AGRICULTURAL ECONOMICS RESEARCH

JULY 1974 • VOL. 26, NO 3

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U.S. DEPARTMENT OF AGRICULTURE • Economic Research Service

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AGRICULTURAL ECONOMICS RESEARCH

A Journal of Economic and Statistical Research in the United States Department of Agriculture and Cooperating Agencies

JULY 1974 • VOL. 26, NO 3

Exchangeable Coupon Gas Rationing

By Clark Edwards

During the gas shortage in the winter of 1973-74, farmers were high on the priority list for gasoline allocations. Under the proposed exchangeable coupon gasoline rationing, this allocative machinery and priority system would be superseded by a coupon resale market. The exchangeable coupon resale market is examined from the perspective of a consuming household and of a producing firm. The conclusion is that the coupon resale market will ration gas among the same uses that a higher market price would—the difference being not one of allocation of gas among alternative uses, but one of redistribution of income. The amount of income to be redistributed is estimated in the neighborhood of $28 billion per year.

Keywords: Economic theory, Income distribution, Gasoline, Rationing.

Harbingers of a gasoline shortage have been around for a year or two. In the early months of 1974, most Americans became acutely aware of the prospect. Retail outlets started running out of gas, price gouging was reported, a trucker's strike was declared, limits were placed on sales, and queues at retail outlets grew several blocks long. Speed limits, alternate-day sales, and voluntary rationing helped consumers adjust to the problem.

Before the shortage, the quantity of gasoline supplied to the economy had been increasing around 6 percent per year. Prices were relatively stable until early 1973 when they inched up to around $0.37 per gallon (including taxes) for regular gas. The steady rise in utilization reflected a growing population, rising income, and a changing technology of production and consumption. The trend was halted abruptly in the fall of 1973, and utilization of gasoline during the first quarter of 1974 was around 6 percent below a year earlier. The shortage put a strain on the economy and raised the specter of rationing.

Two events can obviate the need for rationing if demand remains unchanged: Increased supplies and increased prices. Both events were occurring or in prospect by the spring of 1974. In March 1974, the average selling price of gas exceeded $0.50 per gallon, including taxes, and was some 38 percent above a year earlier. The forecast at the time was for some continued upward pressure on prices, possibly to $0.60, and for some increase in supplies through imports and domestic production. The import embargo was relaxed. Utilization was down and prospective supply was up by the first day of spring to make rationing appear unlikely.

Even so, rationing had been a distinct possibility (one which some consumers wished had already been imposed as they waited an hour or two in line for a tankful) and could become one again. Several plans were proposed for dealing with the gasoline shortage. One of the rationing plans considered by the Federal Energy Office was an exchangeable coupon rationing system. It was a contingency plan and, as such, was never formally approved or "endorsed" by the Federal Energy Office. What was this contingency plan like?

The basic ingredients of the planned gasoline rationing program were price controls below the market level, exchangeable coupons, and ration banking. Suppose we are in equilibrium with utilization of 105 billion gallons of gas per year at $0.60 per gallon when a shortage of 10 percent is suddenly experienced. Market forces will immediately exert an upward pressure on prices. Estimates of the price elasticity of demand for gas consistently confirm an inelastic market. Oil companies have prorationed supplies over the past half-century to avoid lower prices which could drop total revenue below total costs. With an inelastic demand, a small percentage increase in quantity would induce a relatively large percentage decrease in price and a loss in total revenue. Statistical analyses point to market changes consistent with a short-run price elasticity between −0.10 and −0.25. Assuming a price elasticity of demand of −0.2, the 94.5 billion gallons available would clear the market at $0.90 per gallon.

The proposed rationing program, in this situation, would freeze prices at \$0.60 and distribute exchangeable coupons for 94.5 billion gallons to private and commercial users. These coupons could be used by the recipient or traded in the market. It is shown in a subsequent section that the market might value coupons at about \$0.30 per gallon. Post offices could allocate coupons to licensed drivers and to commercial users. (Bulk users might use negotiable drafts instead of small-denomination coupons.) Retailers (or wholesalers to final users) would require coupons (or drafts) to sell gas. The final seller would bank coupons along with cash receipts and use drafts against such coupon bank deposits to obtain gas from wholesalers. Thus coupon banking would move wholesale gas into the regional markets where coupons evidenced demand. Gas would follow coupons as reorders were made by retailers. There would be enough gas to fill such orders because the amount of coupons out would equal the amount of gas available. The \$0.90 opportunity cost of a gallon of gas under the proposed rationing program would distribute the available gas among approximately the same uses that an actual pump price of \$0.90 would. However, the income distribution would be different.

