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RISK AVERSION

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Economists work on two kinds of problems. First, there are the social problems for the sake of which economic analysis is undertaken. Second, before the ultimate social problems can be dealt with, a number of intermediate, professional problems must be conquered. This issue contains examples of USDA economists' concerns for each of the two kinds of problems. Let us take the social concerns first.

A conflict exists between delivering increasing quantities of food at lower prices to the lower income and hungry people of the world, and maintaining adequate incomes to producers. The farm bill signed by President Carter in September 1977 expresses society's concern with this problem. In the first article, Penn and Boehm discuss some of the provisions of the new farm bill and the implications for needed research by agricultural economists.

Diseases and pests continue to limit plant and animal production. Society's concerns for this problem are expressed in part through USDA programs and activities administered by the Animal and Plant Health Inspection Service. Emerson and Plato evaluate the costs and benefits of one of these programs dealing with witchweed, a semiparasitic plant that reduces grain and sorghum yields. The research methods used in their evaluation incorporate the economists' ideas of consumers' surplus, a concept discussed in the October 1977 issue of this Journal.

Urbanites' food costs may rise simply as a result of urbanization, according to a regression analysis by Morris. He shows that increasing population density exerts upward pressure on farmland values, thereby increasing the costs of agricultural production.

Firms making long-term contracts to purchase raw materials, such as tomatoes, and to sell final products, such as tomato paste, face a problem of portfolio management. An analysis of this problem for the Farmers Cooperative Service led USDA economists to the intermediate problem of assessing the preference patterns of plant managers and farmers. In their analysis, Buccola and French rejected the easy-to-use quadratic form of the utility function. They did so because it implies that a manager's willingness to gamble decreases as his earnings increase, although there is an empirical possibility that the manager's willingness to gamble increases as earnings increase. Buccola and French explain how they achieved a compromise by using an exponential function with constant risk aversion. It can be fit to data with relative ease and it has certain desirable features when incorporated as one in a system of equations used in analysis of longrun pricing contract behavior.

Lin and Chang further pursue the intermediate problem of how to deal with risk aversion and to select an appropriate form of the utility function. They propose a form which allows for increasing, constant, or decreasing risk aversion depending on the sign of a parameter in the equation. They offer empirical evidence supporting the hypothesis that risk aversion decreases as income increases.

Economists are faced with an intermediate problem of how to portray the degree of uncertainty in their economic forecasts. Their longstanding answer has tended to be to overlook this problem and simply present the single-valued, central tendency. Recent efforts have turned to an alternative futures concept; the user of the economic information is presented with a subjectively determined high option and low option in addition to the central tendency which is called the most likely option. Tiegen and Bell add a new, useful feature by showing how the variances estimated in fitting a system of simultaneous equations can be used to place confidence intervals around point estimates. Their method allows the economist to estimate, for example, the probability that the price of corn will fall within a specified range. They show how confidence increases as time passes and more information becomes available. Tiegen and Bell, of course, do not address the problem of uncertainty about the level of exogenous variables; in the current version, they assume that we know these variables for certain.

Clark Edwards

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In Earlier Issues

"Within the confines of the political division of the United States known as Minnesota are headwaters leading to the Gulf of St. Lawrence, to Hudson Bay, and to the Gulf of Mexico. With such a continental location, the economy of any commonwealth having even average natural resources is predestined to contribute greatly to the well-being of regions far beyond its borders. Historical and economic analyses of the development of commonwealths thus located have many ramifications and have far more than local significance.

"In successive stages, the fur industry, lumbering, wheat and flour, and "contented" cows have been basic to the economy of Minnesota. Each has resulted from the utilization of natural resources, and each has contributed not only to the development of the State but to that of far-away regions as well.

Everett E. Edwards
Vol. II, No. 1, Jan. 1950

The Secretary of Agriculture has determined that the publication of this periodical
is necessary in the transaction of the public business required by law of this Department.
Use of funds for printing this periodical has been approved by the Director,
Office of Management and Budget, through February 28, 1980.

RESEARCH ISSUES REEMPHASIZED BY 1977 FOOD POLICY LEGISLATION

By J. B. Penn and William T. Boehm[1]

INTRODUCTION

New agricultural and food legislation became effective on September 29, 1977, when the President signed S. 275, the "Food and Agriculture Act of 1977." This act, the most comprehensive of all the so-called "farm bills" since the thirties, treats many subjects: farm commodity programs, grain reserves, domestic food assistance, research (agricultural and human nutrition) and education, conservation, wheat foods promotion, grain inspection, advisory committees, and several other areas. This "omnibus bill" could (under certain conditions) involve Federal budget outlays exceeding $12 billion annually, or near $50 billion for the life of the legislation.

- New food and agricultural legislation became effective on September 29, 1977. The provisions of the bill may be used to help establish a research agenda for policy analysts. This article highlights what appear to be the most important research issues. Specifically discussed are the payment limitation, economic and natural disaster risk protection, the flexible loan level and international grain trading, the current plantings concept and production control, grain reserves, and domestic and foreign food assistance.
- Keywords: Food policy, research agenda, legislation.

Providing broad guidelines for national food and agricultural policy for the next 4 years, it sets forces in motion that may significantly affect the food and fiber system for years to come.

The bill emerged as a product of the political process; its provisions are based largely on compromise. As the various interest groups worked to achieve their goals, they traded support with each other, giving ground on some issues to effect gains on others.[2] The issues debated most intensely were those currently evident or topical. As always, there was little *explicit* consideration of the likely impact of new programs operating in conjunction with existing programs, nor with the longer term consequences of such programs.

The policy decisionmaking process itself has implications for research. *Once set in motion*, the process is inherently not conducive to incorporating to any great extent the relevant economic information. Such information must, therefore, be available before the decision process begins if this information is to affect the compromises that inevitably come. Prior analysis is essential to influence subsequent legislative initiatives—not influence in terms of any particular outcome, but influence in the sense of improving the quality of the decision.

The purpose of this article is to highlight some of the major provisions of the new legislation, emphasizing those which in the authors' view have potentially significant longer term implications for the food and fiber system and/or those which represent significant departures from the previous law. We do not intend for it to be a description of the bill *per se*. This task has already been done by other authors (*10*). Rather this article suggests a broad research agenda for policy, now that the basic architecture of the programs has been determined for the next 4 years. The underlying concern of that agenda is, of course, the analysis of implied longer run impacts of policy decisions taken to "solve" immediate, shortrun problems. The provisions selected and treated, roughly in the order they appear in the bill, include:

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[1] J. B. Penn is senior staff economist, Council of Economic Advisers. William T. Boehm is agricultural economist, Economics, Statistics, and Cooperatives Service. They wish to thank George D. Irwin, J. Dawson Ahalt, Clark Edwards, and Milton Ericksen for helpful comments on earlier drafts. The authors assume responsibility for any remaining errors. Views are their own and should not be seen as official positions of their employing institutions.

[2] A recent paper by Bonnen (*1*) contains an excellent treatment of the policy process for agriculture and food.

Note: Italicized numbers in parentheses refer to items in References at the end of this article.

- The payment limitation
- Economic and natural disaster risk protection
- The flexible loan level and international grain trading
- The current plantings concept and production control
- Grain reserves
- Domestic and foreign food assistance

THE PAYMENT LIMITATION

The impetus for a payment limitation provision in agricultural legislation grew out of the events in the sixties when the income transfers to the farm sector were relatively large, had seemingly become chronic, and few prospects were emerging for solutions that would make the transfers unnecessary.

The eventual adoption of a $55,000 limit in the Agriculture Act of 1970 was perhaps significant only in that to many it signaled tangible evidence of the substantial erosion of the influence of the farm bloc.[3] It had been suggested for some time that the reapportionment of the Congress in 1960 (and 1970), the exodus of several long-time and powerful Southern legislators, and the growing involvement of the "agribusiness" interests in the process were all tending to erode the once powerful influence of rural producers (*1*).

The limitation was continued but lowered to $20,000 in the Agriculture and Consumer Protection Act of 1973. Both disaster and income support (deficiency) payments came under the limit, but the law was administered such that a producer would not receive both types of payment on the *same* production. Of course, because of market conditions, no deficiency payments were made under provisions of the 1973 act.

There have been few indepth studies (*14*) of the economic impact of the payment limitation during 1971-73 when the programs were in full operation (as opposed to 1973-76 when market conditions obviated the need for programs). The number of producers affected was quite small and, as a result, "savings" in Treasury outlays were probably quite small. The approximated numerical relationship between reductions in budget outlays from the limit and total payment outlays (roughly based on 1972 data) is shown in figure 1. For example, using the 1972 data in figure 1, and assuming deficiency payments of $4 billion, the $20,000 payment limitation would reduce budget outlays by only about $0.16 billion. The reduction is relatively small whatever the limit, but the lower the limit, of course, the greater the reduction.

The new bill increased the limit to $40,000 in 1978 and $45,000 in 1979 for wheat, feed grain, and upland cotton producers. Payments to rice producers are limited to $52,500 in 1978 and $50,000 in 1979. For 1980 and 1981, a limit of $50,000 is applicable to payments made under the feed grain, wheat, upland cotton, *and* rice programs. Disaster payments, certain resource adjustments (not land diversion payments), and public access for recreation are exempt from the limitation as are payments under the extra-long staple cotton, sugar, and wool programs.[4] Receipts from Commodity Credit Corporation (CCC) loans and purchases also remain exempt. Thus, the payment limit really applies only to deficiency and land diversion payments.

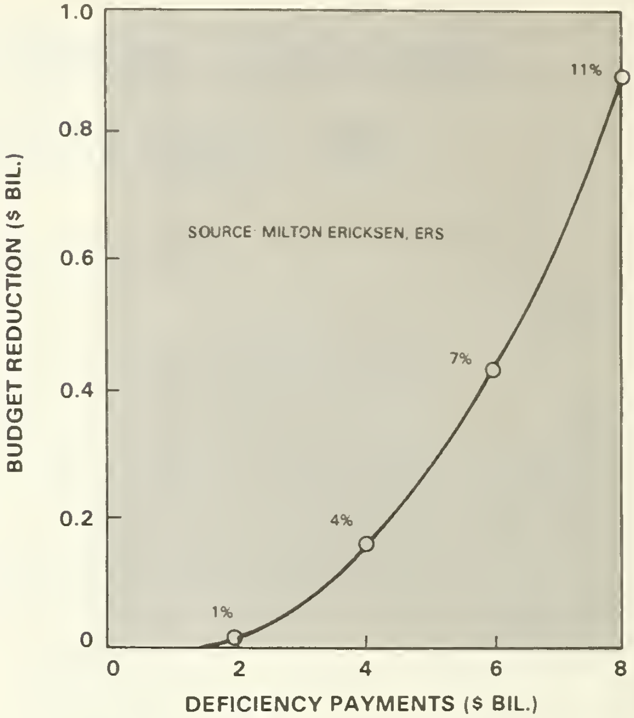

FIGURE 1. BUDGET REDUCTION FROM A $20,000 PAYMENT LIMIT (1972 DATA)

The payment limit, given the structure of the price support loan and payments program in the new bill, raises questions of equity among commodity producers. To illustrate, the 1978 target price for wheat is $3.00 ($3.05 if the crop is smaller than 1.8 billion bushels) and it is $2.10 for corn. These levels cover the same proportion of total cost for each crop. Thus, $3.00 wheat

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[3] A study of the 1971 programs by the General Accounting Office (GAO) concluded that the limit resulted in "no significant reduction" in Government expenditures in that year. The GAO report noted a USDA study which estimated the reduction to be only $2.2 million in 1971, when payments totaled $2.75 billion for the wheat, feed grain, and cotton programs (*16*).

[4] Any increased deficiency payments to farmers resulting from an administrative decrease in the loan level to maintain competitiveness in world markets (treated in a subsequent section) are exempt from the limits.

equals \$2.10 corn on the production side, and a producer should be indifferent between the two as a choice of production enterprise, *ceteris paribus*. But the loan level for corn is \$2.00 (maximum potential payment of \$0.10) and for wheat, \$2.35 (maximum potential payment of \$0.65). Since "loan and purchase" proceeds are *not* subject to the limit as are payments, corn producers are implicitly afforded more (as a proportion of unit cost of production) price and income support *not subject to the limit* than wheat producers.

The practical importance of the limit, if not for budget savings, may perhaps be as a bellwether of the mood of the Congress (and the nonfarm public) towards agriculture and the food system. When initially established, the limit supposedly reflected the public's distaste for large payments being made to a small number of big producers. The willingness of the Congress to raise the limit in 1977, to levels well above that which would have accounted for inflation since 1973 (\$27,000), would perhaps suggest less current concern with that issue.

The increased limit in the new bill suggests this provision will likely continue to have little effect on either program operations or Treasury outlays.[5] However, it could affect firm organization if the affected producers attempt to devise means to circumvent the limit. However, if the limitation does not *effectively* limit the amount of payments to the "larger" producers, then perhaps alternative means of achieving the original objective should be explored. The point is that implications of the payment limitation provision are unclear without further research.

ECONOMIC AND NATURAL DISASTER RISK PROTECTION

The Agriculture and Consumer Protection Act of 1973 initiated a target price-direct payments scheme designed to effect income transfers to the farm sector *inversely* with the market price. Target prices, established for the major program commodities beginning with the 1974 crop, were adjusted for changes in cost of production after accounting for productivity (yield) changes for the 1976 and 1977 crops.

The target price adjustments for changes in cost of production were based on changes in the index of prices paid for production items, interest, taxes, and wages (PPI).[6] This index is a broadly based indicator of production expenses for the agricultural sector generally, not just for crop production. The target prices for each program crop were to be adjusted by the same percentage as the index, varying only by the extent of individual yield changes. Thus, the relationship of the target prices to cost of production for individual commodities could become distorted. For example, suppose one crop was a heavy user of fertilizer relative to another, and the price of fertilizer increased dramatically causing an increase in the index. Then, *all* target prices would be adjusted upward to reflect this increase, not just the one for the crop that is a heavy user of fertilizer and whose cost had increased. The fact that the index was not oriented specificially to crop production could also be regarded as a deficiency.

Thus, while the 1973 act moved agricultural crop support levels away from the concept of parity, it did so by adopting a rather crude, albeit the only available, cost of production measure. The 1973 act did, however, direct the Secretary of Agriculture to undertake cost studies and regularly report its estimates. By 1977, three such reports had been made (*4*, *5*, *6*).

Through use of the USDA estimates, the move to basing target prices on individual commodity production costs is completed in the 1977 act. The 1978 target prices are based (with minor exceptions) on the average of 1975 and 1976 *unit* costs of production.[7] The 1978 target prices, and loan levels, established by the act are shown in table 1.

From the established levels for 1978, adjustments are to be made using variable, machinery, and overhead cost components *only*. Changes in the management and land charges will *not* be considered in making the adjustment. Specifically,

$$PT(t+1) = PT(t) + \left(\left[\frac{COST\ (t) + COST\ (t-1)}{2} \right] - \left[\frac{COST\ (t-1) + COST\ (t-2)}{2} \right] \right)$$

where:

$PT\ (t)$ = target prices in year t, and
$COST\ (t)$ = sum of variable, machinery ownership, and general farm overhead cost components in year t

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[5] Assuming a \$0.65 cent per bushel deficiency payment on wheat in 1978, over 61,500 bushels would be required to reach the limit. For a 30 bushel per acre yield, this would require 2,050 harvested acres. Of course, many farms may have more than one crop eligible for payments. While the payments for each crop may be less than the limit, the total will exceed the limit. Thus, determining maximum size of farms subject to limit is inappropriate except for illustration.

[6] A detailed explanation and examples appear in (*13*).

[7] Cost of production is defined to include variable, machinery ownership, and general farm overhead cost components (as defined in the USDA studies) plus a return to management (7 percent of gross receipts) and to land (3.5 percent of current price).

This procedure is applicable to feed grains, wheat, cotton (the adjustment begins in 1978 with a $0.52 per pound minimum and a $0.51 minimum thereafter), and rice. (The target price for rice is determined in the same manner except the level for 1978 will be an adjustment from the 1977 target price which was established by formula in the Rice Production Act of 1975.)

Table 1.—Commodity target prices and loan levels for 1978

Commodity	Unit	Target price	Loan level
		Dollars per unit	
Wheat[1]	Bu.	$3.00/3.05	$2.35
Corn	do.	2.10	2.00
Sorghum[2]	do.	2.22	1.90
Barley[2]	do.	2.25	1.63
Oats[2]	do.	None	1.03
Cotton[3]	Lb.	0.52	0.44
Rice[4]	Cwt.	8.45	6.34
Soybeans[5]	Bu.	(None)	(Discretionary)

[1] The target price is $3.00 if the crop is larger than 1.8 billion bushels; $3.05, otherwise. [2] A target price is mandated for sorghum but discretionary with the Secretary for barley and oats; all are to be set on the basis of the same cost of production components as for corn (preliminary estimates are shown—the actual estimates have not been announced). The loan level for these feed grains is to be set in relation to corn (preliminary estimates are shown). [3] The loan level is determined as the smaller of 85 percent of the preceding 4 marketing years' moving average spot market price for Strict Low Middling 1-1/16 inch upland cotton at average U.S. locations or 90 percent of the average adjusted price for the first 2 weeks of October of the 5 lowest priced growths of the growth quoted for Strict Middling 1-1/16 inch cotton, cif, Northern Europe—a projection is shown. [4] The rice loan level is increased by the same percentage as the target price except the Secretary has authority to reduce it as low as $6.31 if needed for competitive world trade. The 1977 target price is to be adjusted for changes in the cost of production by the same procedure as used for the other crops to establish the 1978 target price. The estimates shown are projections for both the target price and loan levels. [5] The 1977 act mandates a price support loan for soybeans but the level is discretionary with the Secretary.

While it appears that the 3 previous years' prices are being considered in making the target price adjustment, in fact, only prices in *t* and *t*–2 make any real difference. The effect of the price in *t*–1 may be cancelled algebraically.

While inclusion of the land component was somewhat avoided in the adjustment process (and the likely cost/price spiral), the economic implications of adopting this approach are still unclear.[8] The cost of production concept was advanced in an attempt to minimize farm program influences on producer enterprise selection. Since the basic income support level for each crop reflects its estimated cost of production, producer decisions will theoretically be based on anticipated market price, thereby reducing the propensity to "farm the programs," rather than produce for the market. However, the cost of production approach has the same weakness as the parity concept and the PPI index—it is not a measure of value nor does it account for the role of demand in price determination.

Another departure from the past is that independent target price levels may be established for the minor feed grains (sorghum, barley, and oats) based on their cost of production. As a result, target prices for these crops may be higher (relative to corn) than in the past. The budget implications are obvious. Shifts in production patterns where the minor feed grains are grown could also be significant.

Two major questions related to economic impacts of the provisions in the new law come to mind:

- How do the 1978 price and income support levels compare to previous levels?
- What are the potential longer run impacts of using *national average* costs of production for individual crops as the basis for establishing the target prices?

Price and Income Support Comparison

Brown (*2* compared the total support level (price support loan plus price support payments) and loan level with cost of production for wheat and corn for 1955-76.[9] This comparison and the corresponding estimates for 1977-78 are shown in table 2.

From 1955 through the early sixties, only the price support loan was available to producers. Brown's calculations indicate that the loan was somewhat above the total cost of production (as defined) for wheat and equivalent for corn.

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[8] The shift to individual commodity unit production costs will also highlight the difficulties with current cost concepts. Continuing attention to the improvement of the estimation procedures will also be required.

[9] Since consistent nationwide cost of production estimates were not available prior to 1974, such comparisons must involve "constructed" cost data for the historical period before that year. In this case, the 1974 cost estimates (excluding the land and management components) were "indexed backward" using the PPI. The historical management component was calculated at 7 percent of product price. The land charge is a "composite"—the weighted average of share rent, cash rent, and a return to owner-operated land valued at average acquisition price times the prevailing Federal Land Bank interest rate for new loans.

Table 2—Relation of total price support and loan level to cost of production (COP) for wheat and corn, 1955-76

Crop and period	Loan level as percentage of COP	Total support as percentage of COP
	Percent	
Wheat		
1955-63	119	119
1964-73	73	[1]91
1973-76	48	[2]60
1977	71	92
1978	67	90
Corn		
1955-62	100	100
1963-72	84	[1]88
1973-76	45	55
1977	91	91
1978	86	91

[1] Not all wheat and corn production was eligible for price support payments—only that from the base or allotted acreage was eligible for both the price support loan and payment. If allowance is not made for the portion of the crop ineligible for payment and the portion compensating for required diversion, this percentage could be as high as 149 for wheat and 105 for corn. [2] 1974-76.

Source: Adapted from (*2*). Calculations for 1977 and 1978 are by the authors.

After 1963, the price support loan was augmented with various payment schemes for cooperating producers (those complying with the program provisions). The total support/cost of production comparison is thus not as straightforward because of the existence of allotments and bases (not all production was eligible for *both* the loan and payment). However, if the ineligible production is accounted for, the data suggest that the total support was about 91 percent of production cost for wheat and 88 percent for corn, a slight reduction from the earlier period. The reduction in the loan as a proportion of cost of production is to be expected with the institution of direct payments. Payments allowed income maintenance to producers while allowing the loan level to be kept relatively low so as to minimize the interference with production and consumption adjustments.

The period 1973-76, one of atypical world agricultural market conditions, makes comparison meaningless. The market prices for wheat and corn were far above the supports making the level of support irrelevant.

The deteriorating economic conditions for the 1977 crop prompted the Congress to revise the target price levels resulting from the formula under the 1973 act. The Administration responded by revising the previously announced loan levels for 1977. The revised levels for wheat and corn are 71 percent and 91 percent, respectively, of cost of production and only slightly lower for 1978. The total support (target price) for both is about 90 percent for both years. On balance, this admittedly crude comparison suggests that the price support and total support levels in the new act are not significantly out of line with historical levels relative to cost of production.

The Impacts of Cost-Based Target Prices

The second question posed above is by far the most interesting and, from a research standpoint, perhaps the most important. It involves a determination of how the benefits of the commodity program subsidies are distributed and the implications of that distribution for structural change.

One of the most widely publicized (and emotional) food policy issues is the structure of the farming sector. This issue is often cast as a concern for the demise of the "family farm," the encroachment of "agribusiness," concern for the "small farmer," or increased vertical integration. Ironically, little has been done to analyze the structural impacts of the price and income policies[10] which treat farmers as either a monolithic entity or a set of homogeneous commodity groups. The income support/target price payments under the 1977 act will be based on *national average costs of production.* However, all farmers, in reality, face different actual costs of production. One important research question is, then, who are the "high cost" and "low cost" producers?

The 1974 Census of Agriculture data support the oft-quoted statement that a very small proportion of the total number (2.5 million) of farms generate a very large proportion of total agricultural output. The 19 percent of farms comprising classes 1a and 1b produce over 78

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[10] In title I, section 102 of the 1977 Act, the Congress addressed the family farm issue by reaffirming ". . . the historical policy of the United States to foster and encourage the family farm system of agriculture in this country." It further directed the Secretary of Agriculture to report on the status of the family farm annually submitting ". . . a written report containing current information on trends in family farm operation and comprehensive national and State-by-State data on non-family farm operations in the United States." The Secretary was also directed to include ". . . (1) information on how existing agricultural and agriculture-related programs are being administered to enhance and strengthen the family farm system of agriculture in the United States, (2) an assessment of how Federal laws may encourage the growth of non-family farm operations, and (3) such other information as the Secretary deems appropriate or determines would aid Congress in protecting preserving, and strengthening the family farm system of agriculture in the United States." The Congress did not, however, offer guidance as to what constitutes a "family farm," a particularly controversial point in past research endeavors (*9*).

percent of the Nation's food and fiber (table 3).[11] These data suggest that the farms could realistically be placed in three categories: (1) the small farms, classes IV-VI, largest in number (55 percent of the total) but producing only 5 percent of the total output; (2) a middle group, classes II and III, fewer in number (26 percent of the total) and producing 17 percent of total output; and (3) a large farm group (classes 1a and 1b), much fewer in number but producing the bulk of total output.

The USDA study of the 1974 cost of production (*4*) reported not only average costs but also *distribution* of costs by proportion of production. These cumulative distributions for both quantity of production and number of wheat and corn producers appear in figures 2 and 3. (They have been revised to reflect 1977 projected costs reported in (*6*)).

The figures reflect the wide distribution in costs across producers and emphasize that there is no single cost of production applicable to all. About 57 percent of the total wheat production and 56 percent of total corn production in 1977 was produced *at or below* the national average cost of production.[12] Also, they illustrate that 40 percent of all wheat farms and 45 percent of all corn farms produced *at or below* the national average cost of production. Overall, well over half of all production is *below* the national average cost but over three-fifths of all producers are producing *above* the national cost.

The research question now becomes one of identification—just who are the producers above and below the national average costs (which are used to set the income support levels)? Are producers of that production below the national average the larger producers as reported in the census data (table 3)? Are producers of that production *above* the national average cost of production the smaller producers?

Economy-of-size studies for agricultural firms have indicated that the firm's average total cost curve at first declines relatively rapidly as firm size increases and then flattens.[13] Such studies suggest that the lower cost firms are *indeed* the larger firms. The higher cost firms would be those in classes III-VI (table 3). If these rather loose size/cost relationships are correct, target prices based on national average cost of production would be expected to provide a windfall subsidy to the larger, more efficient firms who can produce below the national average. And such target prices may not provide enough assistance to the medium-sized and small firms to enable them to remain economically viable. Treating all wheat producers and all corn producers as an amorphous group would thus fail to effectively transfer income support to those most in need. Medium-sized and small producers with relatively higher costs of production (the largest *number* of producers) could logically be expected to view the target prices in the bill as inadequate for them.[14]

Again, if the above hypotheses are true, it would

Table 3—Farms by size category and contribution to total output

Size (sales class)	Farms	Percentage of total	Cumulative percent	Value of products sold	Percentage of total	Cumulative percent
	Number	*Percent*	*Percent*	*Thousands*	*Percent*	*Percent*
Ia (S100,000 and above)	152,599	6.2	6.2	43,699,424	53.5	53.6
Ib (S40,000-99,999)	324,310	13.2	19.4	20,071,570	24.6	78.2
II (S20,000-39,999)	321,771	12.1	31.5	9,246,796	11.3	89.5
III (S10,000-19,999)	310,011	12.6	44.1	4,460,239	5.5	95.0
IV (S5,000-9,999)	296,393	12.0	56.1	2,138,392	2.6	97.6
V (S2,500-4,999)	289,983	11.8	67.9	981,880	1.2	98.0
VI (Less than S2,000)	786,838	31.2	99.1	736,244	0.9	99.7
Other	2,238	0.1	100.0	235,800	0.3	100.0
Total	2,466,143	100.0		81,570,300	100.0	

Source: Unpublished, preliminary data, 1974 Census of Agriculture. The numbers shown are for the standard definition of the class VI farm. For comparison, the number of farms in this class by the new definition is 616,728, and the value of sales is S696,944,000.

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[11] It is recognized that the skewness in *value* of output will exceed skewness in quantities produced because of the relatively high prices of 1974 used in valuing output. However, the point remains valid.

[12] The total cost of production is defined as including the variable, machinery ownership, overhead, management and land components, with the land charge defined as the "composite" (see footnote 9).

