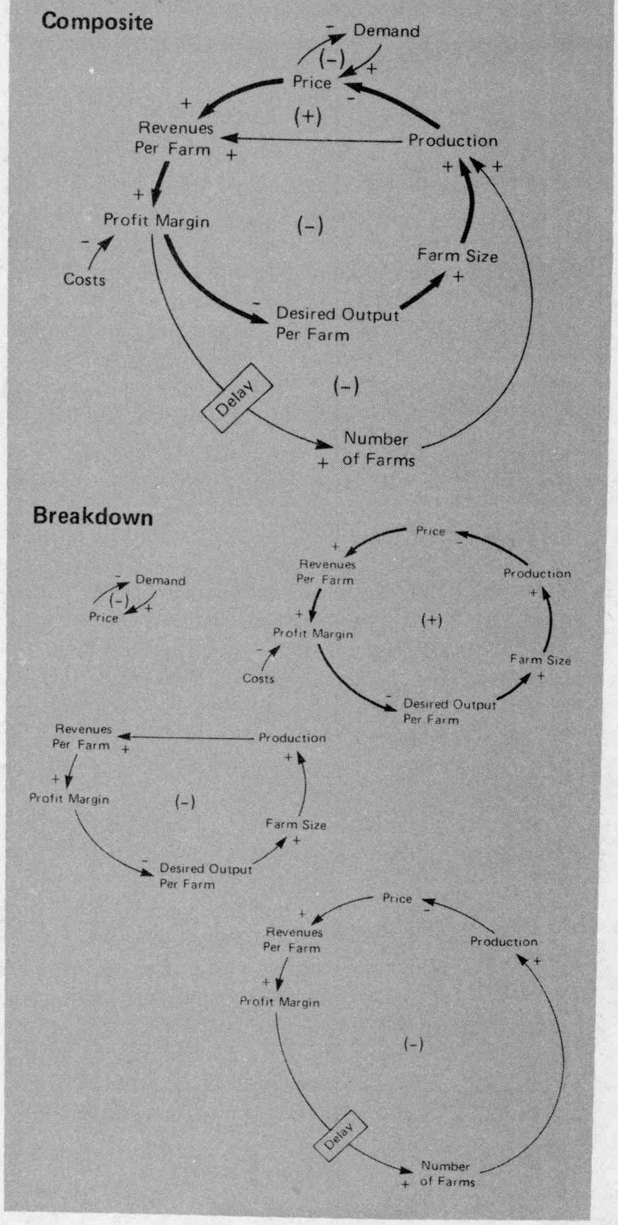
After the finance sector makes and approves the investment decision, farmers make the actual changes in factor inputs. They buy land, if available, which increases the average size of farms. They use differing amounts of current inputs each year and they buy new capital equipment and buildings. The *farm sector* accounts for new capital acquisitions, liquidations of existing stocks, and physical depreciation. As more investment occurs, the asset base increases, and farm market value increases.

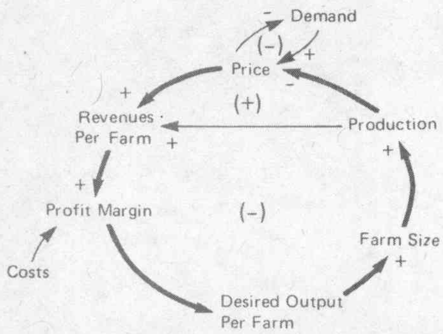
The *expense sector* calculates the total annual costs to subtract from total revenues to produce annual farm income. The major expenses calculated by GRAIN1 include annual loan repayments, current input costs, capital and labor expenses, property taxes, and other overhead expenses.

KEY MECHANISMS FOR STRUCTURAL CHANGE IN THE AGRICULTURAL ECONOMY

The basic structure of the GRAIN1 model can be simply represented by four feedback loops (figure 2). The essential model structure has one strong positive feedback loop, which drives the entire system, and three weaker negative feedback loops, which counteract the key positive loop. The positive feedback chain outlined in heavy black lines in figure 2 may, experimentation based on the model suggests, be a primary cause of structural change in American agriculture.

FIGURE 2
Feedback Structure of the GRAIN 1 Model





Farm costs have been rising steadily because of increasing capital and energy costs. The resulting diminished profit margins have caused farmers to seek ways of reducing costs. Historically, the drive for cost reduction has led to additional investment in technology and in mechanical equipment. In conjunction with capital investment, diminishing profit margins have also led, in many cases, to increases in desired output (to provide a broader base over which fixed costs could be spread). Farmers have expanded the size of their farms, making use of mechanized equipment. As long as the land base existed to draw from, the number of acres in production also rose, resulting in greater production and subsequent decreases in the market price and further reductions in the profit margin. This round of adjustments then set the stage for another round by those who could make the additional investment.