The Theory of Consumer Demand

From the point of view of an individual, private, licensed driver, the problem may be regarded as one of seeking to maximize utility (U) from gas (G) and from nongas goods (M) subject to a budget constraint reflecting income adjusted for purchase or sale of coupons. That is, maximize:

$$(1)\quad U = f(M, G)$$

subject to

$$(2)\quad M = I - pG + q(R-G)$$

where I is income per time period, R is the ration allotted by coupons under the program, p is the price of gas, and q is the price of coupons. If the consumer uses exactly his ration, then $(R - G) = 0$ and M is independent of q. If the consumer buys coupons, then $(R - G) < 0$ and less money is used for nongas goods (M). If the consumer sells coupons and uses less gas then his allotment, then $(R - G) > 0$ and more money is available for nongas goods (M). The marginal condition for maximum utility is

$$(3)\quad \frac{\partial U}{\partial G} = (p + q)\,\frac{\partial U}{\partial M}$$

which says that gas is acquired up to the point that the utility of one more gallon equals the marginal utility of $p + q$. That is, $p + q$ is the relevant choice indicator regardless of whether the consumer buys or sells coupons or refrains from the coupon market. $p + q$ reflects the opportunity cost of using a gallon of gas. If p is \$0.60 and q is \$0.30, one gives up \$0.90 in purchasing power to gain a gallon of gas.

Without rationing, and with no gas shortage, we may consider q equal to zero. The consumer allocates his income between G and M so that $\partial U/\partial G = p(\partial U/\partial M)$. This is shown in figure 1 as the point of tangency of the initial budget line B_0 with the initial indifference curve I_0. The consumer uses the combination (M_0, G_0).

If there is a shortage and the price of gas is raised until the reduced quantity of gas just clears the market, then the budget line rotates to B_1 from B_0 to reflect the higher price (figure 1). Consumption becomes (M_1, G_1). The consumer buys less gas (and with an inelastic demand spends more for it) so that indifference level I_1 is attained instead of I_0. The higher gas price achieves the goal of reduced gas consumption, but, as a side effect, real income or purchasing power is reduced.

It is to prevent the hardships of this loss in purchasing power that rationing is imposed (*19*). For example, if the consumer were given coupons (R) with which to buy G_1 gallons of gas and the price were frozen at the preshortage level, then the consumer could obtain (M_2, G_1) and reach indifference curve I_2 (figure 1). While this is worse for him than I_0, it is better than I_1 and still achieves the program target of reduced gas consumption. This allocative kind of rationing avoids the loss in utility due to the income effect of the gas shortage, but imposes a loss from the substitution effect of using more M and less G than is preferred at prevailing market prices. Consumers with other preference patterns might find that $R > G_0$, in which case they would continue to consume (M_0, G_0).

This allocative form of rationing with nonnegotiable coupons is the type imposed during World War II. Reder (*20*) discusses the welfare economics of rationing. He points out that the