[13] See (*12*) for a critique of economies-of-size studies.

[14] This may be a partial explanation for the widely publicized farmer strikes which occurred late in 1977.

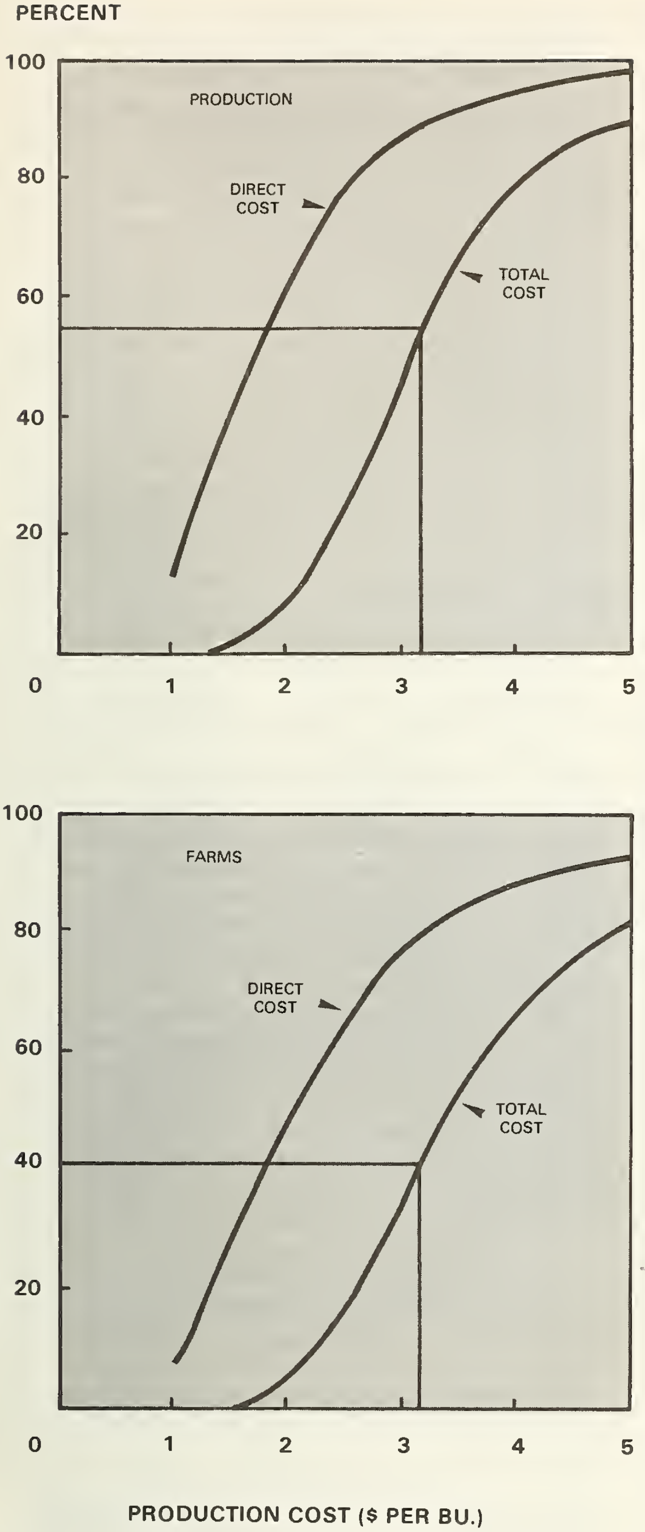

FIGURE 2. CUMULATIVE DISTRIBUTIONS OF WHEAT PRODUCTION AND FARMS BY COST OF PRODUCTION, UNITED STATES 1977

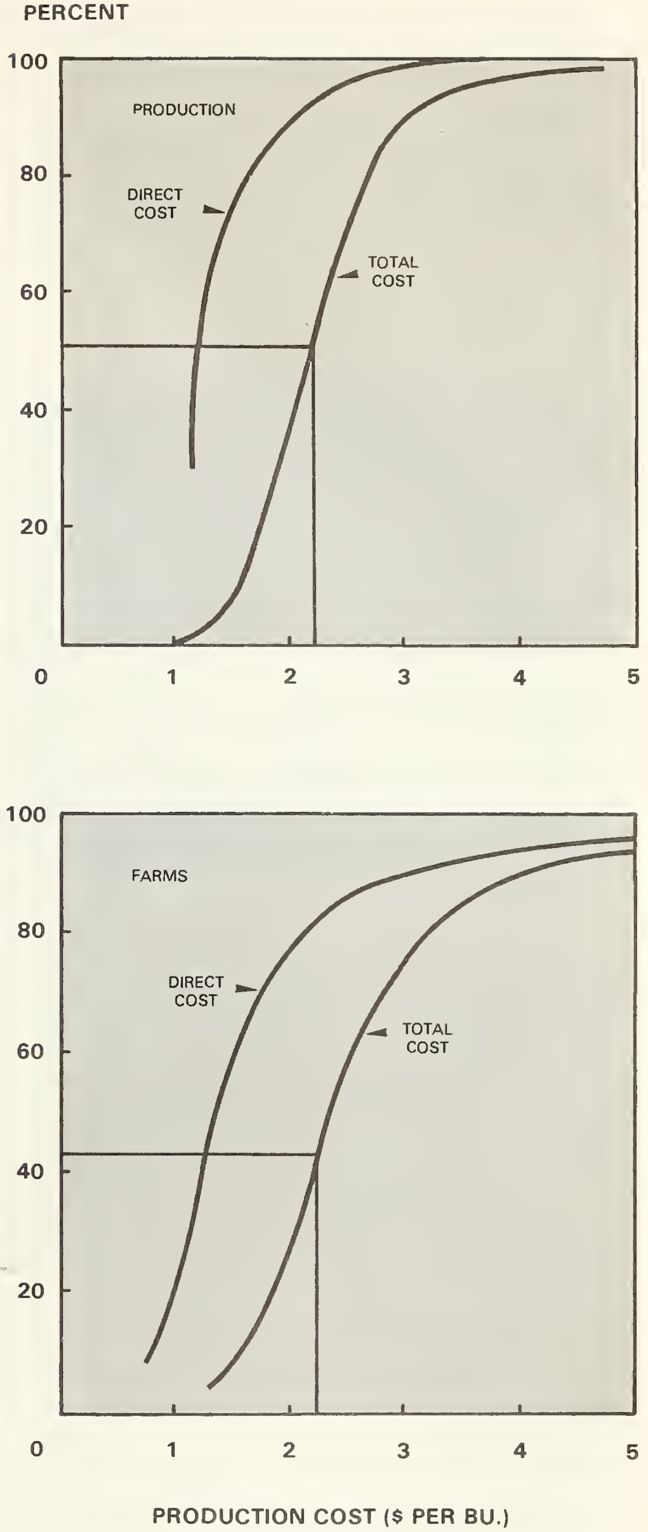

FIGURE 3. CUMULATIVE DISTRIBUTIONS OF CORN PRODUCTION AND FARMS BY COST OF PRODUCTION, UNITED STATES 1977

appear plausible that windfall gains of the large producers would then be capitalized into land values, resulting in increasing land prices until the entire windfall is bid into the price. A recent paper by Doering (8) presents some estimates of returns to equity capital by sales class which reinforces the hypothesis that the larger farms are in the position to bid up asset values (table 4). Thus, an increasingly smaller number of very large farms could emerge and ownership of the Nation's farmland could gravitate to the hands of a smaller and smaller number of people.

Table 4.—Returns to equity capital by size of farm

Farm size (sales class)	Rate of return to equity capital
	Percent
Ia (over $100,000)	6.9
Ib ($40,000-99,999)	5.9
II ($20,000-39,999)	4.4
III ($10,000-19,999)	2.9
IV ($5,000-9,999)	−0.1
V ($2,500-4,999)	−6.5
VI (Less than $2,500)	−6.1
All farms	2.1

Source: (*8*), based on data from 1970 Census Survey of Farm Finance.

However, other structural changes could occur; risk and other constraints could affect the operating unit differently from the ownership unit, and dispersed ownership but combined large operating units could result. The price and income support programs, the current tax laws governing treatment of capital gains and intergenerational transfers, environmental regulations, the disaster assistance provisions in the new bill (discussed below), and so on, all may combine to give a *cumulative* result as suggested above or one totally unsuspected. The essential point is that we really know very little about the combined effect of all such policies and programs on the structure of the farming sector.

A final thought on the cost/size relationship. If the firm cost curve does decline rapidly and flattens, suggesting that increases beyond a "medium" size do not result in further economies, why have farm sizes continued to increase over time? While no more "profit" per dollar of sales may be realized beyond a certain point (size), more "profit" in total is realized as the total volume of sales increases. Hence, the continued pressure to expand.

The hypothesized absence of further economies beyond a certain size (the "family farm size"?) also has important policy implications. If a "family farm" structure is preferred by the body politic and this size does occur at the point (at least) where no further efficiencies are able to be realized, then the structure argument is *not* continued economic efficiency gains (reflected in lower food costs to consumers) versus other social goals. This suggests that if a "family farm" structure is the real policy objective, an explicit *structures policy* rather than a "shotgun" price and income policy approach may have merit. This issue deserves our research attention.

In addition to target price supports, the 1973 act initiated a payments program to help shield producers of major program crops from the risk of natural disasters. The program was modified in the 1977 act and extended for 2 years, through 1978 and 1979. The modified program provides prevented plantings and low yield coverage, the amounts being based on target prices (which are based on cost of production). A bill currently pending in the House (H.R. 7111), would subsume the disaster payments and provide all-crop all-risk insurance protection for farmers. Additionally, the Senate Committee on Agriculture, Nutrition, and Forestry has announced plans to hold major hearings in the next session of the Congress to explore development of a similar program.

The current program and the obvious inclination of the Congress to continue this free or heavily subsidized producer protection means that a significant portion of the total risk in farming is being shifted to society collectively. Thus, through the target price-deficiency payments program and the disaster (or subsidized insurance) programs, society has collectively assumed a very large portion of the risk to farmers from *both economic and natural disasters*. "Average" producers are insured against "going broke" from either of these risks, since the effects of both disasters relate directly to some proportion of the cost of production.

This inclusive risk protection could have significant longer term structural implications. Both economic and natural disaster protection affect the availability of capital (borrowing capacity), the rate of farmer exit (hence entry), the minimum rates of return to equity capital, efficient resource allocation, and so on. Little is known about the *cumulative* impacts of these provisions over the longer term.

FLEXIBLE LOAN LEVELS AND INTERNATIONAL GRAIN TRADING

One of the most significant features of the price support-loan programs was the adoption of a provision proscribing downward adjustment of the loan levels. The act provides that whenever the market price in the preceding year is no more than 5 percent above the loan level, the Secretary may reduce the loan to maintain the competitive position of the U.S. grain exports in world markets. The reduction is limited to 10 percent in 1 year. In no event may loans be reduced below $1.75 for corn and $2.00 for wheat. Also, in any year when the average price exceeds the loan by 5 percent, the subsequent-year loan levels "snapback" to their statutory minimums. Although the 105-percent rule is not applicable, the rice loan may also be reduced, but to no lower than $6.31.

The adoption of this provision clearly resulted from widespread recognition of the importance of world trade to U.S. commercial agriculture. While exercising this authority will be particularly difficult for the Secretary, considering domestic farm sector political pressures, it does provide a mechanism which can be used to avoid the chronic accumulation of grain stocks.[15]

Inclusion of this provision also points up the need for serious study of U.S. trading practices in the international grain markets. Serious allegations have been made about the apparent concentration of U.S. grain exports among only five firms. Yet a recent study suggests that these companies operate no differently than if a large number of competitive firms were involved (*3*).

Some argue that our trading policy has been to maximize the quantity of exports rather than their revenues. A suggestion occasionally advanced is that rather than lower the wheat loan level to remain competitive with the other major exporters, we should tacitly agree with them to hold our domestic support level at the world market price or increase it in concert with the other exporters (see *11*, for the most recent discussion). The argument has been that if these countries supply over two-thirds of the grain in world trade, they should at least attempt to recover internal cost of production. While such a policy would permit us to explicitly consider revenue rather than quantity maximization in our international grain trade policy, it would appear to make us vulnerable in other areas. For example, the U.S. Government has been highly critical of the oil producing nations for forming OPEC and artificially increasing prices. Formation of a wheat exporters group (OWEC) to collude on price would appear no different.

The larger issue, of course, is the form of our grain marketing system. While ours is "open" and competitive, most other nations with which we deal in international agricultural products markets have State trading organizations. Some people allege that this places the United States at a competitive disadvantage. Japanese consumers, for example, pay import taxes on wheat purchased by their State trading organization. The price to its domestic users is thus the cost of the product, transport charges, and the import tax. Some people have alleged that the State trading firms may actually realize more for the wheat than do U.S. farmers and that increased product prices would enable U.S. farmers to capture some of that differential.

As a minimum, we need more research evidence on just how responsive export sales are to "price", given the institutional arrangements actually existing in international grain markets. Related questions also surface, such as to the role of international grain agreements, other commodity agreements, and bilateral, and multilateral trade agreements in the total U.S. marketing system.

THE CURRENT PLANTINGS CONCEPT AND PRODUCTION CONTROL

The new act provides that program compliance and benefit disbursement are to be based upon current plantings, rather than on acreage allotments determined from plantings in a historical base period. There was general agreement during debate on the bill that the existing allotments were out of date and no longer reflected current production patterns. Producers' response to market price signals and the general absence of programs (and controls) since 1973 resulted in significant shifts in the geographic location of production. Thus, requiring compliance and distributing benefits based on the antiquated allotments, some of which were established as long as a quarter-century ago, would have been inequitable. The efficiency of the commodity programs would also have been impaired.

Further, one of the most undesirable features of past programs was that the allotments tended to become capitalized—to take on a value in and of themselves. In effect, therefore, they represented a grant from the Government to the allotment holder. Removing the allotments eliminates this aspect from the commodity programs, and using current plantings prevents this capitalization from recurring in the same manner, although the total value capitalized may not be any less.

The elimination of allotments (except for rice) was a bold step politically, made easier by the economic conditions of the past few years. This step could serve as a precedent or at least bring the allotment system for the remaining commodities—tobacco, peanuts, extra long staple cotton, and rice—under greater scrutiny. Perhaps even further reexamination of the peanut and rice programs will occur.

The implications of using the current plantings concept are uncertain. Some changes in production patterns will likely occur, but most should be in response to market conditions and not artificially influenced by the programs. Also, with all producers now able to plant any program crop and be eligible for the price and income supports, some adjustments may occur in land values in certain areas of the country.

Authority for control of production through the withholding of cropland from production was continued in the bill, with few but important changes. The set aside is to be determined from *current-year plantings* rather

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[15] When this provision is used, the Secretary must ensure that the total returns to producers (loan outlays or market receipts plus payments) are not reduced. The target price payment may be increased if necessary to accomplish this. Preliminary analysis suggests that decreased outlays from reducing the loan level would be offset near dollar-for-dollar by the increased payments resulting from the wider target price-loan level differential.

than allotments. Also, summer fallow acreage no longer qualifies for inclusion, and the Secretary may require as a condition of eligibility for loans, purchases, and payments that the acreage "normally" planted to crops be reduced by the amount set aside. (A "normal" cropping acreage based on 1977 plantings, adjusted for abnormalities, is to be assigned by the Secretary to each farm.) Thus grassland and pasture land cannot be put into cultivation after cropland has been set aside and total acreage cropped cannot be expanded. The requirement that set-aside land be devoted to conserving uses was continued.

Attempts to make the provisions more effective in controlling production than in past programs (to reduce the "slippage") have been made.[16] The exclusion of summer fallow acreage has implications for the Plains States, and the constraint on total program crop acreage is also potentially significant. The acreage part of the slippage may well be reduced and only productivity and other nonacreage sources of slippage remain. As a result, livestock production could be affected if some of the marginal acres brought into production since 1972 are used for set aside and then perhaps permanently returned to grass and pasture. An interesting question also concerns crop yields. Will yields of major crops again return to trend levels prevailing before the early seventies if set asides are used for several consecutive years?

GRAIN RESERVES

The new bill includes several provisions relating to grain reserves. Specifically, a farmer-owned reserve program for *wheat* is mandated, but the terms and conditions are essentially identical to the program announced by the Administration in April 1977 using existing legal authorities. Farmers are encouraged to hold wheat off the market until prices rise to at least 140 percent (the minimum can be set between 140 and 160 percent) of the loan level (for the 1978 loan of $2.35, this is $3.29 to $3.76 per bushel). The Secretary may call the loans when the market price rises above 175 percent of the loan level ($4.11 per bushel). The Secretary is also authorized to provide incentives for storage—payments to producers which may be terminated when the minimum price trigger is reached. Waivers or adjustments of interest charges on the extended loans may also be used.

The minimum amount of the reserve is specified at 300 million bushels (8.16 million metric tons MMT) and the maximum is 700 million bushels (19.1 MMT). The maximum is adjustable depending on the outcome of the international grains agreement negotiations now underway in the International Wheat Council.

The bill also authorizes the Secretary to establish a similar reserve for feed grains. The Administration announced implementation of such a reserve (using existing authority) on August 29, 1977.[17] A feed grain reserve of 17-19 MMT is planned, with a minimum release price of 125 percent of the loan level (for corn, $2.50). The loans are subject to call when the price reaches 140 percent of the loan level ($2.80 for corn).

Through provisions of the bill, the President is encouraged to work with other nations to develop an international system of food reserves to provide for humanitarian food relief needs. At the same time the feed grain reserve was announced, the Administration also announced its intention to request Congressional approval of a 6 MMT food grain reserve to be used for international emergencies. It would also serve as part of any required holdings agreed to in an international grains agreement. The bill sets the Commodity Credit Corporation (CCC) resale price at 150 percent of the loan level when a producer-held reserve is in effect. Otherwise, the resale price is 115 percent of the loan level. This requirement is a change from previous legislation and a more severe restriction on the use of CCC-acquired grain.

The plan is to have a 30-35 MMT managed grain reserve composed of producer-held stocks (8.16 MMT wheat and rice and 17-19 MMT feed grains), the 6 MMT in the International Emergency Food Reserve, plus any CCC holdings (primarily 1976 wheat and rice) acquired through the loan program.

The formation of a *managed* reserve with *specific operating rules* changes the structure of national stockholding from that of the past quarter-century. The intent is to establish a price corridor (between the loan level and the release price) while avoiding the problem of large stocks "overhanging" the market and chronically depressing prices as occurred in the past. The likelihood of extreme grain price runups, such as those that occurred following 1972, appears much reduced. But price increases of 40-50 percent are still quite possible (before the release prices for both the producer-held reserve and CCC acquired grain are reached).

Several research issues arise from these procedures, and little has yet been done to explore them fully. Will this structure result in price moderation, but at relatively low levels? How will private stockholding be affected? The release price triggers put a ceiling on feed costs to livestock producers. What are the stability implications for the livestock sector—overstimulation, and further accentuation of the cycle? As the domestic reserves become linked to international reserves and markets, how will these closer ties affect U.S. agriculture? These are but some of the questions which will need our research attention.

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[16] For a discussion of "slippage" in past programs, see (7).

[17] See "World Food Security and Set-Aside Plans," press release—Office of the White House Press Secretary, Aug. 29, 1977.

DOMESTIC AND FOREIGN FOOD ASSISTANCE

The Food Stamp Program (FSP) was extended by the new bill and continues to represent this Nation's basic public policy instrument for raising the level of nutritional intake among the poor. Therefore, it is legitimately considered as a major component of the food and agricultural policy statement. The program, made permanent by the Food Stamp Act of 1964, has been designed to provide low-income households the food buying income necessary to purchase a nutritionally adequate diet through regular market channels. Since its earliest days, the program has also had the support of farm income as a companion goal. A major research question, still largely unanswered, relates to how successful the program has been in achieving its dual objectives.

FSP reforms embodied in the 1977 legislation relate almost entirely to changes in the institutional rules which specify how, within the rather broadly stated objective, the program will be operated. The longer term effects of these revisions on program participation, costs, and diets of low-income people are uncertain at this point. In all likelihood, participation will increase. The Congressional Budget Office estimates that as many as 2.1 million more eligible participants will enter the program. At the same time, tightened eligibility requirements and more stringent constraints on asset-held wealth are expected to make ineligible about 1.3 million participants with incomes above the poverty line.

Eligibility for program participation is more clearly defined in the 1977 act than has previously been the case. While income continues to be the most basic eligibility criterion, the intent of the new legislation is to tighten program administration, reduce fraud, and eliminate the "nonneedy" from the program. Participation will be limited to those households with an adjusted income (the "net" food stamp income) at or below the poverty level. The deductions system used to establish net income has been simplified.

The 1977 legislation moves the provision of aid away from the philosophical grant of in-kind aid to more nearly a simple transfer-of-cash assistance. This transition was accomplished by eliminating the requirement that most participants pay at least some cash as a condition for participation (EPR). Under the pre-EPR law, the total value of the stamp allotment was determined by household size only. Household income was used to determine what *portion* of the total allotment had to be paid for by the recipient household. For example, all eligible households with four members were authorized to obtain $170.00 worth of coupons per month. Four-person households with a net food stamp income of $100 per month were required to pay $25 for the $170 worth of stamps. Under the new legislation, each eligible household will simply receive, free of any charge, the difference between the total value of the authorized allotment and 30 percent of its net income. Thus, households with $100 per month net income will receive $140 worth of free stamps ($170 minus $30).

This reform provision will likely have a long-term impact on the food system. Elimination of the purchase requirement will almost certainly reduce the food buying effectiveness of the bonus stamp transfer (*15*). Other things being equal, the amount of cash income available for the purchase of products other than food will increase for most participants. Thus, some households who have been participating in the program (pre-EPR) will likely spend less on food for home consumption. The overall impact of EPR on *total* food expenditures is, however, less clear. If participation increases, as some predict, total expenditures for food could be largely unaffected by the change.

Perhaps just as importantly, EPR significantly reduces the "targeted" nature of the program. Forty percent fewer stamps will be issued. And a major policy lever that can be used to influence directly the food purchasing behavior of low-income households is effectively eliminated.

Without the purchase requirement, the stage appears set for making complete the transition to a simple cash transfer. Legislation has already been introduced which would eliminate the program as part of the President's "Welfare Reform" proposal. The implications of such a change for the food policy process, the Agriculture Department, and agricultural producers are unclear. The FSP currently accounts for approximately 40 percent of the USDA budget. In recent years, effective coalitions of producer, consumer, and labor interests were formed to obtain mutually desired farm and food assistance legislation. Some political leaders have stated that the absence of the FSP from the USDA budget would make it significantly more difficult to obtain "favorable" price and income legislation for the agricultural production sector.

The debate which accompanied the passage of these 1977 reform provisions clearly indicated the philosophical disagreements and, therefore, the political difficulties encountered in the development of public programs with multiple national objectives. The debate on the House floor, in particular, highlighted the need for additional social science research in the food policy area. While there has been some good research on particular program issues, little has been done to develop the kind of an analytical system needed to evaluate the impact of program changes *prior* to their adoption. Without such a capability, the policy debate can be expected to flounder as it reaches a compromise.

Consider the provisions which place ceilings on program costs. In an effort to hold program costs close to those anticipated for 1977, expenditure ceilings of $5.847 billion in FY78, $6,159 billion in FY79, $6.189 billion in FY80 and $6.236 billion in FY81 were made part of the law. These provisions were adopted largely because there was no consensus judgment by the analysts on what effect EPR would have on program participation and costs. In the absence of such basic economic intelligence, policymakers spent much time discussing the "possibilities."

Research issues are also highlighted by the foreign food assistance provisions of the new bill. The specific changes in P.L. 480 were not major. The level of funding was increased slightly and an attempt was made to increase the ease and flexibility of program management and to reduce the potential for abuse (such as recent allegations concerning rice shipments emerging from the Korean influence investigation).

There is, however, a widespread and growing opinion that all the Nation's food aid and development assistance programs should be reevaluated. The President's inclusion of world hunger as a part of the Administration's human rights policy provides impetus for such a reappraisal. Furthermore, recent statements by both research scientists and rather diverse political interest groups appear to indicate increased public pressures for the development of an integrated national nutrition policy: a policy statement which will ultimately provide the basis for development of the farm programs. Such a policy orientation will make it increasingly more important for agricultural policy scientists to improve their capability for analyzing the agricultural production implications of policy interventions at the *food consumption* end. If the United States again enters a period of overproduction, there will be a natural inclination, and pressure from the farm sector, to use these food assistance programs as vehicles for surplus disposal. Given current provisions and moods, this method for surplus disposal will be more difficult.

SUMMARY

The basic premise of this article is that the newly enacted 1977 food and agricultural legislation poses a host of research issues. Many of them have existed for some time and the new act merely reemphasizes their importance. Others are new, resulting from the act itself. Still other related issues will emerge.

A second premise is that the longer term impacts of the legislation on the food and fiber system are largely unstudied. The policy process, we believe, is not conducive to such prior analysis as few proposals emerged intact. Most were changed as a result of compromises made necessary by the policy process itself.

We suggested several areas of the legislation having potentially significant impacts. The longer term structural implications for the farm sector are especially noted and a possible scenario is developed to illustrate and to underscore the need for economic research. A scenario could be envisioned whereby all the programs operating together could ultimately produce what has been referred to as a "Public Utility Agriculture." It is, therefore, argued that the long term *cumulative* effect of these provisions should be studied, rather than those of each provision independently.

The price support loan, the target price/deficiency payment, the disaster payment, and the grain reserve programs may be conceptualized as operating together as illustrated in figure 4.

- The price support loan program defends a price minimum which prevents economic disaster for producers due to adverse market conditions. The low yield and prevented planting provisions of the disaster program transfer to society a large part of the risks due to "acts of God."
- Farmers are guaranteed minimum income protection through the target prices, indexed to keep payment levels in line with cost of production.

Thus, through these programs society has effectively assumed a large portion of the economic and natural disaster risk of farming, covering a relatively large share of total cost of production.

- The grain reserve release prices and the CCC minimum release price effectively place a cap or ceiling on commodity prices but at levels well above the price supports. Product prices are thus generally constrained in movement to the price corridor bounded by the loan level and first release price trigger of the reserve. While much of the "downside" risk has been removed, the topside cap means the "big payoff" prices, such as in 1973-74, are also effectively eliminated.

Given the program structures noted above, a major research issue relates to the consequences implied by the "cost of production" concept. In the act, a *national average cost of production* rather than some differentiation based on farm size or other criterion is used to determine the income support. The current farm sector size structure consists of relatively few large firms producing most of the Nation's farm produce. If these firms are the efficient relatively low-cost producers shown by the cost distribution data, the target price levels will allow these producers to secure windfall gains. The smaller, relatively higher cost producers may not be substantially assisted by the program, depending upon their actual cost level.

The large producers may be expected to capitalize the gain, thus bidding up the price of production assets, namely land. As land prices increase, cost situations for the smaller producers will deteriorate relative to the target price (which conceptually will not reflect the land price increases). (But, landowners, regardless of size, benefit from the asset value increase.) It will become more difficult for new producers to enter. And it will become more difficult to raise the capital required to secure the production assets (land) needed to have a viable operation. The long-term trend toward fewer and larger farms would be continued, as resources of the exiting farmers would be assumed by existing (not new) producers.