In a period when our agricultural land base has remained fixed, a second set of dynamics has been at work. When the supply of land is fixed, farmers could not increase farm size, unless other farmers whose operations were marginal went out of business and offered their land for sale. This process is shown by the large negative feedback loop in the lower part of figure 2. Because it may take several successive years of depressed profit margins to ultimately drive a farmer out of business, this negative feedback chain contains a delay that is important to the dynamics of the wheat production system. It causes the desire to increase farm size to be "out of phase" with the availability of farms for sale by operators who are going out of business.

In the manner described above, declining profit margins, the availability of new technologies, and farms available for purchase, prompted successive rounds of farm capital investment to increase farm size and output.

Note that as long as technological improvements make further investment feasible, the positive feedback chain would tend to drive the average farm size to increase indefinitely unless one of the negative feedback loops became strong enough to counteract it. A fixed agricultural land base represents one condition that counteracts the growth tendency of the positive feedback loop.

Policy Analysis

Analysts used the GRAIN1 model to test six forces and policies that act on the driving positive feedback loop which raises farm size.

Reference Run

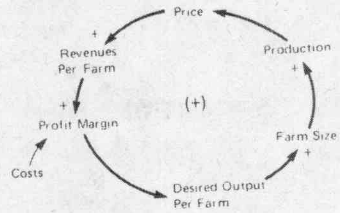
Figure 3 presents the results of the assumptions contained in the major feedback loops of the GRAIN1 model. The figure shows the behavior of the U.S. wheat production system from 1976 to 2000 that is likely to result if no changes are made in the existing system structure. Production and total domestic plus export demand are projected to rise to over 2.2 billion bushels annually.

The amount of exports increases to more than 1.4 billion bushels by 1990 and levels off through the end of the century. The carryover, or remaining inventory, rises to nearly 1 billion bushels by 1979 and becomes steadily lower, to about 140 million bushels by the year 2000. The wheat price drops from nearly $3.70 per bushel in 1976 to $2 through 1979; this drop is followed by price oscillations that exceed $6 in 1983 and $7 after 1988. During the period between 1976 and 2000, the average farm size continues to increase, from 962 acres to 1,262 acres per farm. At the same time, the number of farms would fall from 526,000 to 389,000.

If farm costs continue to rise and no structural changes occur, the 50-year trend toward fewer and larger farms can be expected to continue. The increased cost of production raises the price of wheat, and annual production begins to level off because the per-acre yield is assumed to be approaching its biological limit; thus, it will not increase as rapidly as in the past.

Alternate Futures

Policies that act on the positive feedback loop can make the future look different from that highlighted in the reference run. To illustrate this point and to understand better some of the public policy trade offs, analysts tested six alternate sets of assumptions using the GRAIN1 model.



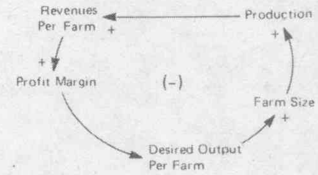
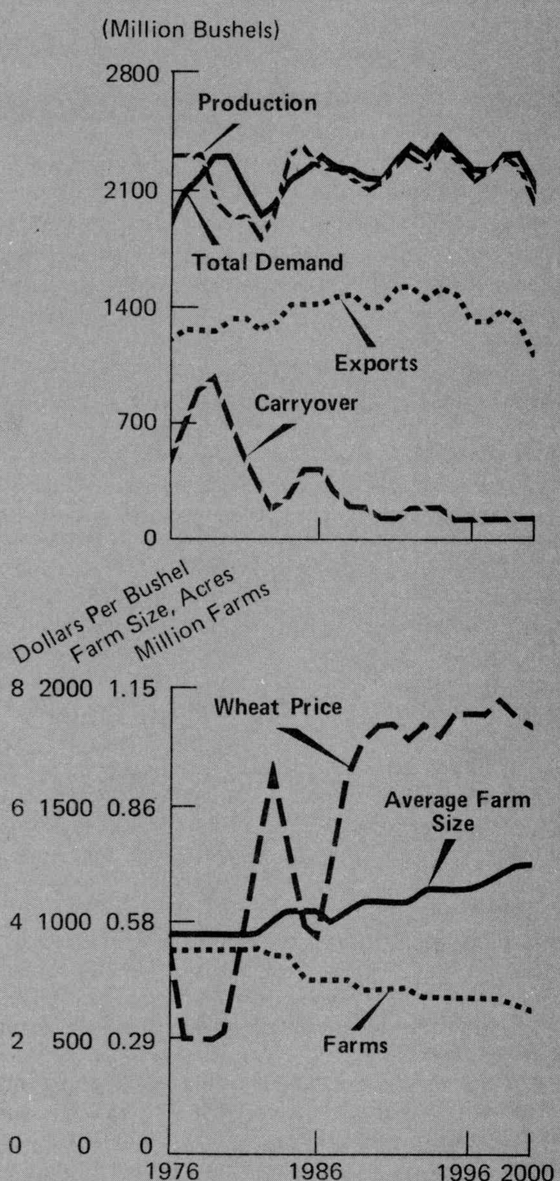