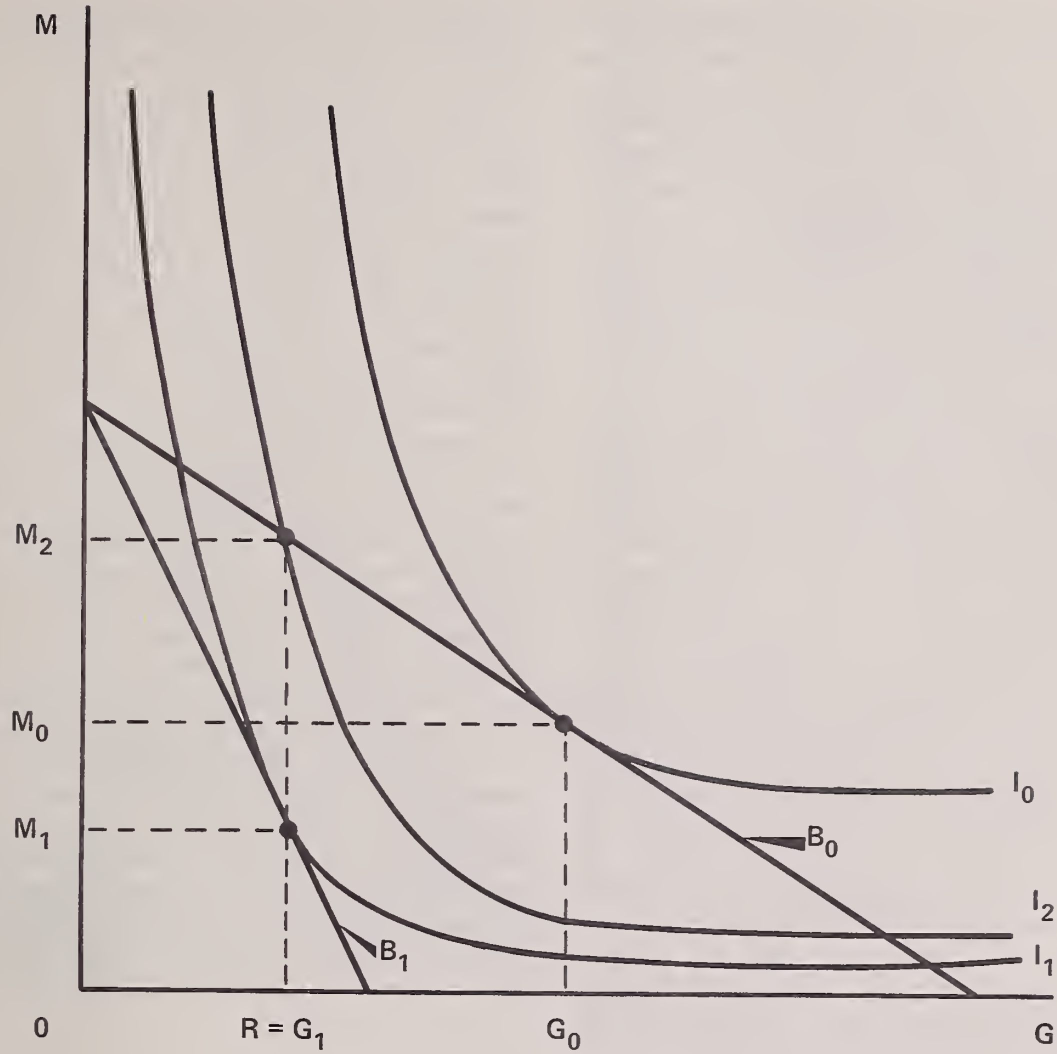

Figure 1

combination achieved under allocative rationing (M_2, G_1) is superior to that under higher market prices (M_1, G_1) but inferior to the initial equilibrium (M_0, G_0). Reder goes on to prove that allocative rationing results in a preferred equilibrium to rationing by means of a tax on gas (which is the same to the consumer as a higher market price), but that the latter is preferred to reduced consumption by means of a general tax on all commodities, or an income tax. Reder does not discuss exchangeable coupon rationing.

Samuelson (*23*) discusses the pure theory of choice under rationing. He explains simple rationing in which the Government specifies the maximum amount of a particular commodity that each individual can consume, such as gasoline. He compares this with "point rationing" in which the individual is limited to a weighted sum of commodities. For example, as Neisser (*16*) suggests, Government can hardly assign a certain amount of each of the different cuts of meat to a consumer, but can limit the consumption of the group of meat products with the point prices of each cut of meat providing the relative weights. In the current gasoline case, it is implied that regular gas carries the same weight as premium. Samuelson works out the equations for maximizing utility under point rationing without exchange of points. He adds that unless the Government were to explicitly ban such transactions, an exchange market for points would arise. From a welfare point of view, he says, it can be shown that the free interchange of coupons for money is, in a certain sense, optimal. But in his concluding sentence he warns that it should not be thought that anything he has said is an argument for making coupons interchangeable, since there might in fact be grave difficulties in the way of devising a method of point allocation which would recognize the harm done to individuals. The harm Samuelson was concerned with was that done to the middle class when the rich bought stamps from the poor and bid up the stamp market price. Samuelson is right in saying that the rich and poor might trade to mutual advantage and to the disadvantage of the middle class, but he overlooks certain corollaries: (a) the rich could bid up the price of scarce gas in the same way if there were no rationing and prices were allowed to rise, and this would disadvantage both the middle class and the poor; society may be better off with allocative rationing than with no rationing at all; and (b) the middle class consumers are better off buying or selling coupons at the price the rich bid them up to than in using their allotment and not exchanging coupons; society may be better off with exchangeable coupon rationing than with allocative rationing. Boulding (2) says that rationing is probably the most equitable method of direct restriction of purchases during a shortage. He added that if price is allowed to rise freely the rich may bid up the price until the commodity is out of reach of the poor.