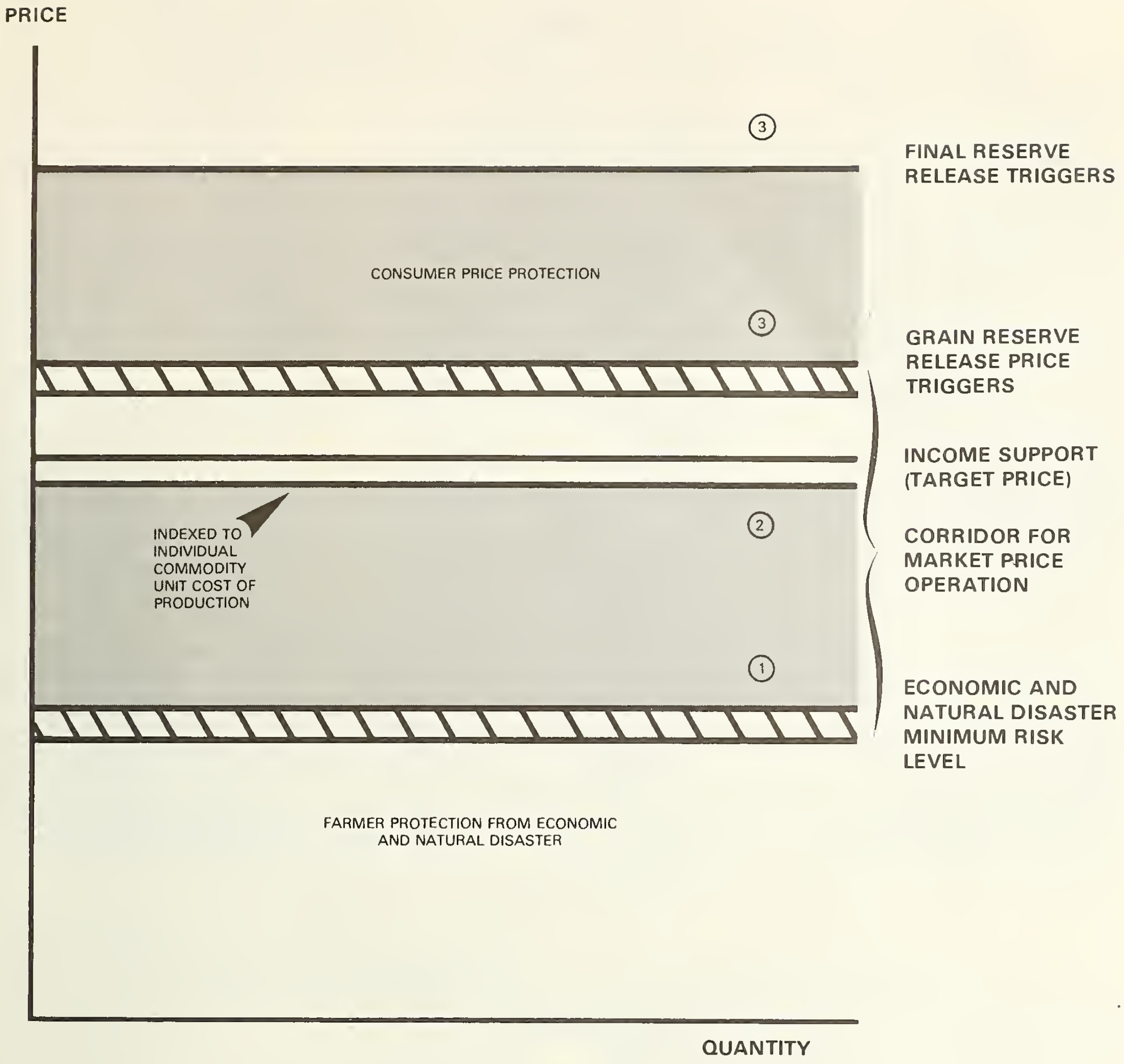

FIGURE 4.
MAJOR PRODUCTION AND MARKETING PROVISIONS OF FOOD AND AGRICULTURE ACT OF 1977

Other questions relate to the impacts of this stability on the livestock sector, on grain producers, and on consumer prices. What happens when the indexed target prices eventually reach the release prices? Does society's assumption of much of the downside economic and natural risk mean society will also want to regulate the short-run profit potential from farming? Could we eventually have a "public utility" agriculture?

Few of the research issues raised in this article are new. They are, however, reemphasized by passage of the Food and Agriculture Act of 1977. Once every 4 years or so, the Congress must consider seriously what role the American people will play in regulating and otherwise influencing the food system. Those of us involved in food policy research are challenged to use the years in between to evaluate the results of their compromises.

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In Earlier Issues

. . . The idea that consumers will react a certain way may be an erroneous one, established by relatively few people in the wholesale trade. For example, the belief that certain cities or areas have color preferences in regard to eggs may be a misconception of a few dominant wholesalers who, by their resulting action establish what appears to be a preference. If these are misconceptions of the market, then merely to study and simulate the present market will not reveal them. Rather, that would require a more ideal set-up in which consumer behavior is the important entity. . . . Marketing logically divides into two major categories: (1) Finding out what consumers want and (2) satisfying consumers' wants with a minimum of effort.

Norman Nybroten
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SOCIAL RETURNS TO DISEASE AND PARASITE CONTROL IN AGRICULTURE: WITCHWEED IN THE UNITED STATES

Peter M. Emerson and Gerald E. Plato[1]

The U.S. Department of Agriculture now spends more than $150 million annually to control diseases, parasites, and other pests that reduce animal and plant production. These programs and activities are administered by USDA's Animal and Plant Health Inspection Service (APHIS). In recent years, program costs have increased rapidly, and USDA officials have been asked many questions by the Congress, the Office of Management and Budget, and others concerning the need for certain programs. Steadily increasing pressure to reduce Federal spending means that public decisionmakers urgently need reliable aggregate measures of the performance of their programs.

- **This study provides *ex ante* estimates of the value to society of the U.S. Department of Agriculture's witchweed program. Program objectives are to contain and eradicate witchweed, a semiparasitic plant which reduces corn and grain sorghum yields. Critical elements which determine the social value are cost of the program, price elasticities of supply and demand, and shifts in supply occurring in the absence of a program.**

- **Keywords: Witchweed, consumers' surplus, program evaluation, social rate of return, benefit-cost ratio.**

One such type of measure, social rate of return to public investment, has been estimated for agricultural research in the United States—by several researchers (*4*, *5*, *12*,).[2] Results are very favorable, indicating rates of return ranging from 30 to 55 percent. A study of public investment in cotton research in Brazil reports a return of at least 77 percent (*2*). However, with a few noteworthy exceptions, much less attention has been directed to deriving aggregate estimates of the social value of specific Government programs (*7*, *19*).

Primary objectives of the research reported here were to derive benefit-cost ratios and rates of return for APHIS programs to contain and eradicate witchweed in the United States.[3] Witchweed is a semiparasitic plant that reduces corn and grain sorghum yields.

The thesis of our analysis is that public investment in a witchweed program allows a given bundle of private resources to produce a larger output (or, allows a given output to be produced with fewer resources), resulting in an increase in domestic consumption and exports. Utilizing a series of assumptions, we provide aggregate *ex ante* estimates of "real social" effects—effects that expand the total production and consumption potential of American society. A comparative analysis of two alternative witchweed programs appears, in which slow and rapid rates of witchweed spread are assumed and key determinants of social value generated by the programs are discussed.

This analysis has been designed to serve as an input for policy officials and program managers faced with specific decisions concerning witchweed in the United States. Therefore, we attempt to overcome the well-known criticism that studies using economic-surplus methodology are often too aggregate in scope and conducted too long after the fact to help in decisionmaking.[4] We believe that the methodology and procedures presented here can be applied in measuring the social value of other disease and parasite control programs.

BACKGROUND

"Officially" discovered in North and South Carolina in 1956, witchweed may have been introduced into the United States as early as 1951. It is an annual seed-producing plant which grows to a height of 6 to 12 inches and normally has red and orange flowers. The witchweed seedling attaches itself to the root of a host plant, and it causes extensive stunting. More than 60 species of the grass family serve as hosts.

Witchweed can exist wherever host plants exist. In the United States, it has been restricted to a con-

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[2] Italicized numbers in parentheses refer to items in References at the end of this article.

[3] It is recognized that the two criteria used, present value and internal rate of return, may lead to conflicting conclusions; for example, see (*6*, pp. 27-42). We believe that it is informative to present results for both criteria. Calculation of the internal rate of return requires data on the flow of benefits and costs alone. It does not require an assumed opportunity cost of capital, or social rate of discount, which is critical to the present-value technique.

[4] The strengths and weaknesses of the economic surplus concept as a tool in applied economic analysis have been widely debated. Two recent surveys are provided by Currie, Murphy, Schmitz (*3*) and Mann (*10*).

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tiguous area of eastern North and South Carolina. In 1956, severe damage to the corn crop was reported in both States, and in some instances, there were total losses (*16*). In many parts of the world, witchweed causes serious economic losses in corn, grain sorghum, and sugarcane.[5]

Witchweed seeds are spread only short distances by natural means such as wind. However, they can be transferred long distances by artificial means, including relocation of farm machinery, shipment of infested host plants or their seeds, and in soil taken from infested fields. Thus, witchweed is a serious threat to corn and grain sorghum production in the United States (*17*).

After witchweed discovery, a Federal quarantine was issued and APHIS developed a program aimed at containing witchweed in North and South Carolina and eventually eradicating it. The program involves three basic tools: (1) a Federal-State quarantine, (2) application of chemical controls, and (3) biometric surveys. Quarantine enforcement and farmer compliance have prevented further spread of witchweed. The North and South Carolina State Departments of Agriculture and APHIS cooperate by furnishing and applying 2,4-D and other chemicals, and farmers plant nonhost crops in some areas.

Today, the American taxpayer can choose from two primary alternatives. One is to have *no witchweed program*. Consequences of this decision are reduced yields of corn and grain sorghum and higher farm production costs as witchweed spreads. Yields on infested acreage could fall about 10 percent and farmer control costs could average more than $11 per acre—without a program. This situation would encourage farmers to shift to nonhost crops, and the users of corn and grain sorghum and products produced from these commodities would reduce their demand and seek lower-priced substitutes.

A second alternative is to *continue a witchweed program*. Consequences are avoidance of reduced yields and higher production costs but only through public spending on a witchweed program.

In our empirical analysis, we divide the second alternative into two budget options, A and B. Budget option A is expected to continue containment, but not achieve eradication. Budget option B, though, is expected to accomplish both containment and complete eradication in 8 years. Program experts anticipate a high probability of success for either option. However, the probability of containment may be somewhat less under budget option A because eradication is not achieved and the possibility of spread by artificial means remains indefinitely.

THE ECONOMIC ANALYSIS

Theoretically, the critical elements determining the social value of a witchweed program are its cost, price elasticities of supply and demand, and negative shifts in supply due to witchweed infestation. For supply shifts, the rate of spread, reduction in yield on infested acreage, and increase in farmer control costs are particularly important factors. All these elements were considered in specifying the economic model used to evaluate the witchweed programs.

Structure and Assumptions of Economic Model

We assume the existence of competitive markets with longrun demand and supply curves for corn and grain sorghum, depicted in the figure.[6] DD represents total market demand after allowing complete quantity adjustments to any price change by domestic (*dd*) and foreign users.[7] SS represents market supply assuming that all factors of production are variable, the rate of return to each factor equals its opportunity costs, and that a witchweed program continues.[8] If the last assumption is dropped, market supply shifts upward and to the left, as shown by S′S′. The magnitude of the shift in supply depends on the rate at which witchweed spreads, the reduction in yield on infested acreage, the increase in farmer control costs, and the opportunities to shift to nonhost crops and other enterprises. Also, total market demand for corn and grain sorghum tends to shift downward and to the left as domestic and foreign users purchase relatively lower priced substitutes.

As the figure reveals, in the presence of a witchweed program, a larger quantity of corn and grain sorghum clears domestic and export markets at a lower price, increasing the social welfare. Benefits may be measured by the increase in consumers' surplus in the domestic market (area P′R′RP) and the export market (area R′U ER). These gains reflect the willingness of domestic and foreign consumers to pay for the additional grain resulting from a witchweed program, rather than do without it. Whether people actually make these payments or whether they pay

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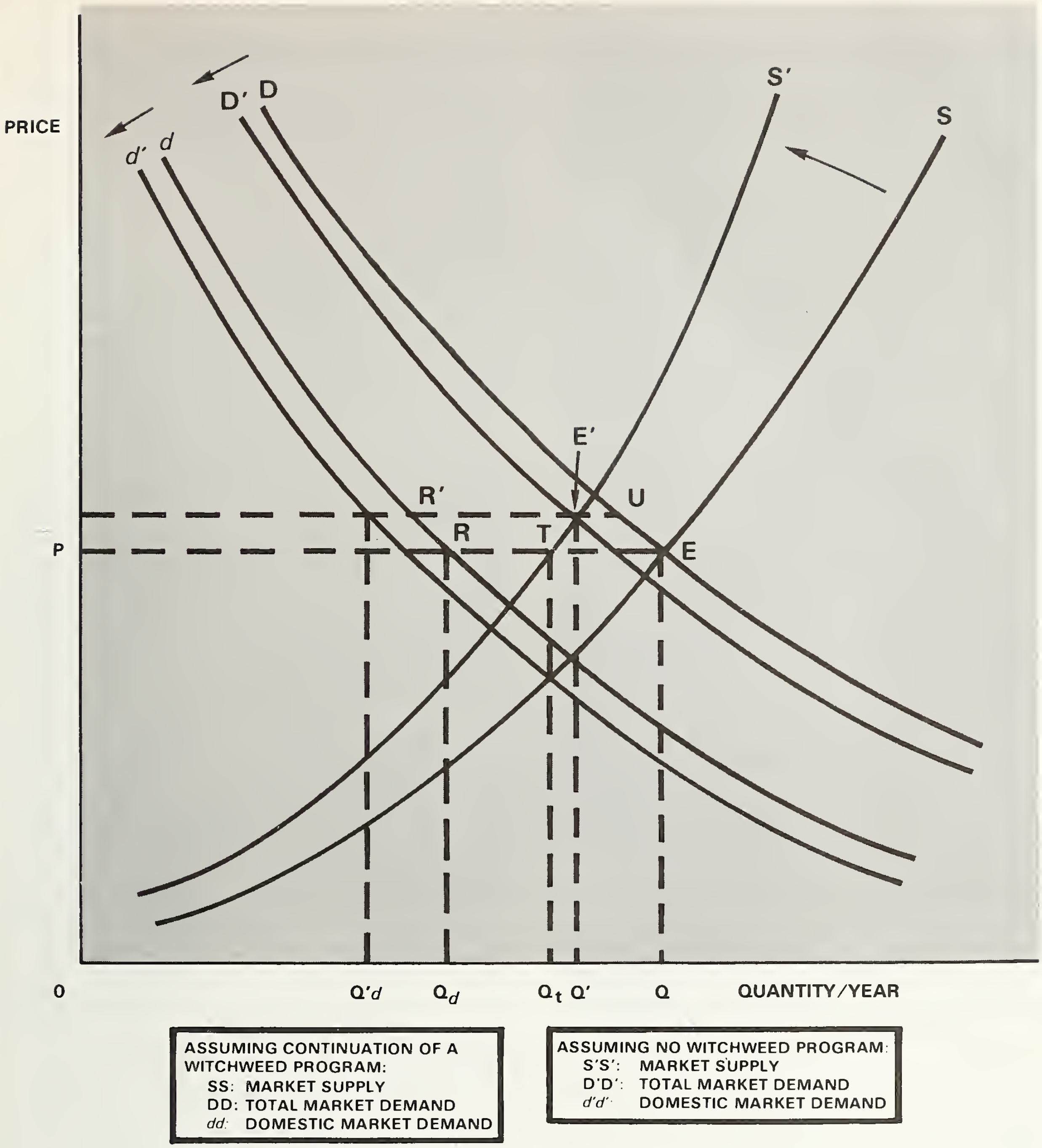
[5] Sugarcane was excluded from the analysis because reliable estimates of witchweed's effect on yields and future market prices and quantities are not available.

[6] Justification for the use of a longrun planning horizon includes our assumption that the results of this analysis will be considered before decisionmakers have selected either primary alternative or program option, and the fact that the benefits and costs of their decisions accrue over many years. Our assumption of competitive markets is naive for exports because the international grain trade is dominated by a few large firms and commodity flows are strongly influenced by tariffs, subsidies, quotas, and negotiated agreements. However, about 75 percent of U.S. corn and grain sorghum moves through domestic markets which are more competitive.

[7] For a discussion of lengths of run in demand theory, see (*20*, pp. 20-22).

[8] We also assume an increasing-cost industry (that is, resource prices rise with resource usage).



LONGRUN DEMAND AND SUPPLY FOR CORN
AND GRAIN SORGHUM IN THE UNITED STATES

less, retaining a "consumers' surplus," does not change the social value of the program; it only changes the distribution of benefits.

Producers' surplus is omitted from the analysis following Mishan (*11*, p. 1278): when "all factors are variable in supply, the industry's supply curve necessarily includes all factor prices and, therefore, all rents." In the long run, economic profit (loss) does not exist because the free entry (exit) of resources forces the rate of return in corn and grain sorghum production to a level comparable to that obtainable in other perfectly competitive industries. Specifically, producers receive only an accounting profit equal to the return they could earn in their best alternative.

Of course, there may be shortrun gains or losses to the owners of resources that are particularly suited to corn and grain sorghum production. These gains and losses are sometimes called economic rent, and they accrue to the owners of fixed resources. In moving from E to E', returns to factors of production may change. While producers earn no excess profits in the long run, landowners gain if shortrun producers' surplus is capitalized into higher rents for a fixed amount of land. The distribution of shortrun benefits and costs of a witchweed program are discussed later.

In the empirical analysis, market demand is measured at the farm level. It has been shown that consumers' surplus under a factor demand curve is consumers' surplus in the final product market plus any producers' surplus in intervening factor markets (*19, 8, 21*). Because this analysis assumes a longrun time period and competitive markets, P'U EP represents global consumers' surplus in final product markets.

Net social benefit due to a witchweed program is found by subtracting program costs from the increase in consumers' surplus. Benefit-cost ratios and rates of return presented here are for American taxpayers. Thus, they include only the consumers' surplus gained in the domestic market. The change in export earnings $(P(Q-Q_d) - P'(Q'-Q'_d))$, increases the opportunity for Americans to purchase and consume foreign goods and services.[9] However, we do not have a direct measure of the surplus Americans gained from consuming foreign goods and services.

Empirical Procedures

A multicommodity model was used to project prices and quantities of corn and grain sorghum from 1981 to 2000, with and without a witchweed program.[10] The empirical model developed by Gerald Plato simulates price-quantity responses of 21 commodities, given a set of exogenous variables. Constant elasticity of demand and supply equations are specified for each commodity at the farm level. Own-price demand elasticities for corn and grain sorghum are −0.58 and −0.64 in the domestic market, and −1.50 in the export market (*15*).[11] The longrun, own-price elasticity of domestic supply is 0.80 for each commodity. Since the equations are nonlinear, a numerical technique, Newton's method, is used to find equilibrium solutions (*1, 13*).

The exogenous variables specify a future scenario or "economic environment" in which commodity prices and quantities are projected. The scenario used here represents trends and "most likely" judgments for the exogenous variables (*14*). For example, we assume a U.S. Census E population projection, which gives an annual growth rate of 0.8 percent. Per capita disposable income in the United States is assumed to grow at 2.6 percent per year, from $5,511 in 1976. Agricultural productivity projections are based on a 3.0-percent annual increase in agricultural research and development expenditures, which cause the index of U.S. agricultural productivity to increase from 111 in 1976 to 135 in 2000 (*9*). Trends in U.S. exports and imports depend on a continuation of current agricultural trade policies, food production in developing countries that grow slightly faster than population, and consumer incomes abroad that gain at rates comparable to those of the sixties.

In solving the empirical model that assumes no witchweed program, the speed at which witchweed seeds spread and infest new acreage becomes crucial. Although the opinions of plant scientists vary widely, if giant foxtail is used as a prototype, there is consensus that witchweed would spread throughout the corn and grain sorghum regions of the United States in 30 to 75 years.[12] Therefore, we consider a slow rate of spread (1.3 percent of corn and grain sorghum acreage infested per year), which means complete infestation in 75 years; and a rapid rate of spread (3.3 percent of corn and grain sorghum acreage infested per year), with complete infestation in 30 years. Because of the manner in which witchweed spreads, plant scientists believe that a constant percentage rate of spread is realistic.

If there is no witchweed program, we assume that farmers adopt private control measures which would hold the reduction in yield on infested acreage to about 10 percent a year.[13] This requires 1.5 herbicidal applications per year at an annual cost of $11.25 per acre (*16*). It is assumed that a 1-percent increase in farmers' control costs results in a 0.20-percent reduction in the supply of corn and grain sorghum, other things constant (*15*). This coefficient reflects the ability of farmers to expand their planting of nonhost crops, such as soybeans, with relatively lower costs of production.

The empirical model was used to make two sets of projections from 1981 to 2000. First, prices and quantities of the 21 commodities are projected, assuming a witchweed program. These projections are based on assumptions underlying the longrun market supply, SS, in the figure. Second, the projections are repeated without a witchweed program, or assuming S'S'. This involves calculating a negative shift in market supply due to witchweed infestation (Q to Q_l in the figure), and allowing movement along the market supply curve to achieve a new equilibrium solution (Q_l to Q' in the figure). The magnitude of the negative shift in market

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[9] A decline in market price from P' to P causes export earnings to increase (decrease) if export demand is own-price elastic (inelastic).

[10] The commodity prices and quantities used in calculating program benefits in this article do not constitute official projections of the U.S. Department of Agriculture.

[11] It has been shown that social returns generated in studies of this type are highly sensitive to assumed demand elasticities (*18*). The domestic demand elasticities used here reflect combined uses of corn and grain sorghum in livestock feeding, industrial uses, and human consumption.

[12] Giant foxtail seeds spread by artificial means throughout the United States in 15 to 20 years.

[13] If farmers do not use private control measures, yields are expected to fall 50 to 100 percent.

supply varies directly with the rate of spread of witchweed, the assumed 10-percent reduction in yield on infested acreage, and the responsiveness of farmers in corn and grain sorghum plantings to an increase in the control costs.

Price and quantity observations generated by the empirical model are used to calculate program benefits over the long run. From a practical standpoint, it should be recognized that the discount factor to be applied to program benefits and costs in the 25th year is 0.09, assuming a 10-percent annual rate of discount. Therefore, the flow of benefits and costs beyond 2000 will not significantly alter results of this analysis.

INTERPRETATION OF RESULTS

Aggregate *ex ante* benefit-cost ratios and social rates of return indicate that a witchweed program is a desirable public investment. The results presented here are based on specific assumptions about economic-surplus methodology, demand and supply elasticities, exogenous variables, rate of spread of witchweed, reduction in yield on infested acreage, private control measures and costs, and Government program options and costs.

The Results

Projected annual benefits and costs in 1976 dollars appear in table 1. If the decision is made in favor of budget option A, containment could be achieved, but not eradication. Annual program costs of $6.0 million from 1977 to 2000 are not sufficient to allow an intensive and widespread application of chemicals. Thus, annual cost outlays must continue indefinitely to achieve containment in North and South Carolina.

If the eradication program is adopted (budget option B), containment and complete eradication could be achieved in 8 years. Annual costs would peak at about $12.0 million in 1980 and 1981. Biometric surveys and related activities would be necessary for 9 years after eradication is achieved. Discounted at the annual rate of 10 percent, the present values of cost flows under budget options A and B are $57.4 million and $52.1 million, respectively.

Annual benefits are measured by the increase in consumers' surplus in the domestic market due to a witchweed program. (The increase is area P'R'RP in the figure.[14] The consumption of the additional corn and grain sorghum creates this surplus, one which domestic consumers would be willing to forego if necessary. The benefits presented in table 1 vary directly with time and the rate at which witchweed spreads. Based on the recommendation of plant scientists, we assume an innoculation period of 4 years. If a decision had been made to have no witchweed program beginning in 1977, significant losses in production would not appear until the end of the innoculation period, or 1981. Also, we assume no measurable differences in benefits under the two alternative programs. Eradicating witchweed in North and South Carolina by 1984, as opposed to absolute containment, will not significantly increase the production of corn and grain sorghum in the United States. There-

Table 1—Projections of annual benefits and costs of witchweed programs, 1977 to 2000[1]

Year	Benefits		Costs	
	Slow rate of witchweed spread[2]	Rapid rate of witchweed spread[2]	Budget option A: Continue current program[3]	Budget option B: Eradication program
	Million dollars			
1977	0	0		4.1
1978	0	0		8.2
1979	0	0		11.3
1980	0	0		11.9
1981	6.6	17.5		11.6
1982	14.5	35.9		9.0
1983	21.7	54.8		6.2
1984	29.5	74.0		3.3
1985	37.4	93.6		2.0
1986	45.6	114.2		1.4
1987	53.8	134.9		1.3
1988	62.5	156.3		1.3
1989	71.6	178.1		1.3
1990	79.9	200.4		0.6
1991	88.9	229.7		0.6
1992	98.0	254.2		0.6
1993	107.4	279.2		0.6
1994	124.4	305.0		0
1995	126.8	330.9		0
1996	136.5	357.8		0
				0
1997	146.7	385.2		0
1998	156.7	412.9		0
1999	167.2	441.5		0
2000	177.6	470.8		0

[1] Benefits and costs are in 1976 dollars. [2] Assumed annual rates of spread are 1.3 percent and 3.3 percent, respectively. [3] 6.0 for each year but 1977, when figure is 4.1.

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[14] The algebraic expression is:

$$\text{area } P'R'RP = \int_{P}^{P'} NP^{\alpha}\, dP,$$

where the domestic demand equation (*dd*) is collapsed into two dimensions: $Q = NP^{\alpha}$, by letting the intercept term, N, include all other parameters and variables.

fore, annual benefits are assumed to be equal under the two budget options.[15]

Benefit-cost ratios and social rates of return appear in table 2. A 10-percent annual rate of discount was applied in calculating the present value of future benefits and costs. The social rate of return (r) is the time discount factor which makes the stream of net social benefits (NSB) equal to zero, or

$$\sum_t \text{NSB}_t (1 + r)^{-t} = 0 \qquad t = 0, 1, \ldots 23^{16}$$

Annual net social benefits are found by subtracting program costs from benefits.

Benefit-cost ratios and rates of return calculated in the study have direct significance for American taxpayers. Program costs represent a public investment financed by taxpayers; program benefits are the increase in consumers' surplus gained in the domestic market. Benefit-cost ratios range from 7 to 1 under budget option A, assuming a slow rate of spread, to 19 to 1 under budget option B, assuming a rapid rate of spread. Social rates of return, however, range from 38 percent under option B, assuming slow spread, to 71 percent under option A, assuming rapid spread. Clearly, public investment in a witchweed program yields positive, real social effects. Program benefits exceed costs in the aggregate, implying that the production and consumption potential of American society is increased. But the decisionmaker is confronted with the dilemma that the two criteria—benefit-cost ratios and social rates of return—result in different conclusions.