FIGURE 3
Reference Run, GRAIN 1 Model



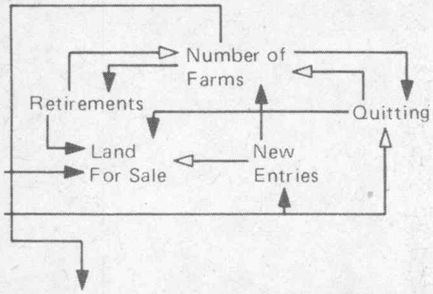
The table compares the six alternate futures and the reference run. The figure presents the year 2000 values for the number of wheat farms and the average farm size, along with the average annual Government cost, production, and exports.

In the first alternate future computer simulation, all supplemental disaster and deficiency payments from the Federal Government to farmers were suspended after 1976. In this case, 70,000 fewer wheat farmers are in business by the year 2000, operating farms with an average size of 1,462 acres. This change can be attributed to the fact that the suspension of farm program payments reduced total farm income, causing the farmers to go out of business. Production falls 180 million bushels annually, throughout 1976-2000. The lower level of production allows the wheat production sector to support fewer bushels of exports annually.

The second alternate future restricts farm size by law to a maximum of 1,000 acres. By the year 2000, 89,000 more farms than in the reference run are producing wheat. Market prices rise slightly above those in the reference run while Government costs fall $84 million. Production and exports also decline slightly. Although the policy is reasonably effective in halting the decline in farm numbers and in holding down Government costs, it would result in above-normal prices and would probably be unpopular among farmers wishing to expand the size of their farms.

The third alternative cuts the average level of exports 15 percent from 1976 to 2000. Such a policy keeps farm prices more stable by protecting grain inventories through mandatory export controls. In this case, grain inventories do not become depleted, farm prices remain lower than in the reference run, farm incomes decline, and more wheat farmers go out of business. By the year 2000, only 354,000 farmers would be in business, and the average farm size would increase to 1,382 acres. Lower prices increase Government payments dramatically to $738 million a year. Lower prices also stimulate less wheat production and, because of the mandatory Government export controls, less production is exported.

In the fourth run, weather is assumed to be more favorable to farming than in the reference run. In the GRAIN1 model, fluctuations are represented by a random weather multiplier that reduces production by an unpredictable amount. In the reference run, the weather



GRAIN 1 alternate futures, U.S. wheat farms

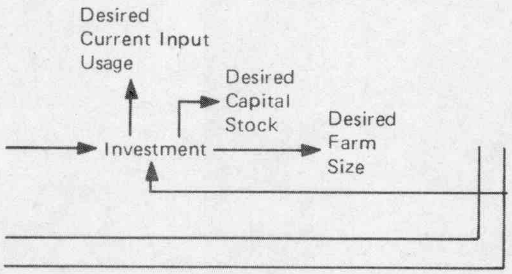
Policy title	Year 2000			Average annual changes	
	Number of farms	Average farm size	Government cost	Production	Exports
	Thous.	*Acres*	*Mil. dol.*	*Bil. bu.*	
0. Reference run	389	1,262	392	2.28	1.42
1. Suspended payments	319	1,462	---	2.10	1.17
2. Restricted farm size	478	1,000	306	2.24	1.38
3. Reduced exports	354	1,382	738	2.12	1.19
4. Favorable weather	310	1,520	629	2.36	1.43
5. Adverse weather	468	1,079	168	1.96	1.02
6. Talmadge proposal	441	1,020	511	2.29	1.42

multiplier has a mean value of 0.89 and a standard deviation of 0.04. This means that, on the average, only 89 percent of expected production is actually harvested. For the favorable weather assumption, the mean is set to equal 0.95 with a standard deviation of 0.0. In this alternate future, 5 instead of 11 percent of the crop is lost annually because of the vagaries of weather.