It will be shown in connection with figure 3, below, that rationing with exchangeable coupons leads to a higher level of consumer utility than does allocative rationing. Under allocative rationing, at (M_2, G_1) in figure 1, the marginal rate of substitution of gas for money is not equal to the price ratio, suggesting that the consumer might move to a higher indifference level than I_2 by entering a negotiable coupon market. Figure 2 shows the effect of such a market on the budget line.

With a resale market and $q > 0$, combination (M_2, G_1) is feasible $(R = G_1)$. This point is common to both the original budget line B_0 and the one with exchangeable coupons B_2. The slope of B_0 is p; the slope of B_2 is $p + q$. If the consumer sells coupons he not only gains q for cash coupons sold but also foregoes buying gas for p per coupon; for each coupon sold, $p + q$ is available to spend on nongas goods (M). The demand for gas now depends on the tangency of B_2 with an indifference curve.

Figure 3 illustrates the solution for a consumer with a preference pattern such that he buys coupons but consumes less gas at $p + q$ than at p. The implications of other preference patterns are discussed below. With exchangeable coupons, the consumer in figure 3 uses (M_3, G_2) and realizes I_3. He is worse off than before the shortage but better off than under higher market prices or under regulated consumption with nonnegotiable coupons.

Several results follow from this analysis. First, if there is an exchangeable coupon market, then the pump price of gas plus the coupon price is the relevant choice indicator in allocating gas among alternative uses. The opportunity cost applies whether the user is buying or selling coupons. If the coupon resale market is functioning smoothly, the allocation of gas obtained by this choice indicator will not be very different from that obtained by the free market price.

Consequently, the allocation of gasoline among alternative ends will be about the same under higher market prices as under exchangeable coupon rationing. The differences will be attributable more to the different income effects than to a difference in the choice indicator. On the other hand, allocation of gasoline among