When projects are mutually exclusive, such as budget options A and B, benefit-cost ratios reveal which project makes the greatest net present-value contribution to society, for an assumed rate of discount. By the net present-value method, budget option B, the eradication program, is the preferred public investment, as indicated by the benefit-cost ratios in table 2. Nonetheless, determining social rates of return is useful because these compare the actual rate of return to society with the accepted or minimum rate. If the accepted rate of discount is increased from 10 percent, to 14 percent or more, the benefit-cost ratios would favor budget option A, the containment program.

Though its estimated benefit-cost ratios show option B to be the preferred public investment, ratios for the two options come extremely close to one another. This proximity suggests that the rankings could easily be affected by relatively small errors in program cost estimates (table 1). Sensitivity analysis shows that a 10-percent reduction in future annual costs of budget option A would make present-value rankings of the two options approximately equal.

We assume implicitly that program accomplishments are certain. The probability that containment will fail may be higher under budget option A (because eradication is not achieved) than under budget option B. If so, the real social value of the containment program is overestimated relative to the eradication program, as shown in table 2. The decisionmaker must also recognize the possibility that, despite control measures, witchweed may spread to new areas, forcing additional program costs and/or a reduction in the production and consumption of corn and grain sorghum.

Table 2 shows clearly the importance of the rate of spread assumption. Social value of a witchweed pro-

Table 2—Benefit-cost ratios and social rates of return for witchweed program, 1977 to 2000

Type of program and rate of spread of witchweed	Benefit-cost ratio[1]	Social rate of return[2]
	Dollars	*Percent*
Budget option A—continue current program:		
Slow spread	7 to 1	45
Rapid spread	17 to 1	71
Budget option B—eradication program:		
Slow spread	8 to 1	38
Rapid spread	19 to 1	61

[1] The annual rate of discount is 10 percent. [2] The time discount factor which makes the present value of the stream of net social benefits equal to zero.

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[15] This assumption, along with the present values of program costs presented, suggests that the social value of budget option B will exceed that of A. However, this does not eliminate the need to calculate benefit-cost ratios and social rates of return. The decisionmaker still needs to know whether either program is a desirable social investment. Also, it is interesting to know approximately how much the social values of the two programs differ, and if the two criteria result in the same conclusion.

[16] $T = 0$ represents 1977; $t = 1$ represents 1978; . . . and $t = 23$ represents 2000. The polynomial equation was solved using subroutine POLRT, IBM 360 subroutine package, version III, 1968.

gram based on benefit-cost ratios is more than doubled, if we assume witchweed spreads rapidly rather than slowly—in the absence of a program. Possibly, the spread of witchweed may be better represented by an "S"-shaped curve, or an exponential function, than by a constant percentage relation. Both of the other alternatives would tend to reduce benefits in the early years of a program, and they would probably lower the estimates of social value.

As mentioned, the presence of a witchweed program also results in additional foreign exchange earnings from the sale of corn and grain sorghum (table 3). In 1974-75, for example, feed grain exports earned about $4.8 billion, making an important contribution to the U.S. balance of payments. The present value of export earnings from a witchweed program—at a 10-percent discount rate—range from $81 million, assuming a slow rate of spread to $204 million, assuming a rapid rate of spread. The resulting consumers' surplus is not reflected in tables 1 and 2. Thus, our estimates of social value are conservative.

Table 3—Average increase in export earnings due to a witchweed program, 5-year intervals, 1981-2000

Years	Slow rate of witchweed spread	Rapid rate of witchweed spread
	Million dollars	
1981-85	20	49
1986-90	61	151
1991-95	115	293
1996-2000	184	465

[1] Export earnings are measured in prices at the farm level.

Shortrun Adjustments

The empirical results reported above pertain to a longrun planning horizon wherein decisionmakers are able to select from a wide variety of different investments and all resources are variable. This is an appropriate time period for measuring the social value of a witchweed program and comparing program options under alternative assumptions. However, all economic agents live in the short run; thus, shortrun benefits and costs cannot be completely ignored.

Farmers in the infested area of North and South Carolina would be primary beneficiaries of a witchweed program through 1980. Because of the program, these producers would avoid annual control costs of $11.25 per acre. A rough estimate of the yearly value of this subsidy is the number of infested acres in 1977 times $11.25 per acre, or slightly more than $4 million. The actual subsidy is probably somewhat less because, in a given year, corn and grain sorghum would probably not be grown on the entire infested acreage. Over time, the subsidy will be capitalized into the price of corn and grain sorghum cropland in the infested area. For example, if the typical buyer of cropland has a 10-year planning horizon and expects to earn a 10-percent rate of return, the subsidy will increase the value of an acre of cropland about $76, other things constant.

Beyond 1980, calculation of shortrun benefits and costs becomes more complicated. Continuing the program prevents witchweed from spreading and allows producers to avoid annual control costs of $11.25 per acre and a 10-percent reduction in yield. Assuming a rapid rate of spread, annual control costs paid by producers in the absence of a program would be $131 million in 1985 and $404 million in 1995. On the other hand, the presence of a program prevents an increase in total revenue. Again, assuming a rapid rate of spread, annual total revenues earned by corn and grain sorghum producers rise by $53 million in 1985 and $177 million in 1995. Without a program, producer benefits from higher corn and grain sorghum prices do not exceed higher annual control costs. Of course, control costs in the absence of a program. Of course, producers who remain outside the infested area for an extended period of time are disadvantaged by the program because they lose an increase in total revenue that would not be accompanied by higher annual control costs.

Consumers derive benefits from a program when the time horizon is long enough so that the spread of witchweed would cause prices to rise and quantities available for consumption to fall. Table 1 shows that annual consumer benefits exceed annual program costs in the sixth year under the most conservative conditions (a slow rate of spread).

CONCLUSIONS AND IMPLICATIONS

Ex ante estimates of longrun social value support the conclusion that public investment in a witchweed program is desirable. The rate of return on such an investment is estimated to be at least 38 percent. Our findings do not necessarily imply that a witchweed program should be funded. There may be other Government programs yielding higher rates of return to which funds should be allocated. However, if funds are not exhausted on programs that would yield higher returns, a witchweed program should be adopted.

Before making a final ranking between budget option A, the containment program, and budget option B, the eradication program, it would be useful to evaluate further several deterministic assumptions of our empirical results. For example, experts could evaluate merits of containment and eradication programs using the following questions:

- What is the probability that containment will fail, given that eradication is not achieved in North and South Carolina?
- What will be the costs to the Government, producers, and consumers if containment fails?
- What is the probability that the intensive eradication effort will be extended from 8 years to 12 or 15 years?
- Will it be necessary to increase significantly annual program costs above the levels in table 1 to provide containment or achieve eradication in future years?

Empirical results presented here show that budget option B, the eradication program, makes the greatest net present-value contribution to society. This conclusion is based on strict assumptions as to the flow of benefits and costs, and the opportunity cost of capital.

The social value of a witchweed program is strongly influenced by the rate at which witchweed would spread throughout corn and grain sorghum producing areas in the absence of a program. According to best judgments, the number of years for complete infestation will fall somewhere between the two extremes we considered—30 and 75. Plant scientists believe that the probability is low that we can improve the reliability of the rate of spread estimate. Since our most conservative analysis indicates a favorable social value, there seems to be little justification for using additional resources to study and refine the accuracy of the rate of spread measure.

Critics have argued that the only beneficiaries of a witchweed program are farmers in the infested areas of North and South Carolina. This argument is based on extremely-shortrun assumptions. Pure economic profits accruing to farmers in the production of corn and grain sorghum will be rapidly bid away by the entry of new resources. In a longrun framework, the decision to invest in a witchweed program imposes a cost on American taxpayers. But a much greater benefit flows to consumers because witchweed does not spread, making larger quantities of corn and grain sorghum available for domestic consumption and export. Further, society benefits from eradication in the two States if it is highly likely that a containment program would fail and/or the future annual costs of such a program are as great as indicated in table 1.

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CONFIDENCE INTERVALS FOR CORN PRICE AND UTILIZATION FORECASTS

By Lloyd D. Teigen and Thomas M. Bell[1]

In recent forecasting activity in ERS, researchers have used alternative scenarios as a means of bounding forecasting errors. One scenario is treated as the "most likely" occurrence. Two others present analysis of consequences when production is at its estimated upper and lower limits. Increasingly, we have been asked to assign probabilities of occurrence to each of these production ranges and to the corresponding ranges of all the other forecasted variables.

- **An approximate variance of forecast is derived based on the structural coefficients and the variance around the structural equations. For the corn model, standard error of price was estimated to be $0.23 per bushel when neither acreage nor yield are known and $0.11 per bushel when production is known.**

- **Keywords: Corn, forecast, variance, confidence intervals.**

In this article we estimate a variance of forecasted price and utilization levels for corn which can be used to estimate the probability associated with the ranges. We base the estimate on the variance around the structural equations of an econometric model of the corn sector used as part of the ERS forecasting process.

In particular, the forecast error for corn prices is 23 cents per bushel before planted acreage is known and 11 cents after the harvest. In applying these standard errors of estimate to official USDA forecasts, it must be assumed that the process of review and adjustment by commodity specialists does not increase variance.

The theory of forecasting variance is well known in the econometric literature. Goldberger and others (*2*) studied the variance of forecast when all exogenous variables are not random.[2] Feldstein (*1*) extended this to the situation in which the exogenous variables were subject to error. Schmidt (*6*) examined the variance of forecasts from a dynamic econometric model. The forecast variance estimated here uses a rather simple adjustment process to bypass the large-scale matrix computations required by the exact variance formulae.[3]

First, the variance estimator will be derived. After a brief statement of the empirical form of the structural model, the reduced-form variances will be evaluated. A set of point estimate forecasts for the 1978 crop year and their corresponding 95-percent confidence intervals will be presented, as will some implications for forecast analysis. The explicit structure of the econometric model of the corn sector used here appears as an appendix.

DERIVATION OF VARIANCE ESTIMATOR

This corn sector model consists of six equations which determine six endogenous variables. Food, feed, and export demand are functions of corn price. Ending commercial stocks are related to corn price and production. Price is determined by the identity which equates supply with utilization; production is a function of variables which are exogenous to the model. Each equation contains variables determined outside this system and also random disturbances (except for the identity).

Price and utilization levels for corn will be forecast by the model, given an estimate of the current corn supply. The variances of these forecasts are estimated from the variance of the corn supply and the variance of the random disturbance in each equation.

In this process we will assume that the coefficients in the equations are now parameters rather than estimates and that the intercept contains all exogenous variables and the disturbances in each equation. Finally, we assume that the disturbances are independent across equations.

In this formulation we can express the corn model as follows:

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 & b1 \\ 0 & 1 & 0 & 0 & 0 & b2 \\ 0 & 0 & 1 & 0 & 0 & b3 \\ 0 & 0 & 0 & 1 & -a & b4 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ -1 & -1 & -1 & -1 & -1 & 0 \end{pmatrix} \begin{pmatrix} \mathrm{FD} \\ \mathrm{FO} \\ \mathrm{CX} \\ \mathrm{CS} \\ \mathrm{QC} \\ \mathrm{PC} \end{pmatrix} = \begin{pmatrix} \mathrm{U1} \\ \mathrm{U2} \\ \mathrm{U3} \\ \mathrm{U4} \\ \mathrm{U5} \\ \mathrm{U6} \end{pmatrix}, \text{ or}$$

$$Ay = U, \text{ in matrix notation}$$

The U_i terms contain both the predetermined variables and the disturbance terms in the equations. Sym-

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[1] The authors are agricultural economists, with the Forecast Support Group, Commodity Economics Division, ERS.

[2] Italicized numbers in parentheses refer to items in citations at the end of this article.

[3] The exact variance of forecast in this six-equation system requires manipulation of matrices of dimension (6x84), (84x120), and (120x120), in addition to the (6x6) matrices used in this article.

bols for the six endogenous variables are defined in the appendix. The covariance matrix, S, for the U vector under the assumption of independence is a diagonal matrix whose nonzero elements are the squared structural standard errors of estimate. The structural variance of U_6 in the identity is assumed to be zero. The compact form for the solution of the model is:

$$y = A^{-1} = U.$$[4]

The covariance matrix for this solution is:

$$A^{-1}S(A^{-1})'$$

under the stated assumptions. Thus the expanded form for the variance of corn price is:

$$\mathrm{VAR(PC)} = \left(\Sigma_1^4 \sigma_i^2 + (1+a)^2 \sigma_5^2\right) / (\Sigma b_i)^2$$

Similar expressions hold for the other variables. If the disturbances in the demand equations were positively correlated with the total supply, this estimate of price variance would be biased upward since the covariance terms would be subtracted from this equation. If this upward bias occurred, our variance estimates would err by predicting a larger variance for price and smaller variances for utilization than might otherwise be true.

These variance estimates assume perfect knowledge of the system parameters. The usually applied variance of forecast definitions in the single equation case allow for variation due to the parameter estimates (for example, see *3* p. 375):

$$\sigma_F^2 = \mathrm{SEE}^2\,(1 + 1/n + (x-\bar{x})'\,(x'x)^{-1}\,(x-\bar{x}))$$

When there is only one independent variable, or when the X's are orthogonal in the multivariate case, the order of magnitude of this correction is approximately a factor of between $(n+k)/n$, and $(n+2k)/n$. Here k is the number of estimated parameters including intercept in the equation and n is sample size. As the X's depart from orthogonality, this factor increases with the correlation among the explanatory variables.

Thus, in a single-equation model, the standard error of forecast inflates the standard error of estimate by between $(1+k/2n)$ and $(1+k/n)$ to account for the variation due to coefficient estimation. Intuition suggests that an analog to this correction in the context of a system of estimates would define k as the average number of parameters per equation and n as the average sample size of each estimated equation.

ESTIMATED STANDARD ERRORS FOR THE ENDOGENOUS VARIABLES

Our empirical analysis used the estimated structural coefficients and standard errors of estimate to obtain the standard errors associated with the model solution. These specific estimates assume that the intercepts were known and the variance of each disturbance was that estimated with the structural equation. To generalize this approach, one could add the variance due to random exogenous variables in the system to the variance of the structural disturbance.

Table 1 presents the estimated standard errors of the endogenous variables in the corn model which correspond to three levels of production uncertainty. The standard errors presented in the first column come directly from the estimated equations. Those in the other three were derived from them. The first estimate of the reduced-form standard errors corresponds roughly to some point prior to the planting intentions report—at a time in which the standard error of the production estimate is 350 million bushels (an estimate used in the monthly Update of Food and Agriculture Outlook).[5] The second estimate is made after the planted acreage has been determined, and the only variation will be due to yield. The third estimate occurs after official production estimates have been made—so that the variance of production (from the standpoint of this model) is zero.

Thus, a March estimate of corn price for the next October-September year would have a standard error of about 23 cents per bushel, using a root mean square error of 350 million bushels for production. An October estimate of the upcoming crop year corn price would have a standard error of about 11 cents per bushel. Between these two estimates, the standard error of commercial exports would be reduced from 94 to 53 million bushels, and feed demand error would drop from 188 million bushels to 86 million bushels.

None of these absolute figures should be used to credit or discredit this model or the modeling system of which it is a part. However, they do indicate the inherent error tolerances in the estimated structure.

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[4] An expanded version of the reduced form of this system is the following:

$$\mathrm{FD, FO, CS} = U_i - \frac{b_i}{\Sigma b_i}\left(\Sigma_1^4 U_i - (1+a)U_5\right) \quad, i = 1,2,3$$

$$\mathrm{CS} = U_4 - a\,U_5 - \frac{b_i}{\Sigma b_i}\left(\sum_1^4 U_i - (1+a)\,U_5\right)$$

$$\mathrm{QC} = U_5$$

$$\mathrm{PC} = \left(\Sigma_1^4 U_i - (1+a)\,U_5\right)/\Sigma b_i$$

[5] ERS memorandum to Director of Economic Policy Analysis and Budget, regularly issued.

Table 1—Standard errors of corn price and utilization

Variable	Units	Structural standard error	Reduced from standard error: Preplanting	Midsummer	Postharvest
Price	Dol./bu.	0	.232	.148	.114
Production	Mil bu.		[1] 350	[2] 162.5	0
Feed demand	do.	148.2	188.1	115.7	85.69
Food demand	do.	13.39	13.98	13.53	13.41
Commercial exports	do.	42.67	93.99	64.16	53.10
Ending commercial stocks[3]	do.	83.95	125.1	87.52	73.90
Ending Government stocks	do.		427.3	227.5	25.7

[1] This corresponds to the root mean square error used in the monthly update of the Food and Agricultural Outlook. To estimate the production variance implied by the econometric model, square the yield times the standard error from the acreage equation and add the result to the square of acreage times the yield standard error. [2] All variation is due to yield uncertainty, since acreage is assumed known. [3] The price effect on next year's acreage was included with the price response in this equation, assuming soybean price is $6.40 per bushel.

A 1978 FORECAST AND ITS CONFIDENCE INTERVAL

We now illustrate the use of these standard errors of forecast. The reduced-form solution of the model will be presented and graphically illustrated using basic data from an update to the Food and Agricultural Outlook. This forecast represents exogenous information that was available May 1, 1977. Because we focus only on the changes in forecast variance through the year, the exogenous variables were fixed throughout the analysis. Thus the point estimates will not change among the alternatives.

Table 2 presents the food, feed, exports, and stock demand equations as functions only of the endogenous price and production variables. The effects of the exogenous variables were collapsed into the intercepts, using the values given in the table. The price slope of the demand for commercial stocks was adjusted to reflect the price response of planted acres. Total demand is the sum of the individual demand equations plus policy exports of 200 million bushels.

Table 2—Exogenous variables and simplified demand equations

Independent variable	Intercept	Production slope	Price slope	Exogenous variable and value assumed					
Food use	448.36	0	-19.649	YPD 688					
Feed use	5,601.57	0	-827.454	PM 10.0	PL 1.87	LO 1.029			
Commercial exports	2,276.53	0	-383.195	PS 6.40	SEEC 16,801	SX 21,221	AUX 102,500	PLX_{t-1} 1.00	XIX 1.72
Commercial stocks	1,201.06	.1049	[1] -317.73		AP 83.9	GS 0			
Total demand	9,727.51	0	-1,548.03	GX 200	GS 0				
Total supply	7,068	0	0	[2] QC 6,219	CS_{t-1} 849				

[1] This coefficient reflects the response of next year's acreage to current corn price, assuming the soybean price is $6.40 per bushel. [2] The acreage harvested is 71.9 million with 86.5 bushels per harvested acre.

Equating total demand with production plus beginning stocks, we can solve for the market clearing price. In this case, the equilibrium price would be $1.72 per bushel. However, the loan rate for corn is $1.75, so that either Government purchases for inventory or additional policy exports are needed to raise the corn price to $1.75. A 46.5-million bushel Government purchase would raise the price the necessary 3 cents. The variance of the Government stock estimate is the sum of the variance of production and the variance of each demand estimate. From table 1 the preplanting standard error of Government stocks is calculated as 427 million bushels, so that the estimated purchase is not statistically different from zero.

The confidence interval for each endogenous variable is calculated from its standard error by multiplying it by the appropriate value of the t-statistic inflated by the $(1+k/n)$ factor which accounts for parameter variation. The k/n correction factor allows the predetermined variables to be up to two standard deviations from their sample means. The result is a conservative estimate of the probability that the interval will cover the actual value. To learn what variability of price and utilization is due to the variables we collapsed into the intercepts, sensitivity analysis must be performed. Upper and lower bounds must be set for the exogenous variables and the system solved again to obtain a new set of price and utilization levels. The maximum should be treated as one scenario and the minimum, another.

The 95-percent confidence interval for the price forecast, as an example, is $P \pm S_{p}t.05\ (1+k/n)$. With an average of 5 parameters, 20 observations, and 16 degrees of freedom, the preharvest confidence interval is $p \pm .59$. Since the equilibrium price level ($1.72) is below the support price, the lower bound of the confidence interval would be at the support price ($1.75) and the upper bound would be $2.34. The 95-percent confidence intervals for the other variables are presented in table 3. The point estimates which represent the "most likely" occurrences are also shown. In addition, confidence intervals based on the midsummer and postharvest variance estimates are included in the table. These intervals are illustrated in figures 1 and 2.

Figure 1 shows the preplanting 95-percent confidence intervals for supply, demand, and price. Figure 2 contains the midsummer and postharvest confidence bands. The outer limits of the shaded bands in this figure define the midsummer confidence interval and the inside of the shaded bands defines the 95-percent confidence intervals when harvest is known. Since the same exogenous data are used in each case, the point estimates of price and utilization are the same. By overlaying the two figures, one can trace the effects of increasing information on forecast precision. The information which reduces the variance of production narrows the confidence intervals for price and consumption.

Table 3—Ninety-five percent confidence intervals for variables in the corn model

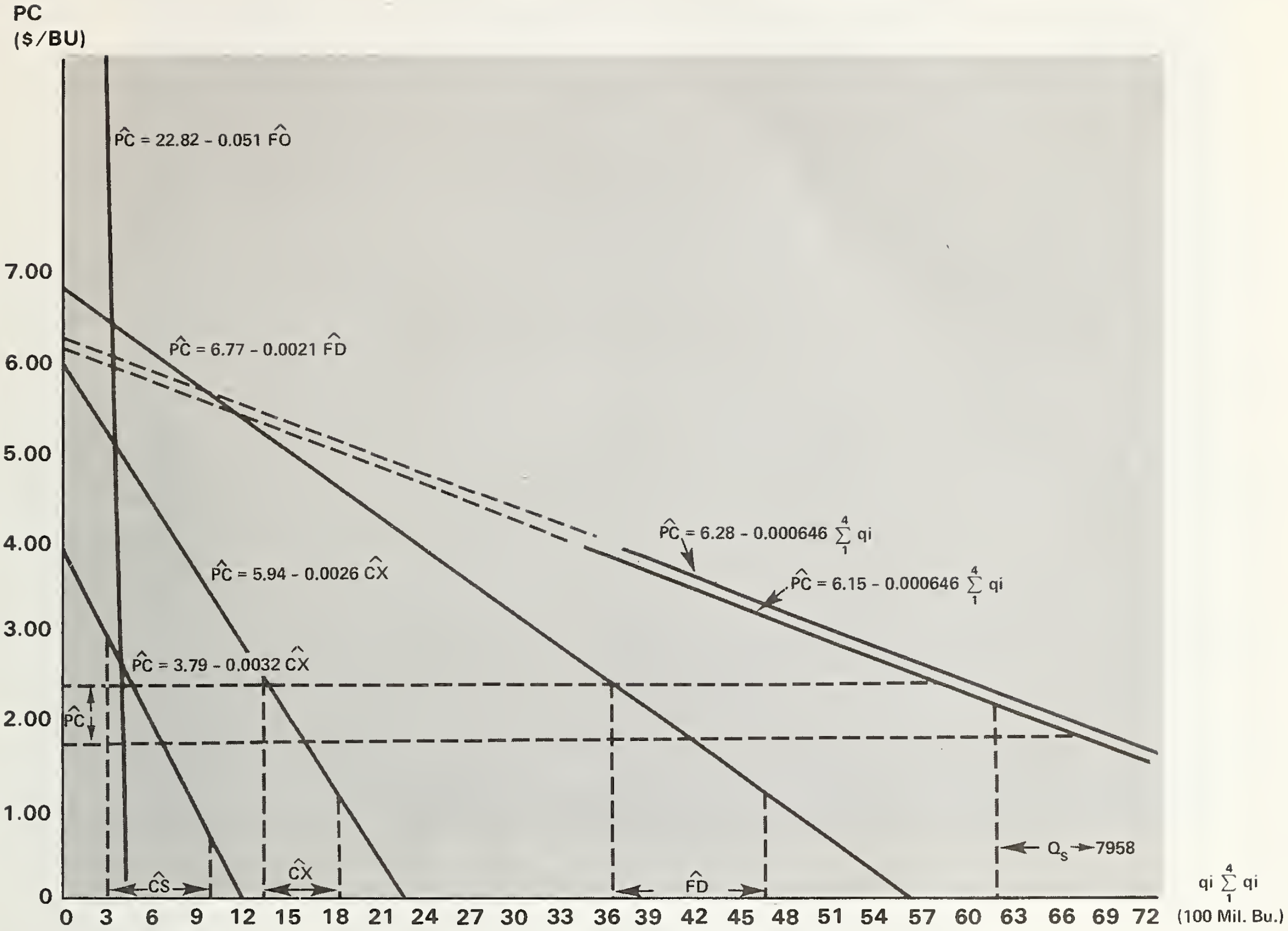
	Lower bound	Point estimate	Upper bound
Preplanting:			
Production	5329	6219	7109
Price	1.75	1.75	2.34
Feed demand	3675	4153	4632
Food demand	378	414	450
Commercial exports	1367	1606	1845
Commercial stocks	327	645	963
Midsummer:			
Production	5806	6219	6632
Price	1.75	1.75	2.13
Feed demand	3859	4153	4448
Food demand	380	414	448
Commercial exports	1443	1606	1769
Commercial stocks	422	425	868
Postharvest:			
Production	6219	6219	6219
Price	1.75	1.75	2.04
Feed demand	3935	4153	4372
Food demand	380	414	448
Commercial exports	1471	1606	1741
Commercial stocks	457	425	833

IMPLICATIONS

Recent forecasting work in ERS has typically derived point estimates of the consequences of three alternative scenarios. Increasingly, probability statements have been requested for each scenario. To the extent that these scenarios estimate the effects of events outside the modeling systems, this variance framework will not help the analysts. But to the extent that the scenarios simply bracket the most likely occurrences, these standard errors could be used to provide an interval estimate of a single most likely scenario, together with the likelihood that the interval contains the observations in the period of forecast. Thus, one interval estimate, requiring little more time to prepare than a single point estimate, would provide more information than the point estimates for three separate scenarios. Analysts would gain more time to evaluate events outside the modeling system and to interpret their analysis to policymakers and the general public.

APPENDIX: STRUCTURE OF THE CORN MODEL

This model of the corn sector was originally developed by Womack (7). It consists of structural demand equations for four components of utilization, a recursive production submodel, and price determination



*378 ≤ FO ≤ 450.

FIGURE 1. 95 PERCENT PRE-PLANTING CONFIDENCE LIMITS FOR CORN

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from the supply-utilization identity. The endogenous variables are corn prices, production, and levels of feed, food, export and stock demand. The production model was patterned after Houck and others (*3*, *4*), and it consists of an equation for planted acreage and an equation for yields. The demand equations describe feed use, food use, commercial exports, and ending commercial stocks.

Many questions of model specification, estimation techniques, sample periods, and so on, could be addressed to this model. Since our purpose was to estimate forecast variance from the given model, we did not consider such questions. For answers to them, see (*7*, *3*, *4*).

Feed demand in the model is a function of corn price, soybean meal price, and indexes of livestock prices and livestock output. The sample period is 1950-72.