Somewhat paradoxically, more favorable weather conditions between now and the end of the century would not be favorable to farmers. Good weather would result in greater production (2.35 billion bushels) and lower prices. Consumers would reap the benefits of the lower prices, while the decrease in farm income would mean fewer farmers, larger farms, and higher Government costs. Because of higher production and lower prices, exports would also rise slightly.

The fifth alternate future presents consistently poor weather conditions, in which the mean weather multiplier is set at 0.8. This choice means that weather destroys 20 percent of the annual crop. Adverse weather results in lower production (1.96 billion bushels per year), higher prices paid by consumers, higher farm income, more farmers, and a lower average farm size. High prices also reduce the need for the Government's supplemental income payments while the lower production level lowers wheat exports.

The sixth simulated agricultural future models a proposal presented recently by Senator Herman Talmadge of Georgia. Some farmers state that the target price USDA pays to participating farmers in times of low prices continually lags far behind the actual cost of producing wheat. Moreover, the Congress sets the target price with each farm bill and, in a case of rapidly rising costs, this price is inadequate. Talmadge proposed that the target price be calculated based on the cost of production and be set to equal 75 percent of that cost. Thus, the target price should rise steadily and be matched to the cost of production. This policy also appears reasonably effective in curtailing the trend toward fewer and larger farms, but at a somewhat higher cost in Government payments, approximately $119 million more than in the reference run. These payments make it possible for 52,000 more farmers, than in the reference run, to be in business by the year 2000. Similarly, farm size averages below that in the reference run, production is slightly above normal levels, while exports remain at the reference run value. The extra production also results in lower prices for consumers.



CONCLUSIONS

Of the six alternate futures depicted in the table, only four—suspended payments, restricted farm size, reduced exports, and the Talmadge proposal—can be somewhat controlled by policymakers, given current technology. Two of these, suspended payments and reduced exports—tend to reduce production and exacerbate the trend to fewer and larger agricultural production units. The complete suspension of farm payments seems least desirable because it results in the largest reduction in both farm numbers and production compared with the reference run. Reduced exports cause a similar decline in production and farm numbers at a dramatically increased cost to the Government. At the same time, the Government and the farmers lose the export revenues resulting from the mandatory export controls.

The other two futures—restricted farm size and the Talmadge proposal—help maintain the number of smaller family farms. Of these two futures, restricting farm investment seems to be the least desirable because it also restricts production, and it causes higher prices for consumers (although the Government's cost is slightly reduced). The Talmadge proposal would cost about $119 million per year more than the reference run and would increase production while lowering prices and allowing 441,000 farmers to stay in business.

In any of the six futures, it will take roughly the same amount of total revenue consisting of farm income and Government transfer payments to keep a farmer in business. As agricultural programs are currently structured, policymakers can decide only where the money will come from. If farm prices are low, consumers may pay less for agricultural commodities, but they must pay more in Federal taxation to provide the necessary income supplements. Or they must forego enough Government spending on other national priorities to make up the difference. Policies that result in lower Government costs are likely to reduce production and increase the prices paid by consumers for agricultural commodities.

A balance between high consumer prices and high Government costs appears difficult to maintain. Government policymakers need a more systematic way to project the consequences of their policy decisions, not only over the short term, but over the long term as well. Policies that seek to increase farm incomes in the short run, for example, may contribute to overinvestment and thus cause further distress in the future.

A model such as GRAIN1 can be useful for testing policies before they are implemented, which can permit a better assessment of the short- and long-term trade offs and the consequences. The model cannot replace human decisionmaking, but it can enhance it. GRAIN1 can help decisionmakers identify ways to influence the future rather than simply react to the present.

In Earlier Issues

Granted that Keynes was the most influential economist of his generation, the question that other economists and wide-awake laymen have pondered is, Why? . . . Keynes' influence came from an amazing amalgamation of heredity, intellectual environments, a keen and exploring mind of a scintillating quality, remarkable diversity of interests and contacts, amazing versatility, a liking for concentrated and sustained work, courage and daring, and endless resource and ideas.

Caroline Sherman (Review of: *The Life of John Maynard Keynes* by R. F. Harrod)
July 1951, Vol. 3, No. 3, pp. 106-7