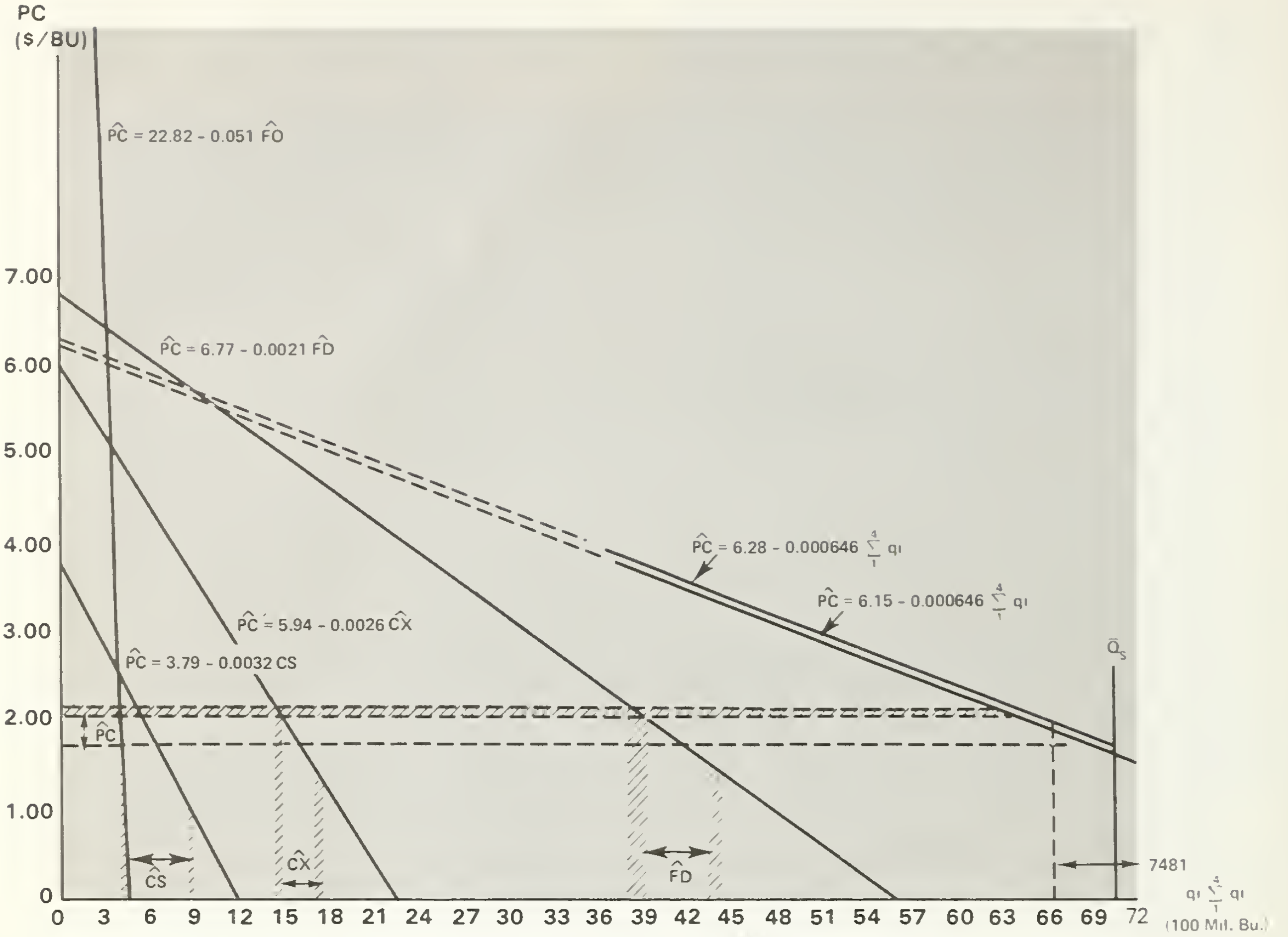
$$\underset{(-3.01)}{FD = -827.454\ PC} + \underset{(1.50)}{57.975\ PM} + \underset{(3.21)}{1004.86\ PL} + \underset{(7.43)}{3490.36\ LO} \underset{(-0.68)}{-448.852}$$

$$R^2 = .935 \qquad SEE = 148.2 \text{ mil. bu.} \qquad DW = 1.304$$

Food demand is a function of corn price and real personal disposable income. This equation was estimated using 2SLS, so no R^2 is presented. The sample period is 1948-72.

$$FO = \underset{(-1.28)}{-19.649\ PC} + \underset{(19.90)}{.4732\ YPD} + 122.2786$$

$$SEE = 13.39 \text{ mil. bu.} \qquad DW = 0.49$$



*380 ≤ FO ≤ 448.

// Denotes reduction in error due to acreage uncertainty.

FIGURE 2. 95 PERCENT MIDSUMMER AND POST-HARBEST CONFIDENCE LIMITS FOR CORN

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NEG. ERS 2900-77 (9)

Commercial exports are a function of U.S. corn price, U.S. soybean price, and production plus beginning stocks in EEC and exporting countries; and animal units, livestock price, and personal consumption expenditures in importing countries. The sample period is 1956-73.

$$CX = -\ 383.195\ PC + 294.363\ PS - .0356\ SEEC$$
$$(-3.13) \qquad (5.50) \qquad (-2.43$$

$$-\ .0279SX + .020AUX$$
$$(-3.74) \quad (2.12)$$

$$+\ 1255.98\ PLX_{t-1} + 610.236XIX - 2772.79$$
$$(2.16) \qquad (1.20)$$

$$R^2 = .98 \qquad SEE = 42.67 \text{ mil. bu.}$$

Ending commercial stocks are related to corn price, this year's production, acres planted for next year's harvest, and ending Government stocks.[1] The sample period is 1949-73.

$$CS = -288.364\ PC + .1049\ QC - 8.138\ AP$$
$$(-3.79) \qquad (3.92) \qquad (-2.18)$$

$$-.1375\ GS + 1231.47$$
$$(-2.67) \quad (4.00)$$

$$R^2 = .825 \qquad SEE = 83.95 \text{ mil. bu.} \qquad DW = 1.935$$

Planted acreage for corn is a function of the maximum of the effective support or farm price of corn relative to soybean price, the deficiency payments for corn, the effective support price of soybeans, a sorghum acre-

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[1] This equation is specified slightly different from Womack's (7).

age variable, time, and a dummy variable. The sample period is 1950-74.

$$AP_{t-1} = \underset{(6.06)}{23.002\ PC^*/PS} - \underset{(-7.13)}{43.627\ DPC} - \underset{(-2.46)}{5.907\ PFS}$$

$$- \underset{(-2.02)}{.287\ APS^*} - \underset{(-2.65)}{.311\ (T-48)}$$

$$+ \underset{(6.06)}{7.153\ D661} + 88.825$$

$R^2 = .965$ DW = 1.532 SEE = 1.72 mil. acres

Yield per harvested acre is a function of the fertilizer/corn price ratio, weather in the current and preceding year, two dummy variables, and a logarithmic time trend.[2] The sample period was 1951-71. This equation was published by Houck and Gallagher (*4*).

$$YLD_{t-1} = \underset{(6.32)}{-.5101\ PF/PC} + \underset{(3.09)}{4019W_{t-1}} + \underset{(2.83)}{.3525W}$$

$$+ \underset{(3.67)}{7.675\ D61} - \underset{(5.24)}{15.28D70} + \underset{(12.72)}{38.093\ LN(T)}$$

$$- \underset{(5.34)}{66.31}$$

$\bar{R}^2 = .980$ DW = 2.12 SEE = 2.472 bu.

Because yield and planted acres are calendar year variables and the time subscripts refer to the crop years, the production for the current crop year equals the product of acres planted and yields in the previous crop year.

$$QC = AP_{t-1} * YLD_{t-1}$$

The system is closed by the supply-utilization identity which equates production plus beginning stocks to feed, food, export, and stock demand, plus Government stocks and policy exports.

$$QC + CS_{t-1} + GS_{t-1} = FD + FO + CS$$

$$+ CS + GS + GX$$

A complete rationalization of the specification and a description of the precise content of each variable are found in (7).

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[2] Currently, within the Forecast Support Group of ERS, researchers are developing yield estimates based on weather information available at different months of the year. Results will allow more finely graded changes in confidence bands than those derived.

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SPECIFICATION OF BERNOULLIAN UTILITY FUNCTION IN DECISION ANALYSIS

By William W. Lin and Hui S. Chang[1]

INTRODUCTION

A few years ago, Lin, Dean, and Moore reported empirical test results of the hypothesis that farmers' operational decisions are more consistent with utility maximization than with profit maximization (*9*).[2] They concluded that Bernoullian utility maximization explained actual farmers' behavior more accurately than did profit maximization.

- The authors propose two general functional forms, and apply them to the specification of utility functions for predicting farmers' production response. The polynomial utility functions were rejected, based on the results of a likelihood-ratio test. The appropriate degree of nonlinearity of the utility function can best be determined by using the general functional forms without *a priori* specification. Further, farmers' utility functions may exhibit a decreasing absolute risk aversion. The tendency for the Bernoullian utility maximization hypothesis to predict more risky behavior than that actually observed may have been partly due to incorrect specification of the utility function.

- Keywords: Functional forms, Bernoullian utility function, risk aversion.

One of the procedures in the above empirical tests involves the derivation of Bernoullian utility function. Lin, Dean, and Moore employed a modified Ramsey model by asking six farm decisionmakers a series of questions in the context of decision games. A linear or polynomial function was used to specify the Bernoullian utility function for each of the six farms studied (*9*, p. 504). However, the polynomial utility function has recently been criticized because it exhibits increasing absolute risk aversion or negative marginal utility.[3] Generally, researchers agree that a utility function should imply a decreasing absolute risk aversion, not a constant or increasing one.

Several pertinent questions thus emerge: In what functional form(s) should a utility function be specified to imply a decreasing absolute risk aversion?[4] How can the chosen functional form be estimated? To what extent does the polynomial utility function bias the predictions of the Bernoullian utility maximization hypothesis on farmers' production response?

Accordingly, our objective is to suggest some answers to the above questions. First, several functional forms are reviewed for their coefficients of risk aversion. Two general forms for the Bernoullian utility function are introduced; and theoretical constraints on the parameters and the estimation procedures are discussed. Second, estimated results for a case-study farm are reported. Finally, we indicate the extent to which the polynomial utility function may have biased the prediction of Bernoullian utility maximization hypothesis on farmers' production response.

ALTERNATIVE FUNCTIONAL FORMS

Because of theoretical shortcomings of the polynomial utility function, alternative utility functions ranging from log linear, semilog, and constant elasticity of substitution (CES), to various exponential functions have been suggested lately (*3*, *4*, *8*). Table 1 summarizes these alternative utility functions and the implied restrictions on parameters, coefficients of risk aversion, and the risk aversion ranges.[5]

All these utility functions require *a priori* assumptions as to their specifications. Recent developments in the area of transformation of variables, however, suggest that the appropriate degree of nonlinearity of the utility functions can be best specified by sample observations (*1*, *12*). For example, the utility function can be specified to have the following generalized functional form:

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[1] William W. Lin is an economist with ESCS and Hui S. Chang is an associate professor of economics with the University of Tennessee, Knoxville.

The authors are indebted to James Seagraves, A. N. Halter, Lindon Robison, and Jitendar Mann for their helpful comments and suggestions. Any errors remaining are the authors' sole responsibility.

[2] Italicized numbers in parentheses refer to items in References at the end of this article.

[3] A utility function exhibits increasing, constant, or decreasing absolute risk aversion, depending on whether the coefficient of risk aversion increases, remains constant, or decreases as income or wealth rise. The coefficient of risk aversion, as defined by Pratt (*11*), is $r(x) = -U''(x)/U'(x)$. In this, $r(x)$ is the coefficient of risk aversion and $U'(x)$ and $U''(x)$ are the first and second derivatives of the utility function.

[4] We give no specific attention to the utility function which contains both convex and concave regions, illustrated by Hildreth (*7*).

[5] Some of the utility functions have been reviewed by Keeney and Raiffa (*8*).

Table 1—Alternative utility functions and the coefficients of risk aversion

Type of risk aversion	Functional form	Restriction	Coefficient of risk aversion	Risk average range[1]
Increasing	$U(x) = a + bx + cx^2$	$a, b > 0$ $c < 0$	$\frac{-2c}{b + 2cx}$	$\frac{b}{2c} \geqslant x \geqslant 0$
Constant[2]	$U(x) = k - \Theta e^{-\lambda x}$	—	λ	all x
Decreasing	$U(x) = a + b \log(x + d)$	—	$\frac{1}{x + d}$	$x \geqslant -d$
Decreasing	$U(x) = ax - be^{-cx}$	$a, b, c > 0$	$\frac{bc^2e^{-cx}}{a + bce^{-cx}}$	all x
Decreasing	$\log U(x) = a + b \log x$	—	$\frac{1 - b}{x}$	$b < 1$
Decreasing	$U(x) = (x + b)^c$	$0 < c < 1$	$\frac{-(c - 1)}{x + b}$	$x \geqslant -b$
Decreasing	$U(x- = (x + b)^{-c}$	$c > 0$	$\frac{c + 1}{x + b}$	$x \geqslant -b$
Decreasing	$U(x) = x + c \log(x + b)$	$c > 0$	$\frac{c}{(x + b)(x + c + b)}$	$x > -b$
Decreasing	$U(x) = -e^{-ax} - be^{-cx}$	$a, b, c > 0$	$\frac{a^2e^{-ax} + bc^2e^{-cx}}{ae^{-ax} + bce^{-cx}}$	all x
Decreasing	$U(x) = -e^{-ax} + bx$	$a, b > 0$	$\frac{a^2e^{-ax}}{ae^{-ax} + b}$	all x
Decreasing	$u(x) = (\beta x^{-\rho} + \alpha)^{-\frac{1}{\rho}}$	$-1 < \rho < \infty$	$(1 + \rho)\left[\frac{1}{x} + \frac{\beta}{(\beta x^{-\rho} + \alpha) \cdot x^{(1 + \rho)}}\right]$	all x

[1] Wherever the value of x goes beyond the risk aversion range, the properties of the utility function in terms of risk aversion may be changed and the utility function probably needs to be reverified. [2] See (*2*) for an example of this type of utility function.

$$\frac{U^{\lambda} - 1}{\lambda} = \alpha + \beta \frac{M^{\lambda} - 1}{\lambda} \qquad (1)$$

where λ is the transformation parameter, U is utility, and M is monetary income or wealth. It can be shown that the coefficient of risk aversion, r(M), has the following form:

$$r(M) = \frac{-U''}{U'} = -(\lambda - 1)\left(\frac{1}{M} - \frac{1}{U} \cdot \frac{\partial U}{\partial M}\right) \qquad (2)$$

where

$$U' = \beta \frac{M^{\lambda - 1}}{U^{\lambda - 1}}$$

and

$$U'' = \beta(\lambda - 1) \frac{M^{\lambda - 1}}{U^{\lambda - 1}} \left(\frac{1}{M} - \frac{1}{U} \cdot \frac{\partial U}{\partial M}\right) \qquad (3)$$

Decreasing risk aversion is associated with a risk coefficient which is a declining function of M; that is $r'(M) < 0$. If one is inclined to superimpose a constraint on the utility function, that the function exhibits a decreasing absolute risk aversion, all that is needed is to restrict the transformation parameter (λ) so that it is negative. Furthermore, the utility function satisfies the theoretical constraint of diminishing marginal utility if the coefficient of risk aversion ($r(M)$) is positive; implying $1/M > 1/u.\ (\partial u)/(\partial M)$ since a negative λ is generally postulated. Finally, this generalized functional form implies that risk aversion decreases as the marginal utility increases—not an unreasonable property for the utility function. Alternatively, the generalized functional form can be specified as:

$$U_i^* = \beta_0 + \beta_1 M_i^* + \beta_2 M_i^{2*} \tag{4}$$

where

$$U_i^* = \frac{(U_i^\lambda - 1)}{\lambda}$$

$$M_i^* = \frac{(M_i^\lambda - 1)}{\lambda}, \text{ and} \tag{5}$$

$$M_i^{2*} = \frac{(M_i^{2\lambda} - 1)}{\lambda}$$

and λ is a transformation parameter to be estimated.

It is obvious that if λ equals one, equations (1) and (4) are the same as the linear and polynomial utility functions. It can also be shown that equation (1) is equivalent to a log-linear form when λ approaches zero.[6] In general, different values of λ represent different degrees of curvature of the utility functions. Therefore, equations (1) and (4) are more general functional forms which provide greater flexibility in the degree and type of nonlinearity than the linear and polynomial utility functions.

Other than transforming both U and M, it is also possible to transform only U or M. If only one side of the equations is transformed, (1) and (4) are equivalent to semilog forms when λ approaches 0. In the most general case, different values of transformation parameters can be applied to different variables. In our study, however, we restrict ourselves to equations (1) and (4) and some semilog transformations.

To estimate λ along with other parameters in equations (1) and (4), we first rewrite them in stochastic forms:

$$U_i^* = \beta_0 + \beta_1 M_i^* + w_i \tag{6}$$

$$U_i^* = \beta_0 + \beta_1 M_i^* + \beta_2 M_i^{2*} + v_i \tag{7}$$

where w_i and v_i are the disturbance terms, assumed to be normally and independently distributed, each with zero mean and constant variance. Using the maximum likelihood method, Box and Cox showed that the maximum likelihood for equation (6) or (7) for a given λ, except for a given constant, is (*1*, p. 215):

$$L_{\max}(\lambda) = -(n/2)\log \hat{\sigma}^2(\lambda) + (\lambda - 1)\sum_{i=1}^{n} \log U_i \tag{8}$$

where $\hat{\sigma}^2(\lambda)$ is the error variance of equation (6) or (7). To maximize equation (8) over the entire parameter space, we only need to choose alternative values for λ over a reasonable range and regress U^* on M^* and on M^* and M^{2*}, and find the transformation parameter λ that maximizes equation (8). The maximum likelihood estimates of β's can be obtained directly from the least squares results of $\hat{\lambda}$.

Using the likelihood ratio method, an approximate $(1-\alpha)$ confidence interval for λ can be constructed since $2[L_{\max}(\hat{\lambda}) - L_{\max}(\lambda)]$ is approximately distributed as χ^2 with one degree of freedom (*1*, p. 216). Therefore, the $(1-\alpha)$ confidence interval for λ is obtained by finding that value of λ on either side of $\hat{\lambda}$ such that

$$L_{\max}(\hat{\lambda}) - L_{\max}(\lambda) = \frac{1}{2}\chi_1^2(\alpha) \tag{9}$$

REGRESSION RESULTS

Input data used in our study are those reported by Lin (*10*). Of the six cases investigated by Lin, Dean, and Moore, case-study farm 5 was chosen for the current study because the data contain no negative observations on monetary income. All the other cases contain negative observations on monetary income, for which the logarithm is undefined.

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[6] $(U^\lambda - 1)/\lambda = [\exp(\log U^\lambda) - 1]/\lambda = [\exp(\lambda \log U) - 1]/\lambda$. Through the Taylor expansion of $\exp(\lambda \log U)$ around $\lambda \log U = 0$,

$$(U^\lambda - 1)/\lambda = [1 + \lambda \log U + (1/2!)(\lambda \log U)^2 + (1/3!)(\lambda \log U)^3 + \ldots - 1]/\lambda = \log U + (\lambda/2!)(\log U)^2 + (\lambda^2/3!)(\log U)^3 + \ldots$$

Therefore, when $\lambda = 0$, $(U^\lambda - 1)/\lambda = \log U$. Similarly, $(M^\lambda - 1)/\lambda = \log M$ and $(M^{2\lambda} - 1)/\lambda = \log M^2$ when $\lambda = 0$. But when $\lambda = 0$, equation (4) is not estimable since $\log M^2 = 2 \log M$ and, hence, $\log M$ and $\log M^2$ are perfectly related.

Observations on the utility index of this case, however, contain four negative values. To utilize all 14 observations, every utility index was adjusted upward by 100 so that no observation would be negative. Such a linear transformation does not affect the shape of the utility function.[7]

To estimate parameters in equations (6) and (7), data on U_i, M_i, and M^2 were transformed according to equation (5) by λ's that lie between -0.10 and -1.7, at intervals of 0.1. The least-squares regressions of U^* on M^* and on M^* and M^{2*} were performed on each set of the transformed data. $L_{max}(\lambda)$ was calculated for each regression by using equation (8) with $\hat{\sigma}^2(\lambda)$ taken from the estimated variance of the disturbance term of the regression. Estimated coefficients and related statistics for selected values of λ for equations (6) and (7) appear in table 2. The estimates obtained from the linear and second-degree polynomial forms (λ=1), as well as the estimates for the log-linear form (λ=0) also appear in the table. These results show that the coefficients are all significant at the 0.01 level and that the maximum likelihood estimate of λ, $\hat{\lambda}$, is -0.70 when applied to equation (7). Based on equation (9), the null hypotheses that the utility function is a second-degree polynomial form, a linear form or a double-log form, are all rejected at the 0.05 level. Equations (6) and (7) do not exhaust other functional forms and they also do not include the third-degree polynomial form used by Lin, Dean, and Moore for this case-study farm. Thus, other functional specifications were also estimated with results shown in table 3. A comparison of the maximum likelihood values in tables 2 and 3 reveals that equation (7) with $\lambda = -0.70$ is still the maximum likelihood estimate of the Bernoullian utility function. This specification also has the highest R^2. This result conforms with the recent finding of Granger and Newbold (*5*). They state that the true model, from a set of alternative regression specifications involving different transformations of the dependent variable and under the assumption of normality, is the formulation for which R^2 is the highest. Estimated results based on positive λ values all yield lower likelihood values, supporting the theoretical constraint we employed that λ be restricted to be negative.

TESTS OF UTILITY VERSUS PROFIT MAXIMIZATION HYPOTHESES

Lin, Dean, and Moore tested three alternative behavioral hypotheses (Bernoullian utility maximization, lexicographic utility maximization, and profit maximization) by comparing the optimal plans along the "after-tax" E-V frontier. For case-study farm 5, lexicographic utility maximization predicts actual behavior better than Bernoullian utility maximization and profit maximization. The latter two perform equally poorly in this case.

It is of interest to see if the optimal plan derived from the Bernoullian utility maximization based on the "best" functional specification ($\hat{\lambda}$=–.70) predicts the actual plan differently. To do this, we first express expected utility as a function of mean and variance of "after-tax" net income. According to Taylor series expansion, the utility function U(M) can be expanded to a function in powers of (M-C) where M is a random variable (after-tax net income) and C is a fixed value (*6*):

$$U(M) = U(C) + (M-C)\frac{dU(C)}{dM} + \frac{1}{2}(M-C)^2\frac{d^2U(C)}{dM^2}$$

$$+ \frac{1}{3!}(M-C)^3\frac{d^3U(C)}{dM^3}$$

$$+ \frac{1}{4!}(M-C)^4\frac{d^4U(C)}{dM^4} + \ldots$$

By letting C equal E(M), expected net income, and by taking the expectation of this equation, we obtain the expected utility of plan *a* as:

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[7] Given the following quadratic utility function,

$$U = a + bM + cM^2 \qquad (1')$$

a linear transformation can be expressed as:

$$U^* = d + eU = d + ea + ebM^2 + ecM^2 \qquad (2')$$

or

$$U^* = a^* + b^*M + c^*M^2 \qquad (3')$$

where

$$a^* = d + ea$$

$$b^* = eb$$

$$c^* = ec$$

For equation (1′), the measure of risk aversion is, according to Pratt:

$$r(M) = -U''(M)/U'(M) = -2c/(b + 2cM).$$

For equation (3′), it is:

$$r^*(M) = -U^{*''}(M)/U^{*'}(M) = -2ec/e(b + 2cM)$$

$$= -2c/(b + 2cM).$$

Table 2—Bernoullian utility functions estimated from the generalized functional form;

λ	β_0	β_1	β_2	$\bar{R}2$[1]	$L_{max}(\lambda)$
		$U_i^* = \beta_0 + \beta_1 M_i^*$			
1.00	86.605	2.222		0.780	-49.53
	(6.43)	(6.86)			
0.00	3.953	0.366		0.977	-37.47
	(80.27)	(23.30)			
-0.10	3.283	0.270		0.987	-34.21
	(142.87)	(31.14)			
-0.20	2.767	0.190		0.986	-35.62
	(188.27)	(29.83)			
-0.50	1.760	0.053		0.936	-49.03
	(248.75)	(13.79)			
-1.00	0.989	0.004		0.895	-58.87
	(923.59)	(10.60)			
-1.70	0.588	0.0001		0.944	-66.13
	(9643.68)	(14.85)			
		$U_i^* = \beta_0 + \beta_1 M_i^* + \beta_2 M^{2*}_i$			
1.00	65.532	5.166	-0.038	0.904	-43.75
	(6.31)	(6.82)	(-4.05)		
-0.10	3.296	0.207	-0.034	0.986	-34.47
	(115.06)	(2.48)	(-7.60)		
-0.50	1.712	0.107	-0.017	0.995	-30.82
	(396.73)	(23.76)	(-12.27)		
-0.70[2]	1.331	0.055	-0.007	0.998	-28.60
	(865.27)	(32.93)	(-21.18)		
-1.00	0.977	0.019	-0.001	0.998	-31.57
	(2004.35)	(31.14)	(-24.12)		
-1.30	0.764	0.007	-0.0003	0.998	-36.51
	(4462.60)	(25.15)	(-21.54)		
-1.70	0.587	0.001	-0.0002	0.998	-41.49
	(16097.80)	(21.57)	(-19.87)		

[1] $\bar{R}^2$ is the corrected coefficient of determination. Figures in parentheses are *t*-values. [2] The maximum likelihood estimate of λ since $L_{max}(\lambda)$ is maximum at $\lambda = -0.70$.

Table 3—Bernoullian utility functions estimated from other functional forms[1]

Utility functions	$\bar{R}^2$	L_{max}
$\log U = 4.296 + 0.187 M$	0.53	-58.52
(21.74) (3.93)		
$U = 64.455 + 36.058 \log M$	0.95	-39.73
(8.60) (15.09)		
$\log U = 3.988 + 0.054 M - 0.0005 M^2$	0.69	-55.49
(20.61) (4.01) (-2.74)		
$\log U = 3.786 + 0.113 M - 0.002 M^2 + 0.00002 M^3$	0.78	-53.25
(20.21) (4.00) (-2.76) (2.27)		
$U = 45.992 + 9.673 M - 0.192 M^2 + 0.0012 M^3$	0.96	-38.28
(5.10) (5.60) (-3.31) (2.56)		

[1] $\bar{R}^2$ is the corrected coefficient of determination, L_{max} is the logarithmic maximum likelihood value, and figures in parentheses are *t*-values. [2] This is the polynomial functional form reported in (*9*).

$$U(a) = U[E(M)] + \frac{1}{2}\sigma^2 \frac{d^2U[E(M)]}{dM^2}$$

$$+ \frac{1}{3!} g_1 \frac{d^3U[E(M)]}{dM^3}$$

$$+ \frac{1}{4!} g_2 \frac{d^4U[E(M)]}{dM^4} + \ldots$$

where

$E[M - E(M)]^2$ = σ^2, the variance of the distribution of M
$E[M - E(M)]^3$ = g_1, the skewness of the distribution of M
$E[M - E(M)^4$ = g_2, the kurtosis of the distribution of M

Assuming normal distribution of M, the expected utility becomes:

$$U(a) = U[E(M)] + \frac{1}{2}\sigma^2 \cdot \frac{d^2U[E(M)]}{dM^2}$$

According to (7), it can be shown that:

$$U[E(M)] = [1 - \beta_1 - \beta_2 + \beta_0\lambda + \beta_1 E(M)^{\lambda}$$

$$+ \beta_2 E(M)^{2\lambda}]^{1/\lambda} \text{ and}$$

$$\frac{d^2U[E(M)]}{dM^2} = (\lambda - 1)\frac{\partial U[E(M)]}{\partial E(M)}$$

$$\cdot\left\{\frac{1}{E(M)} - \frac{1}{U[E(M)]}\frac{\partial U[E(M)]}{\partial E(M)}\right\}$$

where

$$\frac{\partial U[E(M)]}{\partial E(M)} = \left[\frac{U[E(M)]}{E(M)}\right]^{1-\lambda} \cdot \left[\beta_1 + 2\beta_2 E(M)^{\lambda}\right]$$

Based on the results of table 2 at λ equals -0.70, we computed the expected utility for each of the 13 alternative plans (table 4). It is clear that plan 13 (point B_5 in *9*, p. 506) no longer is the optimal plan. Instead, plans 10, 11, 12, and 13 all yield the same highest expected utility index. Thus, any plan lying within the segment between L_5 and B_5 in (*9*) is considered optimal to case-study farm 5. Thus, the Bernoullian utility maximization hypothesis could have predicted the farmer's production decision better than that reported by Lin, Dean, and Moore if a better functional specification had been adopted. At the very least, the strong preference leaning toward plan 13 as shown by the three researchers is now much reduced with the use of the "best" functional form.

Table 4—Computed expected utilities for alternative plans: $U_i^* = \beta_0 + \beta_1 M_i + \beta_2 M^{2*} + \nu_i$, $\hat{\lambda} = -0.70$

Plan	Mean income[1] E(M)	Standard deviation[1] σ_M	Expected utility $U(a_i)$
4	210	168	236
5	270	187	242
6	330	205	246
7	390	245	248
8	426	283	249
9	485	315	250
10	520	353	251
11	560	410	251
12	595	465	251
13	630	517	251

[1] Mean income and standard deviation are expressed in thousands of dollars.

CONCLUSIONS

The empirical results support our hypothesis that linear and polynomial specifications of utility functions are too restrictive. The log-linear form, although it performs slightly better than linear and polynomial forms, is still not the best to use. Semilog forms perform even worse than do polynomial. The appropriate degree of nonlinearity of the utility function can best be determined by applying the maximum likelihood method to sample observations without *a priori* specification. The empirical results further suggest some limited empirical evidence that farmers' utility function may exhibit a decreasing absolute risk aversion.

The tendency for Bernoullian utility maximization hypothesis to predict more risky behavior than that actually observed (*9*) may have been due to incorrect specifications of the functional form. Our study shows that this tendency is subdued considerably with proper functional specifications. Obviously, this study presents only a very limited evidence in this inquiry. Extension of this test to a large number of sample forms is needed before our conclusions can be generalized. Nevertheless, the study does suggest that future research efforts to derive Bernoullian utility functions should pay more attention to the specification of the functional form.

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In Earlier Issues

(Carl) Alsberg's career never broke away from his past. Each stage in his life's journey made its contribution and moved him toward the next stage. His intellectual frontier moved from the natural to the social sciences; from pharmacology to biochemistry, on to the specialized chemistry of foods and then to the economic and social problems of the food supply, until he found himself accepted as an agricultural economist, his spurs having been earned by 40 years of contributory related experience. As he recognized no barriers in the flow of knowledge, his interests naturally extended into the field of international scientific cooperation. Science to him was a tool for universal application.

As a research administrator Alsberg early learned that you cannot buy research." He advised, "Never assign a man to do a research job unless he has a twinkle in his eye and wants to do it more than anything else." Moreover, he was an advocate of inductive research in both the natural and the social sciences. He expressed his position in these words, "I am convinced that in any science the accumulation of facts is of first importance . . . when the time is right, because of an adequate accumulation of facts, the general unifying principle is sure to occur at about the same time to a number of persons."

This led him to hold with respect to the social sciences that there was "too much integration, too little differentiation; too much spinning of hypothetical theories without regard to their verifiability; too little spade work in digging out facts. If in the social sciences, and especially in economics, more attention were devoted to the recording of what seem important facts and to the analysis of their significance, I am confident we should not need to worry about theory." This line of reasoning led Alsberg to suggest that there be "less writing of books and more publication of brief communications."

"Review of: *Carl Alsberg—Scientist at Large* (Joseph S. Davis, ed.)" by Joseph G. Knapp. AER, Vol. I, No. 3, July 1949, p. 102.

ESTIMATING EXPONENTIAL UTILITY FUNCTIONS

By Steven T. Buccola and Ben C. French[1]

In a recent study for the U.S. Department of Agriculture's Farmer Cooperative Service, we developed a framework in which a processing/marketing cooperative or other firm might evaluate alternative long-term contract provisions for final product sale and raw product purchase. The study focused on a California cooperative fruit and vegetable processor. Selection of alternative contract pricing arrangements for tomato paste sales and tomato purchases was treated as a problem in portfolio analysis.

- **The exponential utility function for money has long attracted attention from theorists because it exhibits nonincreasing absolute risk aversion. Also, under certain conditions, it generates an expected utility function that is maximizable in a quadratic program. However, this functional form presents estimation problems. Logarithmic transformation of an exponential utility function does not conform to the Von Neumann-Morgenstern axioms. Hence, it cannot be used as a basis for best fit in statistical analysis. A criterion is described that can be used to select a best-fit exponential utility function, and its application in grower utility analysis is demonstrated.**

- **Keywords: Exponential, utility, risk.**

Bernoullian utility functions were estimated for a cooperative management spokesman and a board member, and for eight tomato growers, to identify contract portfolios that would maximize expected utility for growers or processors. An important issue in this identification process is the utility functional form employed, since this form influences the expected utility formulation that is the basis for portfolio choice.

In this article, we review some of the questions raised in selecting a utility functional form, suggest a method for fitting exponential forms to utility response data, and discuss several applications of this method.

SELECTING A UTILITY FUNCTIONAL FORM

Since the development of the Bernoullian money utility function, the issue of its proper functional form has been discussed with no determinate conclusion in sight.[2] Early theorists and practitioners preferred the quadratic utility function:

$$U = a + bM - cM^2, \quad b, c > 0 \tag{1}$$

where U is utility and M is money, for three reasons. If properly constrained, the function conforms to the risk averter's requirements of a positively sloping, concave function; when combined with linear profit functions, it generates quadratic expected utility functions that are easily maximized with current programming routines; and it is easily fitted by OLS to utility questionnaire data.

Criticism of quadratic forms began with Arrow's and Pratt's identification of a coefficient of absolute risk aversion, $R_a(M) = -U''/U'$. If this coefficient is a declining function of M, the decisionmaker becomes more willing to accept a gamble with fixed probabilities of fixed "small" payoffs as his wealth increases (*1*, pp. 95-96).[3] A rising coefficient implies decreased willingness, and a constant coefficient, unchanged willingness, to adopt this gamble. Intuition suggests that declining risk aversion ought to describe many persons' behavior, but coefficient $R_a(M)$ in quadratic utilities is $2c/(b-2cM)$, which instead rises with M.[4]

Alternative forms that are more acceptable according to the hypothesis of declining absolute risk aversion include the semilogarithmic

$$U = d + g \ln M, \quad g > 0, \tag{2}$$

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[2] Utility functions may refer to money wealth or money profit, where the latter reflect changes from an initial wealth position. Functions discussed in this article may be applied to either wealth or profit. The empirical applications involve profit utilities.

[3] Italicized numbers in parentheses refer to items in References at the end of this article.

[4] Rising absolute risk aversion is consistent with a predilection for hoarding, and hence is not to be ruled out of hand. Besides, one may argue that the data and not researchers' expectations should determine functional form. We do not propose to judge the merits of the hypothesis of decreasing absolute risk aversion.

where $R_a(M) = 1/M$; and the negative inverse exponential (hereafter called exponential)

$$U = K - \Theta \exp[-\lambda M], \quad K, \Theta, \lambda > 0, \qquad (3)$$

with $R_a(M) = \lambda$, a constant. In addition, Lin and Chang propose in this issue of the journal a polynomial specification with variable transformations on U or M; in their article, $R_a(M)$ coefficients depend upon the values taken by transformation constants. Among the more traditional forms, (2) and (3) have not been widely used because they are not, as with the quadratic, associated with a quadratic and thus tractable expected utility function.

This presumably exclusive advantage of the quadratic was, however, undermined as early as 1956. At that time, R. Freund demonstrated that exponential utility, linear profit function, and normally distributed profit generate an expected utility model that is maximizable by operating with an associated quadratic function. Following Wiens' notation, exponential utility (3) and normally distributed profit $M \sim N(\mu, \sigma^2)$ produce expected utility[5]

$$E[U(M)] = K - \Theta \exp[-\lambda\mu + (\lambda^2/2)\sigma^2]. \qquad (4)$$

Expression (4) is maximized by minimizing the exponent, a quadratic function. No such tractable solution procedure, other than use of the Taylor expansion with its associated error term, has been offered for the semilogarithmic form. For empirical researchers, this is an important disadvantage which overrides the hypothetical superiority of the semilog's declining absolute risk aversion.

There is no difficulty fitting quadratic or semilogarithmic forms to utility questionnaire data. In the latter case, for example, one merely expresses money values (positive only) in logs and regresses utility observations on these logs. A more complicated issue arises in fitting exponential forms. Treatment of this issue in the current article may be helpful to persons with theoretical objections to increasing risk aversion and with preference for conveniently maximizable expected utility.

THEORY OF ESTIMATING THE EXPONENTIAL PARAMETER

In general only utility parameters encountered as coefficients of income probability moments in an expected utility model have ultimate importance to the decision theorist or researcher. This observation may be inferred from the fact that the maximized expected utility model is the hypothesized basis of choice under risk, and that, under known programming methods, only coefficients of income probability moments affect optimal variable levels in these models. Since neither K nor Θ are coefficients of probability moments μ, σ^2 in (4), they are in themselves irrelevant to decisionmaking. Conversely, a decision is uniquely determined once λ, μ, and σ^2 are known.[6]

It would seem reasonable that a regression approach to estimating λ in (3) would first require λ's removal from the exponent. Experience with Cobb-Douglas and other variable exponent functions suggests expressing (3) in log form to accomplish this. Subtracting K from both sides of (3),

$$U - K = -\Theta \exp[-\lambda M]. \qquad (3)'$$

Taking natural logs of both sides,

$$\ln(U - K) = \ln(-\Theta \exp[-\lambda M]). \qquad (5)$$

If utility in (3) is positive, $K > \Theta \exp[-\lambda M]$, so that $K > U$. Thus $(U-K) < 0$, $\ln(U-K)$ does not exist, and (5) cannot be estimated. However, multiplying (3)′ by -1,

$$-U + K = \Theta \exp[-\lambda M] \qquad (3)''$$

and

$$\ln(-U + K) = \ln\Theta - \lambda M \qquad (5)'$$

Equation (5)′ implies that λ is the negative of the observed coefficient of money if the natural log of $(-U+K)$ is regressed against money. Parameter Θ is

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[5] Expected utility (4) is computed by appealing to the primitive form

$$E[U(M)] = \int_{-\infty}^{\infty} (K - \Theta \exp[-\lambda M]) \left\{ \frac{1}{\sqrt{2\pi\sigma^2}} \exp[-(M--\mu)^2/2\sigma^2] \right\} dM.$$

Terms in the integral are combined and the square completed in the resultant exponent. The indicated form (4) then emerges upon appropriate cancellations.

[6] Lambda's sole importance for decisionmaking purposes does not rest on its status as the exponential utility's $R_a(M)$ coefficient. Under semilogarithmic utility (2) and normally distributed income $M \sim N(\mu, \sigma^2)$, expected utility is, by reference to the Taylor expansion, approximately $E[U(M)] = g \ln \mu - (g\sigma^2)/(2\mu^2)$. Here, a decision is uniquely determined when g, μ, and σ^2 are known, but g does not appear in the semilog utility's absolute risk aversion coefficient $1/M$.

found as the constant term's antilog. K must be determined in advance and it is equivalent to an additive adjustment to the original utility scale.

Because of the logarithmic transformation on $(-U+K)$, the estimated values of both Θ and λ depend upon the originally chosen utility scale U or the additive adjustment factor K. Presumably, a unique value of λ reflects the decisionmaker's true aversion to risk at interview time.[7] One procedure for finding this value is to alter the utility scale or K and sequentially fit (5)′ under each set of altered values, with the fit yielding the highest R^2 providing the best estimate of λ. This would appear to satisfy a "best-fit" criterion for selecting λ and remove the arbitrariness of utility scale selection.

The immediate difficulty with this procedure is that (5)′ represents a nonlinear, though monotonic, transformation on (3)″. Von Neumann and Morgenstern have shown that the uniqueness of a utility function is preserved only under linear transformations $U^* = \alpha + \beta U$, where α and β are constants (*5*, pp. 24-25). More specifically, the value of λ providing the best fit to (5)′ is not necessarily that providing the best fit to (3); furthermore if (3) conforms to the axioms of Bernoullian utility, (5)′ does not.

The prohibition against nonlinear utility transformations tells us we cannot rely on (5)′ as a specification for selecting a best-fit λ in (3). Goodness of fit must refer to equation (3) or a linear transformation of (3). This does not imply that a regression approach to estimating λ is futile. The following procedure, for example, might be used: (a) assign arbitrary values to K, Θ, λ in (3); (b) generate values of U for each of the money levels employed in the original utility questionnaire; (c) calculate vertical deviations of predicted points from those obtained in the interview; (d) sum the squares of these deviations, and select the set K, Θ, λ minimizing this sum.

In connection with the method suggested, note that K and Θ delimit the utility range where money income is positive. If $M = 0$, $U = K$ minus Θ; and as $M \rightarrow \infty$, $U \rightarrow K$. The utility range of positive income M is Θ. Thus K, Θ merely serve to accommodate the original utility scale selected. Candidates (K minus Θ) should be chosen so as to approximate the utility intercept as estimated from a look at the utility questionnaire plot, and K's should be chosen so as to fall "somewhat" above the highest utility value assigned.

Steps (a) through (d) above essentially involve exploring the $S(K, \Theta, \lambda)$ response surface, where S is sum squared errors about the exponential fit. The intent is to discover the globally minimum value of S. Several procedures have, in the general nonlinear case, been proposed for finding this minimum value that do not require full factorial exploration of the response surface. These include utilization of linear Taylor series expansions of the nonlinear function, and methods of following the steepest negative gradient on the S surface. Draper and Smith note that such procedures are likely to converge slowly for exponential functions, which generally exhibit elongated or "ill-conditioned" equi-S elipses in Θ and λ space (*2*, p. 284).

An alternative which avoids both full factorial exploration and multiparameter search procedures is to employ log specification (5)′ in conjunction with steps (b) through (d) outlined above. The researcher need only select trial values of K, and for each value regress *ln* $(-U+K)$ on M as indicated by (5)′. Calculated values Θ and λ are then substituted, along with associated K levels, into (3) and steps (b) through (d) are followed as described. Prior incorporation of K into the utility scale assures that associated sets Θ and λ will generate a function falling at least roughly within range of the original utility questionnaire responses. $S(K, \Theta, \lambda)$ surface exploration reduces to a single-dimension search since trial values Θ and λ are uniquely related to trial values K.

TWO GROWER UTILITY FUNCTIONS

Illustrations of the method presented above are provided by two of the grower utility functions estimated in the cooperative processor study. Table 1 shows growers' utility responses to a Von Neumann-Morgenstern type of questionnaire, in which dollar values refer

Table 1—Utility questionnaire responses of growers 1 and 2

Utility	Money values, grower 1	Money values, grower 2
Utiles	*Thousand dollars*	
100	700	1000
80	300	–25
60	200	–62
40	–50	–100
20	–150	–300
0	–300	–500

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[7] The requirement of a unique λ value derives from the one-to-one correspondence it bears to the optimal quadratic program $\max Z = -\lambda\mu + (\lambda^2/2)\,\sigma^2$, which in turn determines the exponential decisionmaker's maximum expected utility course of action. No such uniqueness is required of the quadratic utilist's coefficients *b*, *c* in (1). By reference to the Taylor expansion, the latter individual's expected utility is $E[U(M)] = b\mu - c(\mu^2 + \sigma^2)$, the optimal variables of which depend only upon the ratio c/b. Thus quadratic utility estimation involves discovering a best-fit ratio c/b only.

to prospective annual incomes. The patience of most respondents limited risk responses to four, which provided six data points. Regressions were fitted to these data according to specification (5)′ and selected K values. The results are summarized in table 2 and plotted in figures 1 and 2.

Table 2—Coefficient estimates of grower exponential money utility function $U = K - \Theta \exp[-\lambda M]$

K	Θ	λ	R^2(log)[1]	SSE[2]
		Grower 1		
200	158.6	.000708	.978	131.78
160	117.3	.001002	.984	93.37
120	74.0	.001819	.984	150.57
101	46.2	.004458	.882	6,283.12
		Grower 2		
200	146.0	.000443	.795	1,450.54
160	104.5	.000635	.818	1,335.23
120	60.0	.001194	.879	975.41
101	27.7	.003240	.966	2,227.19

[1] These R- squares correspond to log fits (5)′. [2] These sum squared errors correspond to original data fits (3).

Grower 1's responses well approximate an exponential shape, and relative goodness of fit among competing parameter values is slight. Parameter set $K = 120$, $\Theta = 74.0$, and $\lambda = .001819$ has the highest R^2 under log specification (5)′; but set $K = 160$, $\Theta = 117.3$, and $\lambda = .001002$ generates the least sum squared errors under original exponential specification (3). Hence, $\lambda = .001002$ is our best estimate of grower 1's risk aversion coefficient if utility is exponential.

Grower 2's responses do not well approximate an exponential fit but more nearly suggest a cubic shape. However, one's philosophical commitment to the hypothesis of nonincreasing absolute risk aversion, or the structure of the expected utility model which implements the utility information, may justify exponential estimation. The discrepancy in goodness-of-fit ranking between specifications (5)′ and (3) is more marked here than in the first case. Set $K = 101$, $\Theta = 27.7$, and $\lambda = .003240$ provides the highest log fit R^2, but it behaves poorest of the four alternatives as an approximation to the original data. Sum squared errors to the original data are minimized by set $K = 120$, $\Theta = 60$, $\lambda = .001194$, so that .001194 is our best estimate of grower 2's risk aversion coefficient if utility is exponential.

By way of comparison, quadratic forms were also fit to the utility response data in table 1. For grower 1, $U = 43.04 + .1265\,M - .000064\,M^2$; and for grower 2, $U = 66.13 + .1069\,M - .0000725\,M^2$ (all coefficients significant at the .01 confidence level). In both cases the quadratic function is more concave than the corresponding best-fit exponential function. As money values increase, the quadratic approaches the exponential from below, crosses it, then approaches the exponential again at high money values. In each case, coefficients of absolute risk aversion R_a (M) under the quadratic specification are, below the point of intersection, lower than under exponential specification (λ itself). The coefficients are equal at or near intersection, and the quadratic's coefficient rises above the exponential's beyond the point of intersection. With grower 1, for example, R_a (M) under quadratic specification is .000841 at minus \$200,000; .001066 at minus \$50,000 (the intersection point); and .001269 at plus \$200,000. At point plus \$500,000, the quadratic's R_a (M) has risen to .002048, approximately double its value at intersection point and double the exponential parameter (.001002). In a research context, much of choice behavior under risk is determined by the absolute risk aversion coefficient. Thus researchers need to be wary of not only the utility functional form employed but also the feasible expected profit range of the set of risky ventures considered. In the current study, exponential and quadratic forms predicted similar choice behavior for expected profit ranges near the intersections of these functions, but highly divergent behavior elsewhere.

PROPERTIES OF THE ESTIMATOR

The method developed here for estimating the parameter λ of an exponential utility function minimizes sum squared errors. Hence it is a maximum likelihood estimator if utility response deviations about the regression line have zero mean and constant variance and if they are independently and normally distributed.[8] On these assumptions, therefore, the estimator is asymptotically unbiased and efficient. However no evidence exists that it is unbiased in small samples such as those employed in this study.

Functions such as (5)′ estimated under a log dependent variable develop concavity under the original, linear dependent variable scale (here, $-U + K$). This shape results because the first derivative of log values with respect to original values decreases as the original values themselves increase. However, the rate of decrease in the first derivative of log functions declines as

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[8] This hypothesis is proven for the general nonlinear case by observing that the likelihood function is a negative function of sum squared residuals (2, p. 265).

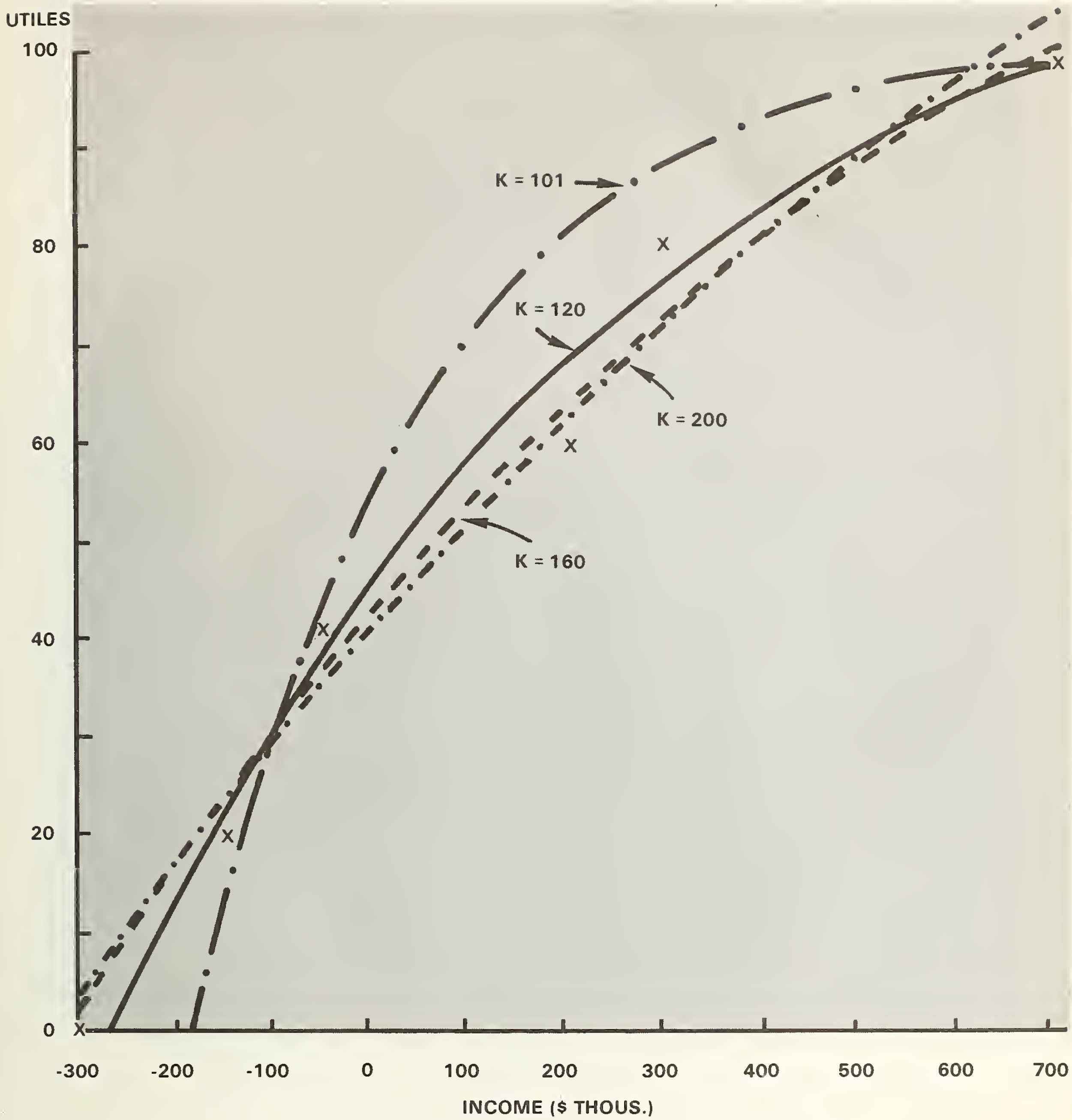

FIGURE 1. EXPONENTIAL FITS
TO UTILITY RESPONSES OF GROWER 1

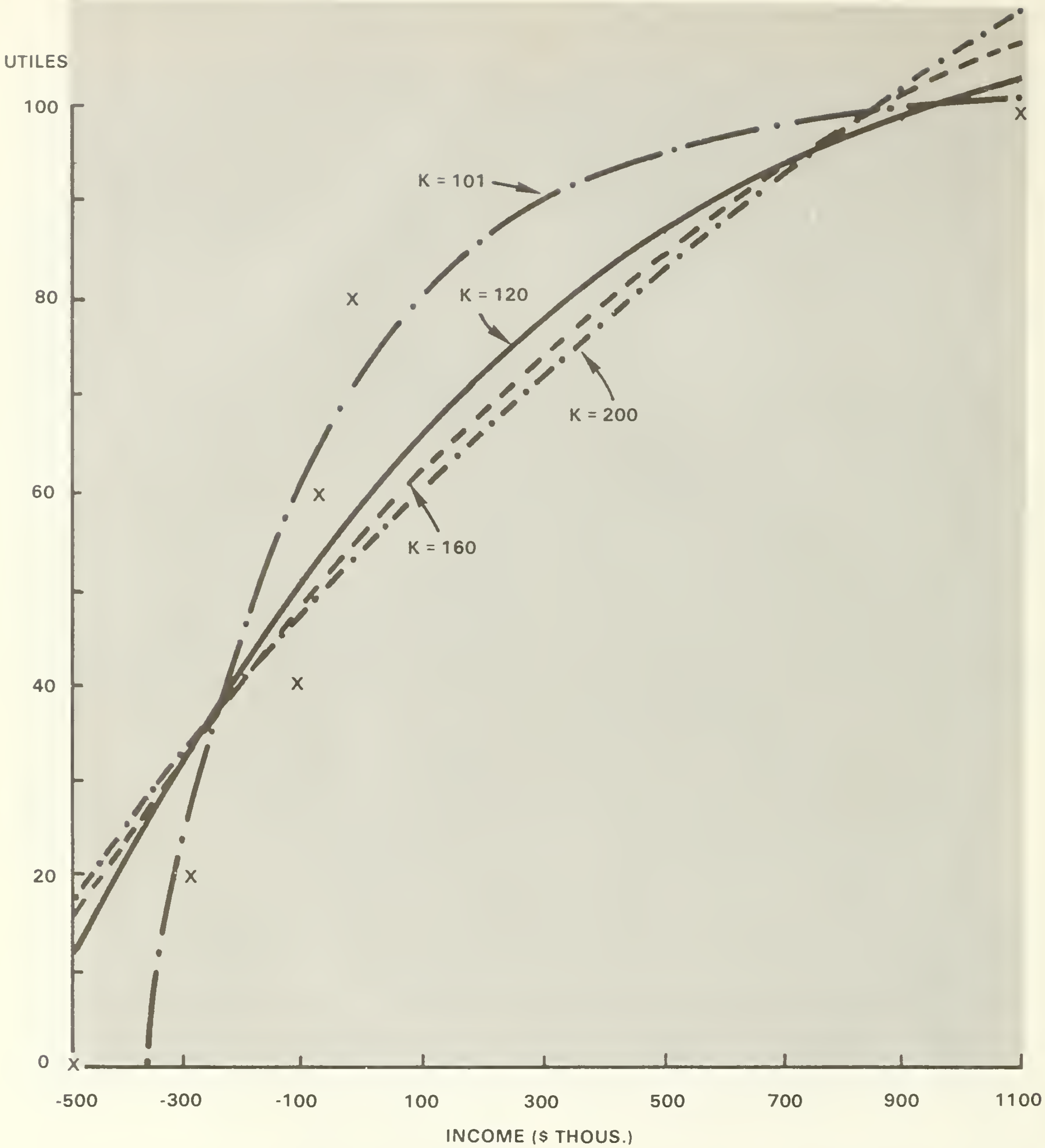

FIGURE 2. EXPONENTIAL FITS
TO UTILITY RESPONSES OF GROWER 2

larger numbers with constant differences are employed in the original scale.[9] Thus, larger values of K reduce concavity in functions estimated according to this procedure. Identical K values in the cases illustrated here generate identical dependent variable series and, hence, highly similar exponential functions.

To ensure that exponential utility estimates such as these do not depend upon the arbitrary utility scale U chosen, we note that any linear transformation $U^* = \alpha + \beta U$ on (3) produces

$$\begin{aligned} U^* = \alpha + \beta U &= \alpha + \beta\,(K - \Theta \exp[-\lambda M]) \\ &= \alpha + \beta K - \beta\Theta \exp[-\lambda M] \\ &= (\alpha + \beta K) - (\beta\Theta) \exp[-\lambda M] \end{aligned}$$

K changes to $(\alpha+\beta K)$ and Θ to $(\beta\Theta)$, but λ is unaffected. The independence of λ to such utility scale changes is only maintained if (3) rather than (5)′ is utilized as a goodness-of-fit criterion.

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[9] The second derivative of a natural log function $y = \ln x$ is $-1/x^2$, the negative sign of which indicates the decreasing first derivative of y and the reciprocal $1/x^2$, the sign of which indicates the decreasing rate of this decrease.

In Earlier Issues

". . . Interest in land classification for the purposes of tax assessment has been a subject of recurring importance . . . the greatest interest and activity in this method of improving property-tax assessments has been centered in areas in which agricultural land accounts for a large part of total real estate values. . . . Early attempts at classification netted little in the way of permanent improvement . . . local assessors usually classified the land or shifted this responsibility to the individual owner. . . . Real progress has been made in recent years in assembling information on soil capabilities and records of farm production. . . . Attempts to classify land on the basis of its use and annual average productivity should result in some general improvement in farm real estate assessments. . . . New and unexplored possibilities for improving tax assessments on farm property appear to lie not in the direction of more accurate classification of land but in application of the concept of an income-producing entity to the farm.

Samuel L. Crockett
Vol. II, No. 1, Jan. 1950

FARMLAND VALUES AND URBANIZATION

By Douglas E. Morris[1]

Urbanization affects agriculture in two ways. It reduces the cropland base and it increases the value of the remaining farmland on the urban fringe. Of these two facets, the actual loss in agricultural production capacity has been the main issue to date (*7*, *5*, *12*, *13*).[2] The other facet, how urbanization affects farmland values and food production costs, has been largely ignored and it is the issue addressed here.

- Estimates of the effect of urbanization on farmland values and eventually food prices are presented. These estimates, which reveal a strong positive relationship between urbanization and farmland values, are used to construct elasticities of farmland value related to population density for the 10 farm production regions in the 48 contiguous States. These elasticities are generally elastic; thus the author examines the issue of including a land charge in commodity cost of production budgets that could eventually be used as a basis for loan rates.

- Keywords: Farmland value, urbanization, elasticity, cost production.

Nationally, the loss of agricultural land so far to urban uses has had little net effect on the total supply of cropland. Irrigation, clearing, and drainage in some areas have more or less offset losses in other areas. Should these offsets fail to occur, price pressures on land could result from the reduced quantity and possibly changing quality of land. However, I address a different and less well-understood relationship between urbanization and farmland values.

In a specific county, for example, urbanization affects contiguous farmland supplies *in that county* and it can drive up farmland values through local opportunity costs for nonfarm uses. To the extent that a significant share of farm production occurs close to urban areas, there can be important implications for farmland values, the cost of agricultural production, and prices received by farmers for farm products.

The results of the following analysis may be used by policymakers to assess the impact on average farmland values as a county becomes increasingly urbanized. The degree to which urbanization affects farmland values has important implications for such policies as farmland assessment acts and purchase of development rights. For instance, land acquisition, transfer, and taxation are materially affected by the magnitude of farmland value. As such value is "pushed up" by nonagricultural forces, important changes in land tenure and land use may well occur. One area not directly addressed here is the land price spiral that occurs when farmers bid up the price of land in anticipation of a future income stream (see *9* for information).

THE MODEL

Farmland value is hypothesized in the model used here to be a function of the impact of urbanization after differences in agricultural value associated with productivity have been adjusted for.

The following functional form was specified:

$$FV = \beta_0 + \beta_1 D_{70} + \beta_2 D_\Delta + \beta_3 S + \beta_4 A + u \qquad (1)$$

where

FV = average farmland value per acre in 1969
D_{70} = population per square mile (density) in 1970
D_Δ = percentage change in density, 1960-70
S = average agricultural sales per acre in 1969
A = average farm size in 1969
u = random disturbance

D_{70} and D_Δ are proxies for urbanization. The inclusion of D_Δ allows the change in population density for each county to enter the model, so the effects of urbanization are not based on purely cross-sectional, static data. It is expected, *a priori*, that D_{70} and D_Δ will have estimated coefficients that are positive in sign. The proxy for agricultural value is S, the value of agricultural sales per acre. Farm size, A, is included to correct for the impact of average tract size on the per acre value. The coefficient for S is expected to be posi-

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[2] Italicized numbers in parentheses refer to items in References at the end of this article.

tive as agricultural sales should have a positive impact on farmland value, an expectation supported by Hammill (*4*). A negative coefficient for A is expected, a contention supported by Clonts (*2*), Bovard and Hushak (*1*), and Lindsay and Willis (*6*).

The unit of observation is the county. Counties were grouped into the 10 farm production regions (commonly used by USDA) of the 48 contiguous States. Counties with less than 5 percent of total land area in farms were omitted. Farmland value per acre, value of agricultural sales per acre, and farm size are all county averages from the *1969 Census of Agriculture* (*10*). Density (population per square mile in 1970) and percentage change in density from 1960 to 1970 are from the *County and City Data Book*, 1972 (*11*).

Farmland value (FV) as reported in the *Census of Agriculture* is the subjective value of farmland provided by the farm owner at the time of the census. A landowner would be expected to incorporate the results of recent sales of nearby land into the estimate; hence, both agricultural and urbanization (if present) values may be contained in the estimate. The value of buildings is included in FV as well as land value. This is not expected to be a severe problem since (1) FV is expressed per acre, (2) the farm production regions delineate similar types of agriculture, and (3) buildings are also included in cost of production budgets. Further, when FV is determined mainly by urbanization, the "salvage" value of the existing buildings is probably minimal. The proxy for agricultural value (S) is admittedly gross. Operations such as feedlots, poultry production, and nurseries are included even though sales from such enterprises are not closely related to land productivity. Hence, the use of S may overstate the agricultural value portion of FV.

THE RESULTS

Equation (1) was estimated for each farm production region and the United States using OLS techniques. For brevity, only the results for the United States (all counties) appear in table 1. The regression coefficients for the farm production regions are used to construct the estimates of elasticity developed in the following section—the major thrust of this article. For the equation presented in table 1, all coefficients have the expected sign and they are statistically significant at the .001 level. The statistical properties are similar for the regional equations. The coefficients of determination (R^2) are generally higher than would be expected from such a model (see *1* and *6*).

Urbanization pressure is not evenly spread throughout a region or even a county. Farmland on the urban fringes necessarily is more strongly affected than farmland farther away. One limitation of using the county as the unit of observation is that the pressure of urbanization is statistically spread over the entire county. County size differences tend to compound this problem. The results reported in table 1 for all counties probably understate the impact of urbanization on farmland values. To correct for this problem, the counties were disaggregated into two groups: Standard Metropolitan Statistical Area (SMSA) counties and non-SMSA counties for each farm production region and the United States.[3] By disaggregation of the

Table Regression estimates for equation 1: farmland value per acre in 1969, the dependent variable, is a function of the indicated independent variables

County	Regression coefficients[1]					R^2
	Constant	D_{70}	D_{Δ}	S	A	
All counties n = 2952	108.00	[2]0.41 (0.01)	[2]2.36 (0.14)	[2]1.95 (0.05)	[2]-0.004 (0.0008)	0.68
SMSA counties n = 406	55.45	[2]0.34 (0.02)	[2]6.24 (0.58)	[2]2.28 (0.16)	[3]-0.03 (0.02)	0.69
Non-SMSA counties n = 2487	100.84	[2]1.00 (0.03)	[2]0.64 (0.11)	[2]1.65 (0.04)	[2]-0.003 (0.0006)	0.62

Note: See text for definitions.

[1] The numbers in parentheses are the standard errors of the regression coefficients. [2] Significant at the $\alpha = .001$ level. [3] Significant at the $\alpha = .05$ level.

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[3] SMSA's are defined at the town level for New England. Thus, Maine, New Hampshire, Vermont, Massachusetts, Connecticut, and Rhode Island were omitted from the Northeast for the disaggregated analysis.

observations into two more nearly homogeneous groups as to level of urbanization pressure for the SMSA counties and agricultural pressure for the non-SMSA counties, the problem of underestimation should be lessened. The problem of county size differences among farm production regions still remains.

The estimated coefficients of Equation (1) for SMSA and non-SMSA counties appear in table 1. The most notable difference between the aggregated and disaggregated results is the magnitude of the coefficients for density change. This difference is even more pronounced for the regional SMSA equations ranging from 1.57 (Mountain) to 16.86 (Pacific). Overall, the aggregated and disaggregated analyses support the hypothesized relation between farmland value and both urbanization and agricultural value.

DENSITY ELASTICITY OF FARMLAND VALUE

Given the estimated coefficients in table 1, the responsiveness of farmland value to changes in density can be calculated in the form of an elasticity. The *density elasticity of farmland value* is derived as follows:

Given:

$$FV = f(D_{70}, D_{\Delta}, S, A) \tag{2}$$

$$D_{\Delta} = g(D_{60}, D_{70}) \tag{3}$$

Then:

$$\epsilon = \frac{dFV}{dD_{70}} \cdot \frac{D_{70}}{FV}$$

$$= \left[\frac{\partial FV}{\partial D_{70}} + \frac{\partial FV}{\partial D_{\Delta}} \cdot \frac{\partial D_{\Delta}}{\partial D_{70}} \right] \cdot \frac{D_{70}}{FV} \tag{4}$$

From (1) and (4):

$$\epsilon = \left[\beta_1 + \beta_2 \frac{100}{D_{60}} \right] \cdot \frac{D_{70}}{FV} \tag{5}$$

Elasticities (table 2) were calculated from Equation (5) using the estimated coefficients in table 1 and the unreported estimates for the farm production regions. The elasticities based on all counties are elastic for the Northeast, Corn Belt, Appalachian, and Pacific regions, while for the Lake States, Southeast, and Southern Plains, they are nearly unitary. The remaining regions (Northern Plains, Delta, and Mountain) are inelastic. For the United States, the elasticity is close to unitary (ϵ=1.05). For instance, a 1-percent increase in density in the agriculturally important Corn Belt would result in a 1.25-percent increase in farmland value. In the Northeast, a similar increase in density is associated with nearly a 3-percent increase in farmland value. Except possibly for the heavily urbanized Northeast, the elasticities appear to be surprisingly high.

Table 2—Density elasticity of farmland value by farm production region and the United States

Region[2]	Elasticities[1] All counties	 SMSA counties	 Non-SMSA counties
United States	1.05	1.67	0.47
Northeast[3]	2.92	2.56	3.25
Lake States	0.97	0.91	0.65
Corn Belt	1.25	1.51	0.37
Northern Plains	0.48	1.51	0.16
Appalachian	1.62	2.24	1.17
Southeast	0.95	1.53	0.62
Delta	0.51	1.77	0.49
Southern Plains	0.95	1.36	0.38
Mountain	0.59	1.15	0.51
Pacific	1.93	2.86	0.74

[1] Elasticities calculated at data means. [2] Northeast: Maine, New Hampshire, Vermont, Connecticut, Rhode Island, Massachusetts, New York, New Jersey, Pennsylvania, Delaware, Maryland. Lake States: Minnesota, Michigan, Wisconsin. Corn Belt: Ohio, Indiana, Illinois, Iowa, Missouri. Northern Plains: North Dakota, South Dakota, Nebraska, Kansas. Appalachian: West Virginia, Virginia, North Carolina, Kentucky, Tennessee. Southeast: Alabama, Georgia, Florida, South Carolina. Delta: Arkansas, Louisiana, Mississippi. Southern Plains: Oklahoma, Texas. Mountain: Arizona, New Mexico, Nevada, Utah, Colorado, Idaho, Montana, Wyoming. Pacific: Washington, Oregon, California. United States: 48 contiguous States. [3] See text footnote 2.

The elasticities based on the coefficients from the SMSA counties are quite elastic, excepting the Lake States (ϵ = .91). As expected, the elasticities are generally lower for the non-SMSA counties. These estimates of the responsiveness of farmland value to density changes are quite revealing and have important policy ramifications for many land related issues.

IMPLICATIONS

The extent that urbanization can affect commodity production costs depends upon the proportion of production under urban influence and the importance of land charges in costs of production. In 1969, 16.8 percent of the corn, 15.4 percent of the soybeans, and 22.3 percent of all cotton were produced in SMSA counties. In the Corn Belt, 19.6 percent of the corn, 18.7 percent of soybeans, and 23.4 percent of the wheat were grown within SMSA counties. In the recent USDA report on costs of production, two methods are used to estimate land charges for the crop budgets; current value and acquisition value (*3*). Based on corn budgets in 1977, for example, land allocation (current value) comprises 38 percent of production costs, whereas land allocation (acquisition value) comprises 30 percent of production costs. These estimates of land values are composites reflecting share rents, cash rents, and current and acquisition costs of owner-operated land. Land comprises a large portion of production costs for corn, most of which is produced in the Corn Belt. Thus, a corn cost-of-production spiral could result largely from population growth in this region (ϵ = 1.25 based on all counties or ϵ = 1.51 based on SMSA counties), should corn loan rates be based on cost-of-production estimates. Similar spirals could occur for other commodities, such as soybeans, wheat, and cotton.

Urbanization can and does inflate the cost of agricultural lands, a cost which ultimately must be paid. Urbanization processes which force land prices upward seem also to be forcing up food and fiber production costs and eventually raising prices to consumers. Results of this research demonstrate the need to link natural resource policy and agricultural commodity policy legislation. Land use planning to control the location of increases in population density can be an important tool in farm and food price legislation as well.

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CONFERENCE ON HUMAN NUTRITION AND THE AMERICAN FOOD SYSTEM: A REVIEW

Increasingly loud voices are being raised by participants in the public policy process regarding the adequacy of the American diet. Consumer groups, social scientists, nutritionists, and participants in the food marketing process are forming alliances and they are forcing the development of an integrated domestic food policy. Adoption of such a policy framework will likely bring an increased demand for human nutrition research and food policy analysis.

Some important research questions, as well as the political realities accompanying development of a "food policy", received attention at a conference on "Nutrition and the American Food System: A New Focus" held in July 1977. The sponsors, the Community Nutrition Institute in cooperation with the Food Marketing Institute and Family Circle Magazine, brought together representatives from government, industry, consumer groups, and academia. The objective was to improve the information flow among food system participants so that priority research needs could be identified, so that present nutrition-related practices could be more completely understood, and areas of agreement on an integrated focus for national nutrition policy could be isolated. Invited paper presentations in four major areas were followed with discussions by response panels. The format generated shared ideas which were developed further in organized discussion work groups.

Senator Robert Dole (Rep.-Kans.), in the keynote address, stressed the need to integrate farm policy considerations with the national concern for improved nutrition. He emphasized a need for recognition of the linkage between producers and consumers, and noted the alliances required for passage of the 1977 "omnibus" agriculture bill.

The theme was carried further by Representative Fred Richmond (D-N.Y.). "Nutrition Policy Structure: Is It There?" underscored his belief that Government must provide leadership in seeing that American diets improve. His conclusion, one shared by most conference participants, was that no unified policy relates food and nutrition with other Federal programs. Richmond announced the initiation of a five-part investigation on the role of the Federal Government in nutrition education. The study will be undertaken in 1978 by the House of Representatives' Domestic Marketing, Consumer Relations, and Nutrition Subcommittee.

Of the eight major issue papers, four had particular relevance because of their potential impact on the ERS nutrition-related research program. William Gahr, Assistant Director of the Food Staff in the U.S. General Accounting Office, spoke on "Nutrition Planning as a Community Process." His thesis, that we are now thinking more in terms of world systems, highlighted the need for an integrated social science approach to the nutrition research issue. ". . . The active groups interested in nutrition policy in recent years have expanded and, as a result, nutrition planning has become more complicated in the process." The community, he said, now involves all those interested in the food system—consumers, retailers, processors, and producers. Food and nutrition research must therefore involve more than the technical composition of foods. It must focus attention on the social consequences of poor diets and inadequate nutrition, allow for a changing environment, and encourage a simultaneous consideration of interdependent political systems, partially conflicting national goals, and changing cultures.

Mark Hegsted, professor of nutrition at Harvard University, discussed the development of a common language for nutrition education and public policy. A major question he raises: What will be the likely social value of accomplishing current dietary goals versus the costs of not achieving them. He cited a need for better data and more thorough analyses: "Much of the presumed malnutrition in the United States is due to errors in data collection and analysis." Yet Hegsted also urged initiation of a nutrition reform program based on available data.

In a set of questions, Sheldon Margen, professor of human nutrition, University of California-Berkeley, suggested research needed for a new focus on the nutrition question. Most of them involved the technical aspects of nutrition research, such as determining which elements are necessary for an adequate diet. However, his plea to determine more clearly the relationship among nutrition, health, social productivity, and disease implies the need for a sizable input by economists and other social scientists. So also did his request to broaden the research definition for food and nutrition to include considerations within the social setting. Certainly, he said, food is "the carrier of nutrients, but it is much more than that." Food consumption and nutritional adequacy have cultural as well as biological aspects. It may therefore be ineffective to use legislative decree to alter dietary intake—even if it is clear that certain purchase patterns are unhealthy. Given that we can rely on a relatively free market economy to allocate resources and on free-choice human behavior for purchase decisions, we must learn much more about the determinants of choice if public nutrition intervention programs are to succeed.

Otto Doering, associate professor of agricultural economics at Purdue University, discussed what conference planners called "the first problem for the new focus on nutrition"—the energy situation. Doering emphasized "end product use" rather than simple energy accounting as crucial to the development of an energy policy which recognizes the relationship between nutrition and food. Though advocating continued reliance on prices to allocate energy inputs in the food system, Doering stressed that, "to be effective in allocating energy inputs, energy prices must be allowed to rise *relative* to other inputs." Such a policy would, he said, undoubtedly influence nutrition as food price relationships—and even the availability of some foods—would be affected.

The conference highlighted fertile areas for economic research in food policy. Clearly, food and agricultural programs of the Department of Agriculture affect the amount and kinds of food consumed, and, thus, the nutritional adequacy of the American diet. Before new public policy measures are adopted, it is crucial, then, that we better understand those now operating. Much more needs to be known about the factors affecting food choices. Retail level demand and the household expenditure process need greater study. Further, conference speakers underscored the immediate need to identify and document the implied nutritional consequences of changes in food industry technology and market structure. Such an undertaking would be reasonably familiar territory for most marketing economists. More also needs to be known about the linkages between food and farm programs. Finally, we need to better understand the relationships among nutrition, energy use in the food system, and food industry regulatory programs. Such issues are the key to better nutrition in the future.

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In Earlier Issues

"My personal preference is for individual papers. At best a committee report is a compromise that covers up real differences in judgment about important issues. This is all right if the reader wants an authoritative statement of areas of agreement among the most competent experts. But the subject of policy really gets interesting when we go beyond these areas of agreement, or when some economist is bold enough to attack principles that have been accepted by most other students.

Frederick V. Waugh
Vol. II, No. 1, Jan. 1950

A NOTE ON THE ACCURACY OF COMPUTER ALGORITHMS FOR LEAST SQUARES

Numerous investigators have reported on the accuracy of computer algorithms used for least squares since Longley's article in 1967 (*9*). The most recent, an article by Boehm, Menkhaus, and Penn (*4*) prompted the testing of computer software currently used by ERS researchers.[1] The intent here is to present results collected from tests of program packages listed below. The computer used in all cases was an IBM 370, Model 168.

ERS researchers have access to a variety of software:

BMD—*BioMeD*ical Computer Program package acquired from the University of California at Berkely. ERS has access to both the 1973 BMD version and the 1975 BMDP version.

DAMSEL—*D*ata *M*anagement *S*ystem and *E*conometric *L*anguage is the property of Boeing Computer Services, Inc., and was used extensively in early 1977 by the Forecast Support Group in the Commodity Economic Division, ERS.

ECONA—A generalized program for multiple regression originating at the University of Pennsylvania but modified at Cornell University.

ECONPAK—A generalized multivariate analysis package developed at Pennsylvania State University.

ERSBLS—A generalized program for multiple linear regression developed at the Bureau of Labor Statistics, U.S. Department of Labor.

OSIRIS—*O*rganized *S*et of *I*ntegrated *R*outines for *I*nvestigations with *S*tatistics (Release III.2) acquired from the Institute of Social Research at the University of Michigan.

SAS—*S*tatistical *A*nalysis *S*ystem developed at North Carolina State. ERS has access to both the 1972 and 1976 versions.

SPEAKEASY—A high-level, user-oriented computing language developed at the Argonne National Laboratory, Argonne, Illinois.

SPSS—*S*tatistical *P*ackage for the *S*ocial *S*ciences (Release 6.02) acquired from the National Opinion Research Center at the University of Chicago.

TSP—*T*ime *S*eries *P*rocessor (Version 2.7) developed at the Harvard Institute of Economic Research, Harvard University.

Data Services Center staff tested the multiple regression procedures in these software using a technique employed originally by Wampler (*11*) and most recently by Boehm and others (*4*). In this experiment, two equations were processed; both were fifth degree polynomials. The X-variable was a consecutive series of integers 0, 1, 2, . . . , 20. Observations for Y1 and Y2, the respective dependent variables, were calculated as follows:

$$Y^1 = 1 + X + X^2 + X^3 + X^4 + X^5$$

and

$$Y^2 = 1 + .1X + .01X^2 + .001X^3 + .0001X^4 + .00001X^5$$

If least squares solutions were derived with no rounding error, the expected parameter values would be those used to calculate the Y's. Thus, for the first equation, one would expect the constant and each regression coefficient to be 1. Similarly, coefficients in the second equation would be .1, .01, .001, .0001, and .00001 for the successive powers. Since there is no error term, the standard error of estimate is zero, the standard errors on the

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[1] Italicized numbers in parentheses refer to items in Bibliography at the end of this note.

regression coefficients are zero, and the multiple coefficient of determination is 1.

Wampler (*11*) adds:

> The two test problems, Y1 and Y2, were chosen because they are so highly ill-conditioned that some programs fail to obtain correct solutions while other programs succeed in obtaining reasonably accurate solutions. Polynomial problems were chosen because polynomial fitting is an important type of linear least squares problem which occurs frequently in practice.

Boehm and others then observed "... that if computer routines successfully handle these test problems, computational accuracy should not be a serious issue for less ill-conditioned cases" (*4*). When we used a power transformation to create our test variables in two of the packages (DAMSEL and OSIRIS), additional error was introduced. Therefore to maintain consistency for the test, all data were constructed by taking successive products of X. For example, we multiplied X·X·X to generate X^3.

The resulting matrix of highly intercorrelated correlation coefficients appear below:

Power of X	X	X^2	X^3	X^4	X^5
X	1.0				
X^2	.965	1.0			
X^3	.912	.986	1.0		
X^4	.861	.958	.992	1.0	
X^5	.816	.927	.975	.995	1.0

Results for the regression on Y1 are shown in table 1. Numbers in the table were rounded to five deci-

Table 1—Summary of statistics with Y1 as dependent variable

Computer package	Constant	X	X^2	X^3	X^4	X^5	R^2	S
BMD (03R)	(¹)	-1792.00000 (0.0)	1616.00000 (0.0)	-96.00000 (0.0)	7.00000 (0.0)	0.83203 (0.0)	1.0815	0.0
BMDP (P1R)	-188.0625 (NA)	390.924 (857.148)	-139.437 (156.728)	19.368 (8.779)	NA (NA)	1.019 (.008)	1.0000	1573.8774
BMDP (P5R)	1.00000 (.00000)	1.00000 (.00000)	1.00000 (.00000)	1.00000 (.00000)	1.00000 (.00000)	1.00000 (.00000)	NA	NA
DAMSEL²	1.00000 (.00000)	1.00000 (.00003)	1.00000 (.00010)	1.00000 (.00014)	1.00000 (.00008)	1.00000 (.00002)	1.000	0.0
ECONA	1.00000 (.02081)	1.00000 (.02285)	1.00000 (.00754)	1.00000 (.00098)	1.00000 (.00005)	1.00000 (.00000)	1.00000	.02282
ECONPAK	1.00000 (2.02641)	1.00000 (2.22267)	1.00000 (.73289)	1.00000 (.09543)	1.00000 (.00531)	1.00000 (.00011)	1.00000	2.21947
ERSBLS	1.00000 (NA)	1.00000 (.00000)	1.00000 (.00000)	1.00000 (.00000)	1.00000 (.00000)	1.00000 (.00000)	1.00000	.00000
OSIRIS	1.0000 (.0000)	1.0000 (.0000)	1.0000 (.0000)	1.0000 (.0000)	1.0000 (.0000)	1.0000 (.0000)	1.00000	.0000
SAS72	1.00000 (.00000)	1.00000 (.00000)	1.00000 (.00000)	1.00000 (.00000)	1.00000 (.00000)	1.00000 (.00000)	1.00000	.00000
SAS76	1.00000 (0.0)	1.00000 (0.0)	1.00000 (0.0)	1.00000 (0.0)	1.00000 (0.0)	1.00000 (0.0)	1.00000	0.0
SPEAKEASY	1.00000 (.00000)	1.00000 (.00000)	1.00000 (.00000)	1.00000 (.00000)	1.00000 (.00000)	1.00000 (.00000)	1.0000	.00000
SPSS	1.00000 (NA)	1.00000 (.01032)	1.00000 (.00340)	1.00000 (.00044)	1.00000 (.00002)	1.00000 (.00000)	1.00000	.01030
TSP	.61738 (1.24977)	1.13655 (1.37241)	.98624 (.45253)	.99981 (.05893)	1.00007 (.00328)	1.00000 (.00006)	1.00000	1.37044

[1] Number exceeded allotted print format. [2] Standard errors on regression coefficients not printed; derived from *t*-values that were displayed.

NA=Not available from computer printout. S=Standard error of estimate. R^2=Multiple coefficient of determination.

Note: Numbers in parentheses are standard errors on coefficients.

Table 2—Summary of statistics with Y2 as dependent variable

Computer package	Constant	X	X^2	X^3	X^4	X^5	R^2	S
BMD (03R)	-.46927 (NA)	.11719 (0.0)	.01563 (0.0)	.00195 (0.0)	.00008 (0.0)	.00001 (0.0)	1.0541	0.0
BMDP (P1R)	.9839 (NA)	.135 (.009)	-.003 (.002)	.003 (.000)	NA (NA)	.000 (.000)	1.0000	.0174
BMDP (P5R)	1.00000 (0.0)	.10000 (0.0)	.01000 (0.0)	.00100 (0.0)	.00010 (0.0)	.00001 (0.0)	NA	NA
DAMSEL[1]	1.00000 (.00000)	.10000 (.00000)	.01000 (.00000)	.00100 (.00000)	.00010 (.00000)	.00001 (.00000)	1.0000	0.0
ECONA	1.00000 (0.0)	.10000 (0.0)	.01000 (0.0)	.00100 (0.0)	.00010 (0.0)	.00001 (0.0)	1.00000	0.0
ECONPAK	.99997 (.00195)	.10002 (.00214)	.01000 (.00071)	.00100 (.00009)	.00010 (.00001)	.00001 (.00000)	1.00000	.00214
ERSBLS	1.00000 (0.0)	.10000 (0.0)	.01000 (0.0)	.00100 (0.0)	.00010 (0.0)	.00001 (0.0)	1.00000	0.0
OSIRIS	1.0000 (0.0)	.1000 (0.0)	.0100 (0.0)	.0010 (0.0)	.0001 (0.0)	.0000 (0.0)	1.00000	0.0
SAS72	1.00000 (0.0)	.10000 (0.0)	.01000 (0.0)	.00100 (0.0)	.00010 (0.0)	.00001 (0.0)	1.00000	0.0
SAS76	1.00000 (0.0)	.10000 (0.0)	.01000 (0.0)	.00100 (0.0)	.00010 (0.0)	.00001 (0.0)	1.00000	0.0
SPEAKEASY	1.00000 (0.0)	.10000 (0.0)	.01000 (0.0)	.00100 (0.0)	.00010 (0.0)	.00001 (0.0)	1.0000	0.0
SPSS	1.00000 (NA)	.10000 (0.0)	.01000 (0.0)	.00100 (0.0)	.00010 (0.0)	.00001 (0.0)	1.00000	0.0
TSP	1.00000 (.00002)	.10000 (.00002)	.01000 (.00001)	.00100 (.00000)	.00010 (.00000)	.00001 (.00000)	1.0000	.00002

[1] Standard errors on regression coefficients not printed; derived from *t*-values that were displayed.

NA=Not available from computer printout. S=Standard error of estimate. R^2=Multiple coefficient of determination.

Note: Numbers in parentheses are standard errors on coefficients.

mal positions when the printout presented greater detail.

Results from BMD multiple regression programs were poor and misleading compared with most other packages. BMD programs 03R and P1R produced unacceptable results. On the other hand, BMD's polynomial regression program (P5R), specially designed to fit a power series, gave the expected regression coefficients but the R^2 and the standard error of estimate were not part of the printed output.

The least squares algorithm in Harvard's TSP package also gave undesirable test results. Other packages —DAMSEL, ECONA, ECONPAK, and SPSS although producing the expected coefficients calculated standard errors that differed from zero by varying amounts. Tests of the remaining packages produced the results that we sought.

Results for the regression on Y2 are shown in table 2.

These numbers raise questions about the validity of the algorithm used for BMD programs 03R and P1R. The calculation of the standard errors in ECONPAK also is somewhat suspect. All other procedures produced acceptable results. The results in table 2 are generally better than those in table 1, apparently benefiting from the scaling used in creating the observations for Y2.

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PLANNING NOW?

Planning has recently been getting more attention in the Congress, the Executive Branch, universities, industry, and elsewhere. In USDA, the Secretary has emphasized the need for more effective planning and for strengthening the planning role of the Department. Yet there is no clear trend. As in the past, confusion continues to accompany increased attention to planning. Some of the confusion stems from different political views of our economy and society, and some of it arises from different definitions and concepts of planning.

I do not attempt to untangle that confusion. I will simply try to offer some views on the need for a more effective long-term planning activity in the Department of Agriculture.

So long as we had fairly well agreed upon national and international goals and we and the rest of the world were making steady progress toward them, there was little need for or thought given to long-term planning in the United States. This seems to have been the situation in the post World War II period—during the fifties, sixties, and perhaps very early in the seventies. With agreed-upon economic goals, steady growth, and reasonably stable social systems, uncertainty about the future was at a low level. Simple projections based on past trends and agreed-upon values seemed to serve our purposes. We were a wealthy Nation with abundant and growing resources and certain of the future. Both our planning and budgeting activities were incremental. They focused more strongly on tactics than strategies.

Beginning in the sixties and continuing strongly into the seventies, our social and institutional stability began to break up. Not everybody was sharing equally in the economic growth. Economic growth in itself was not a fully satisfactory social goal for the less affluent. For the more affluent, environmental values began to take precedence over economic values. As our disagreements about national values and goals grew, they were suddenly aggravated by the energy crisis, more variable weather and food prices, questionable leadership, and, more recently, by unexpected levels of unemployment and inflation.

It has become apparent that we can no longer control or predict major events impacting on our economic and social condition. With the loss of agreement on goals and values, we lost the "steering wheel" to direct our future. With the loss of control or predictability of future events, we also lost the "compass" to tell whether we were headed in the right direction. In this state of national uncertainty, planning becomes an attempt to redefine alternative directions and to recover the compass. Given the state of the planning art, it is a hand compass with a very unstable needle.

The objects of planning are these: (a) to provide better information about the sources and extent of uncertainty and their potential impacts, (b) to evaluate the probability of events that would increase or reduce those uncertainties, and (c) to define strategies that can effectively help us cope with the uncertainties and achieve the type of future our society desires. I exclude establishment of national goals and values as an object of planning. The results of planning can be informative for goal and value choices. However, in our type of society, they are generally arrived at through democratic debate and social interaction in peaceful, stable times. They can, of course, also be forged by war, or by economic, social, or environmental catastrophe.

The planning process starts with identification of major uncertainties, or sources of concern and with estimates of the probability of events that would increase or reduce those uncertainties. This information takes the place of assumptions in traditional projections. Planners start with the future, as best they can, and they develop potentially credible scenarios by moving back to the present.

Planners identify strategies to cope with the uncertainties. This aspect of the process corresponds to the definition of policy alternatives in traditional projections. But, because strategic planning focuses on how to deal with future issues rather than estimating the outcome of a given policy, this part of planning requires a dynamic approach to policy over time as well as effective analysis of interactions among factors impacting on the sources of uncertainty, policy responses, and the future itself. Some people would define this aspect of the process as futures research. I call it strategic or long-term planning. It moves from the future to the present as it identifies alternative strategies for coping with future uncertainties.

To be effective, planning needs to address issues of high interest and concern among policy officials. The planning results and their presentation must be credible and understandable to policy officials without the complexities of the analytic methods and procedures. The alternatives for addressing the future must include avenues of action that could succeed in the political arena. The policy officials must be willing to use information developed through the analytic process.

A number of relevant issues confront us which suggest the need for increased planning and research in agricultural economics. Among these are: an overriding uncertainty about the long-term outlook for the amount and mix of export demand; an increasing pessimism about world food supplies; and, incomplete information about our domestic agricultural capacity and projected levels of production. These and other critical issues are too important to our future to take the chance of letting them work themselves out when planning now can increase the probability that they will work out satisfactorily.

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CURRENCY ADJUSTMENTS UNDER TRADE RESTRICTIONS

The impact of an exchange rate change on equilibrium price and quantity under free trade was determined by Bredahl and Gallagher in this journal.[1] We extend that analysis here by incorporating trade restrictions similar to those employed by the European Economic Community (EEC). The impacts of an exchange rate change given free trade are reviewed, impacts under restricted trade determined, and the impacts in the two cases compared.

The impact of an exchange rate change under restricted trade is not symmetrical. The impact of a devaluation by the exporting country is different from that of a revaluation by the importing country. The impact of an exchange rate change may be greater under restricted trade than under free trade.

EXCHANGE RATE CHANGES AND FREE TRADE

The effect of an exchange rate change on equilibrium prices and quantitites is illustrated through the traditional two-country one-commodity closed system used in many international trade textbooks. The model assumes zero transportation cost; competitive, unrestricted markets; and a homogeneous commodity.

The net or reduced-form elasticity of the equilibrium price with respect to the exchange rate was shown to be in the earlier Journal article to be:

$$E_{\$P,\gamma} = -\frac{1}{1-\dfrac{\eta_{es}}{\eta_{ed}}} \qquad (E.1)$$

where η_{ed} is the own-price elasticity of the excess demand and η_{es} is the own-price elasticity of the excess supply. The percentage change in the equilibrium price is bounded by 0 and −1. Therefore, the percent change in equilibrium price will be, at most, equal to the percentage change in the exchange rate.

The excess supply curve (measured in dollars) does not shift because of the exchange rate change. Therefore, the elasticity of the equilibrium quantity with respect to the exchange rate was shown in the earlier Journal article to be:

$$E_{q,\gamma} = \frac{\eta_{es}\eta_{ed}}{\eta_{es}+\eta_{ed}} \qquad (E.2)$$

The multiplication of the net elasticity of the equilibrium price with respect to the exchange rate and the own price elasticity of the excess supply function yields the elasticity of the equilibrium quantity with respect to the exchange rate. Logically, this elasticity, which is negative, is bounded on the upper end by zero, *but it has no lower bound.* Depending on the elasticities of the excess supply and demand relationships, this net elasticity may be less than a minus one; the percentage change in equilibrium quantity may exceed the percentage change in the exchange rate.

EXCHANGE RATE CHANGES AND EEC POLICIES

Initially, the effect of EEC trade policies assuming stable exchange rates is developed. The effects of exchange rate changes are determined and the effects of exchange rate changes given EEC-type policies are compared with those of the free trade model.

The EEC trade policies are explicitly intended to restrict imports by the application of variable levies to most imported agricultural products. The minimum import price is termed the *threshold price*. The *variable levy* is calculated as the *residual* between the threshold price and the c.i.f.price of imported grains delivered to Rotterdam.

Consider a simple trade model:

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[1] Bredahl, Maury, and Paul Gallagher. "Comment on 'Effects of an Exchange Rate Change on Agricultural Trade.'" *Agr. Econ. Res.* 29, No. 2: 45-48, Apr. 1977.

The excess demand equation 2 of the importing country is treated as a function of predetermined policy price ($\overline{PP}$) rather than \$P which would be used in the free trade model.

$$Q_{es} = \alpha_1 + b_1\$P \quad (b_1 > 0)$$

$$\text{(Excess supply)} \qquad (1)$$

$$Q_{ed} = \alpha_2 + b_2\overline{PP} \quad (b_2 < 0)$$

$$\text{(Excess demand)} \qquad (2)$$

$$Q_{ed} = Q_{es}$$

$$\text{(Equilibrium)} \qquad (3)$$

Since equation (2) is based on exogenous variables (other equations are the same as the free trade model), trade is not affected by price (\$P) changes unless the world market price exceeds the threshold price.

The effect of currency adjustments given a threshold price depends on the source of the currency adjustment. *The effect of a devaluation by the exporting nonmember country may be different from the effect of a revaluation by an importing member country.*

The mechanism establishing EEC-wide threshold prices must be explained briefly to illustrate the effect of a currency adjustment by non-EEC countries. These prices are quoted in *units of account* (U.A.); the U.A. is defined in terms of gold. The threshold prices are translated into the currency of member countries by fixed exchange rates.

The devaluation of the exporting country's currency will not affect equilibrium values. Assume a devaluation of the dollar from equality with the unit of account to 1.25\$ = U.A. Assume one unit of the commodity is offered by the United States at \$50; initially, 50 U.A., and after devaluation, 40 U.A. If the threshold price is 100 U.A., the variable levy will increase from 50 to 60 U.A. Assume that a member country's currency (MCC) is valued at 4 MCC units to one unit of account. Before devaluation, an importer would pay 200 MCC units for one unit of the commodity plus a levy of 200 MCC units. After devaluation, one unit of the commodity would cost 160 MCC units plus a levy of 240 MCC units. Therefore, the devaluation would not reduce the cost (effective price) to the importer.

The excess demand function can be rewritten

$$Q_{ed} = \alpha_2 + \gamma b_2\left(\frac{\overline{MCP}}{\gamma}\right) \qquad (2a)$$

to illustrate the offsetting effects ($\overline{MCP}$) is the member country's threshold price). The exchange rates (γ) cancel; the exchange rate between the importing and exporting countries' currencies has no effect on equilibrium prices and quantities.

There are two cases to be considered. First, the MCC will be revalued against the dollar and the unit of account. Second, the MCC will be revalued against the dollar but not against the unit of account.

To determine the reduced-form effects in Case I, the revaluation of the MCC against the dollar and the unit of account, the excess demand relationship will be rewritten to reflect the fixed import price quoted in units of account (UAP) and the MCC-UA exchange rate (δ).

$$Q_{ed} = \alpha_2 + b_2\gamma\left(\frac{UAP \cdot \delta}{\gamma}\right)$$

$$(b_2 \leqslant 0). \qquad (2b)$$

The excess supply function does not determine equilibrium quantity. The differential of the excess demand equation determines the change in the equilibrium quantity, which may be expressed as a net elasticity:

$$E_{q,\delta} = \eta_{ed} \qquad (E.3)$$

Therefore, the net elasticity of the equilibrium quantity with respect to the exchange rate equals the elasticity of the excess demand relationship. This elasticity (E.3) is greater than that under free trade (E.1).

The change in the equilibrium dollar price may subsequently be determined from the differential of the excess supply function and expressed as a net elasticity:

$$E_{\$P,\gamma} = \frac{\eta_{ed}}{\eta_{es}} \qquad (E.4)$$

The net elasticity of the equilibrium price with respect to the exchange rate equals the ratio of the excess demand function elasticity to the elasticity of the excess supply function. Comparing the elasticity under free trade (E.2) and that under restricted trade (E.4) indicates that if the sum of the absolute elasticities of the excess demand and supply curves is less than one, the restricted trade elasticity will be greater than the free trade elasticity.

Case II, revaluation of the MCC against the dollar, is numerically illustrated and reduced from effects determined. Assume one unit of the commodity is offered at \$50, a threshold price of 100 U.A. and a unity exchange rate between the dollar and the unit of account. The \$-MCC exchange rate will decrease from 4 to 3; the MCC-U.A. exchange rate will be 4. The offer price is converted into units of account and the variable levy determined. In this case, the variable levy will be 50 U.A. The tabulation below indicates the MCC effective import price (cost) before and after the revaluation:

	Threshold price	Commodity price	Variable levy	Import price
	Units of account			
Before	400	200	200	400
After	400	150	200	350

After revaluation, the effective import price declines and is less than the official threshold price.

The excess demand relationship must be rewritten to reflect the fixed variable levy:

$$Q_{ed} = \alpha_2 + b_2\gamma\left[\$P + \frac{VL_{ua} \cdot \delta}{\gamma}\right]$$

$$(b_2 \leqslant 0) \qquad (2c)$$

Totally differentiating the equations (1) and (2c) yields:

$$dQ_{ed} = b_2 \gamma d\$P + b_2 \$P d\gamma$$

$$dQ_{es} = b_1 \, d\$P$$

which is exactly the same result derived if trade were not restricted.

The devaluation of the exporting country currency (dollar) has no impact on equilibrium values. However, in the absence of counter measures by the EEC, the impact of a revaluation by a member country dramatically affects equilibrium prices and quantities. In the first case (revaluation against the dollar), impacts are identical to those of free trade. In the second case (revaluation against the dollar and the unit of account), impacts are greater than those of free trade.

Any analysis of the impact of currency value changes on U.S. exports must consider these theoretical results. The exports of U.S. commodities to the European Community cannot be considered independent of changes in the value of member countries' currencies relative to the dollar and the unit of account. Any research effort, seeking to quantify the demand of the European Community must consider exchange rate impacts.

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GROWTH AS A DIFFERENTIAL EQUATION

Growth can be described by the level of a variable and the change in that level with respect to time. Hence, the economist needs two measures to describe growth. These two measures are functionally related and, according to Allen, "the conditions of a dynamic model reduce to . . . a differential equation" (*3*, p. 5).[1]

Say we are interested in the growth of variable Y at time t, where the rate of change in Y with respect to time is dY/dt. Then the first-order differential equation which describes the growth process is:

$$aY + \frac{1}{b}\frac{dY}{dt} = c \qquad (1)$$

where a, b, and c are parameters. If we ignore terms of second order and higher, this differential equation underlies all growth processes both in and outside of economics. The differential equation has the solution:

$$Y_t = \frac{c}{a} + \left(Y_0 - \frac{c}{a}\right)e^{-abt} \qquad (2)$$

The usual exponential growth curve is implicit in equation (1). To make it explicit, note that we can set $a = -1$ without loss of generality, and take the special case where $c = 0$. Then solve equation (1) for dY/dt:

$$\frac{dY}{dt} = bY \qquad (3)$$

which says the rate of change in Y over time is a constant proportion of Y. Equation (3) has the solution:

$$Y_t = e^{bt}Y_0 \qquad (4)$$

which is the usual exponential growth curve with a rate of growth equal to b. A graph of this solution is shown in figure 1.

When c is not zero, a number of interesting applications of the growth equation arise. For example, define Y as aggregate income of an economy and the parameter a as the labor requirement per unit of income. These definitions imply a definition of aggregate employment (E):

$$E = aY \qquad (5)$$

The parameter c limits the level to which income (Y) can grow. We can interpret c as the labor force from which employment is drawn:

$$LF = c \qquad (6)$$

Substituting (5) and (6) into (1) gives:

$$E + \frac{1}{b}\frac{dY}{dt} = LF \qquad (7)$$

This can be solved for the rate of change in income with respect to time:

$$\frac{dY}{dt} = b(LF - E) \qquad (8)$$

which shows growth to be a product of two factors. One can be interpreted to be a supply factor, and the other a demand factor. A graph of the solution to equation (8) is shown in figure 2.

The supply factor limiting growth is the degree of unemployment in the economy. If the term (LF − E) is positive, there are idle workers and the economy can continue to grow. It will grow more slowly as unemployment decreases. At full employment (LF − E = 0), growth in income will cease.

The demand factor is b, which can be interpreted as the ability of the economy to absorb idle labor through job creation. This factor b might be increased, for example, through an investment tax credit. If b increases, idle labor is more rapidly absorbed. If b is zero, growth ceases and the economy can experience persistent unemployment.

The differential growth equation suggests, in this application, that two factors affect the growth of an economy: its ability to absorb idle labor through job creation, and the presence of unemployed labor. If either factor goes to zero, growth stops.

The parameter a affects the rate of and the limit to growth. It was in-

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[1] Italicized numbers in parentheses refer to items in References at the end of this note.

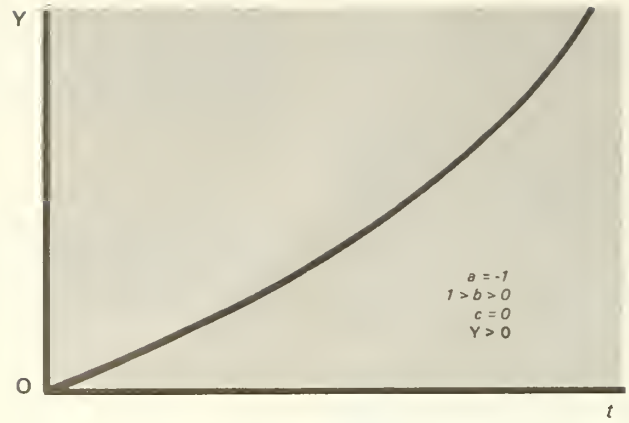

FIGURE 1
GROWTH WITHOUT LIMIT

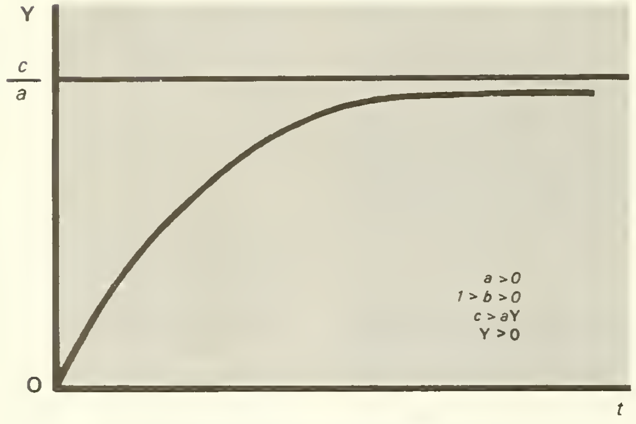

FIGURE 2
GROWTH TOWARD A FIXED LIMIT

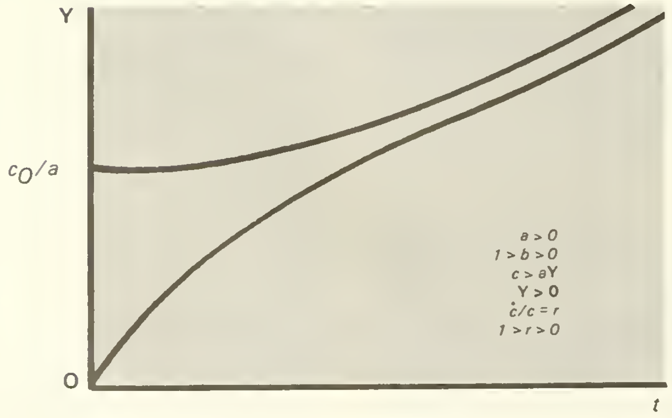

FIGURE 3
GROWTH TOWARD A GROWING LIMIT

terpreted in equation (5) as the labor requirement per unit of income. The reciprocal of a is the productivity of labor. An increase in labor productivity reduces the labor requirement at a given level of income and increases the idle labor supply at that level. The larger idle labor supply results in an increase in the rate of growth at a given level of income, and it increases the limit toward which income can grow.

There are many ways to interpret equation (1) within economics, in addition to the examples above. Allen associates it with distributed lags (*1*, *2*). He demonstrates use of the equation in tracing the path price will follow in closing a gap between demand and supply, and also in tracing the path quantity will follow in closing a gap between bid and ask prices. Alternatively, Allen interprets Y as national income, c as investment, and a as the propensity to save (*2*, *3*). The model traces the path income will follow in closing a gap between planned saving and actual investment. Allen variously sets the coefficient b equal to one, calls it a speed-of-response coefficient, and associates it with the power of the investment accelerator.

Outside of economics, parameter b might be associated with the metabolism of penicillin cells growing in sugar or of trees growing in a forest. Parameter c in these examples could be defined as the limit to growth of penicillin represented by the sugar supply, or as the space required by the roots of a mature tree. As another example, if Y is interpreted as velocity and the reciprocal of b as mass, then c is a measure of force and a is a coefficient of friction. Velocity increases with either a smaller mass or with an increase in net force after allowing for friction.

It is frequently more convenient to use difference equations instead of differential equations. That is, to study growth in discrete intervals of time instead of over a continuous duration. The difference equation which replaces equation (1) is:

$$aY_{t-1} + \frac{1}{b}(Y_t - Y_{t-1}) = c \quad (9)$$

which has the solution:

$$Y_t = \frac{c}{a} + (Y_0 - \frac{c}{a})(1 - ab)^t \quad (10)$$

Now if $a = 0$, and (9) is solved for Y_t:

$$Y_t = Y_{t-1} + bc \qquad (11)$$

and the growth increment is an additive constant. Let $a = -1$ and $c = 0$, and solve (9) for Y_t:

$$Y_t = (1 + b)\, Y_{t-1} \qquad (12)$$

which has the solution:

$$Y_t = (1 + b)^t\, Y_0 \qquad (13)$$

and b can again be interpreted as a compound rate of interest, as in equation (4) (see fig. 1). Solving (9) for Y_t gives:

$$Y_t = Y_{t-1} + b(c - aY_{t-1}) \qquad (14)$$

which is the difference equation counterpart to the differential equation (8) (see fig. 2). It again shows the increment of growth to be the product of what can be interpreted as a supply factor and demand factor. The supply factor $(c - aY_{t-1})$ represents idle capacity and the demand factor b represents the propensity to absorb idle capacity.

Equation (14) is the form which may be found by economists to be most convenient for use in economic models which simulate growth processes. See (*4*) for an illustration of its use in analyzing rural development problems. There, the limit to growth, parameter c, was considered itself to be a function of time as it was in (*2*, pp. 50, 66).

Consider, for example, that the limit to growth is a function of time:

$$c_t = (1 + r)c_{t-1} \qquad (15)$$

and that Y grows as in equation (14). A graph showing the growth of Y toward a growing limit over time for this two-equation system is shown in figure 3. In this model, Y grows rapidly when there is a high level of excess capacity, as before. The interesting new result is that the economy approaches an equilibrium rate of idle capacity as a limit and can never reach full employment.

To illustrate, interpret c as the labor force as before, then equation (15) becomes:

$$LF_t = (1 + r)LF_{t-1} \qquad (16)$$

Let Y grow as in equation (14) with employment defined as in equation (5). Then, in the long run, the economy will approach an equilibrium rate of utilization of the labor force.

$$\frac{E_t}{LF_t} = \frac{b(1 + r)}{b + r} \qquad (17)$$

where the equilibrium rate of unemployment is a constant.

The longrun equilibrium rate of growth in income in this example equals the rate of growth in the labor force. That is:

$$Y_t = (1 + r)Y_{t-1} \qquad (18)$$

By way of illustration, suppose that the economy is able to absorb a third of its idle labor force each year ($b = 0.33$), where the idle labor force is defined as this year's new entrants to the labor force plus last year's unemployment; and that the labor force grows at 2 percent per year ($r = 0.02$). Then:

$$\frac{E_t}{LF_t} = \frac{0.33(1.02)}{0.33 + 0.02} = 0.96 \qquad (19)$$

resulting in an economy which, in longrun equilibrium, will grow at the rate of 2 percent per year and have an unemployment rate of 4 percent.

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In Earlier Issues

The fight against tuberculosis and the drives of the Red Cross which reached rural areas almost as early as they reached urban areas, and the development of health services, form a good example of a steady development that is taking place and the principles upon which the welfare movement has developed in rural areas. From the time 40 or 50 years ago, when practically nothing more was done than to care for those in the almshouses and on outdoor relief, to 1946 when 1,842 counties had full-time professional services, development of rural services has moved forward.

The evidence is that farm people thoroughly approve these advances in welfare programs and there is some indication that the traditional aversion to becoming recipients of social-welfare services has not been so deeply set in the minds of farm people as many have assumed.

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