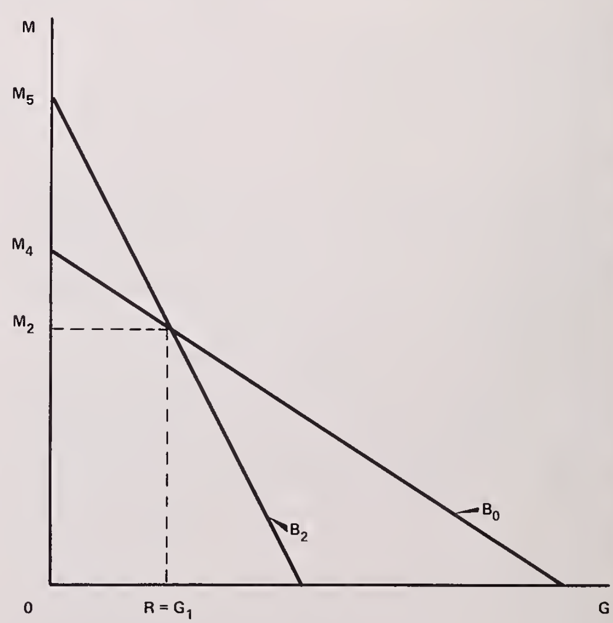

Figure 2

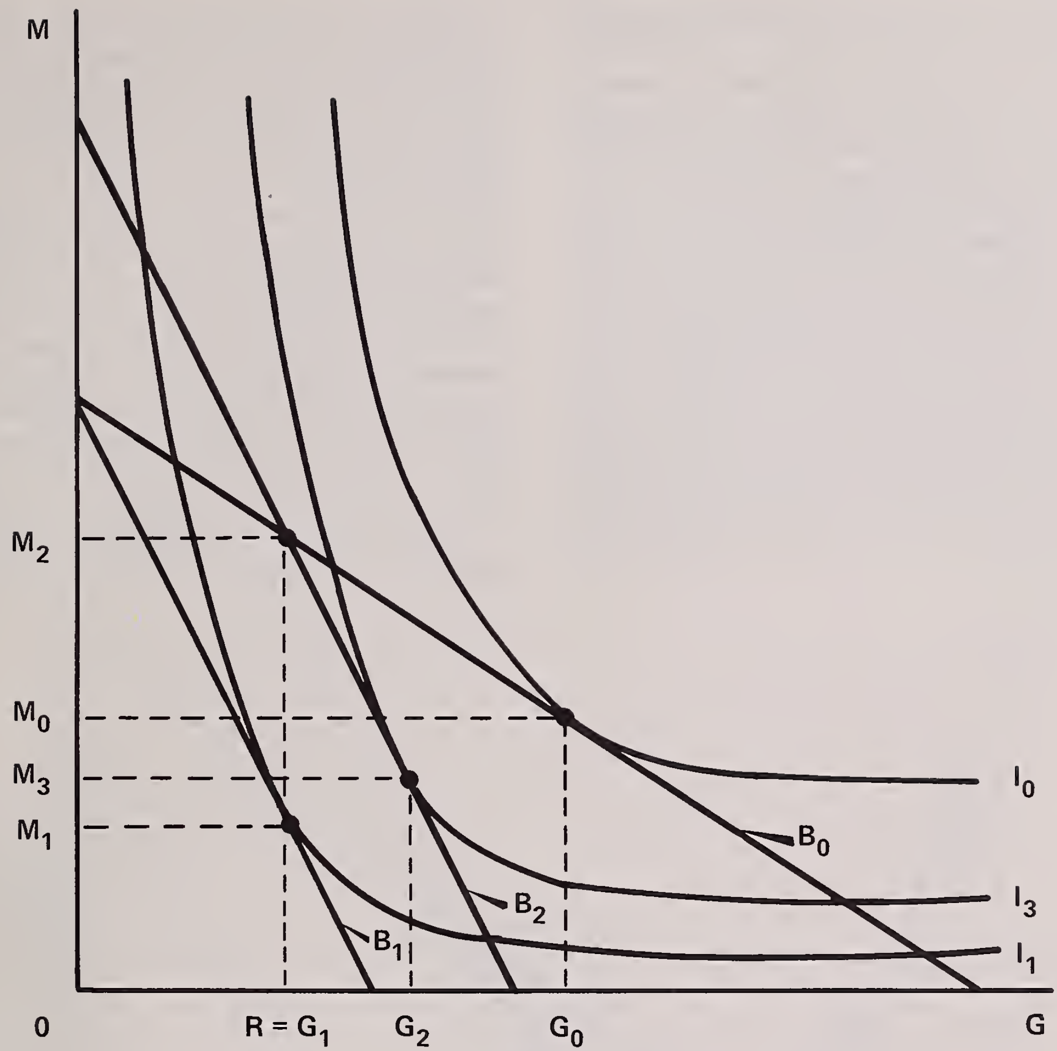

Figure 3

alternative ends is likely to be different under exchangeable coupon rationing from what it would be under an allocative rationing system where priorities have to be set by the Government.

Second, rationing under an exchangeable coupon market is likely to lead to higher levels of consumer satisfaction than allocative rationing which, in turn, is preferred to programs which reduce consumption through higher taxes or higher prices.

Third, inasmuch as the allocation of gas among alternative uses is about the same under exchangeable coupons and higher market prices, the difference between those programs is one of income distribution. Coupons give the added value to final users, and higher prices transfer it to the oil industry. A tax equal to the coupon value would result in approximately the same allocation of gasoline while transferring income to the Government. The income effect will have some impact on the allocation of gas among alternative uses. If we are thinking of 94.5 billion gallons of gas per year and a coupon price of $0.30 per gallon, the implied income transfer is $28 billion per year. For an individual, private, licensed driver allocated 10 gallons per week, it amounts to $156 per year.

Fourth, the utility of the program depends on controlled pump prices. If the pump price is allowed to rise toward the free market price, then the value of a coupon in the market is diminished and the need for a rationing program is reduced.

The curves were drawn in figure 3 to reflect a consumer who will buy coupons and consume gas so that $G_2 > R$. Other consumer psychologies can be superimposed on the money constraint of figure 2 to suggest selling rather than buying coupons. At the extreme, if a licensed driver received coupons but always rode a bicycle, he could sell all his coupons. The situation can be imagined with reference to figure 2. Before rationing, the bicyclist had M_4 to spend. After receiving and selling his gas ration R at price q per unit, he finds he has M_5 to spend. Hence the income effect of the program is $M_5 - M_4$. All licensed drivers receive this income effect. The bicyclist realizes all the effect in cash.

Some consumers may be better off under exchangeable coupon rationing than in the initial, prerationing equilibrium. The result depends on a utility surface reflecting a high marginal utility of money relative to the marginal utility of gas. Figure 4 depicts a consumer who sells some coupons, buys some gas, and is better off than under the initial conditions. This result is particularly likely to obtain for a consumer whose preference pattern is such that $R > G_0$ (not shown in the diagram). Such a consumer would be indifferent between allocative rationing and the prerationing situation. He benefits from a program which keeps pump prices lower. And he benefits from the income effect of exchangeable coupons.

Attention needs to be turned to the effects of gasoline rationing with exchangeable coupons on

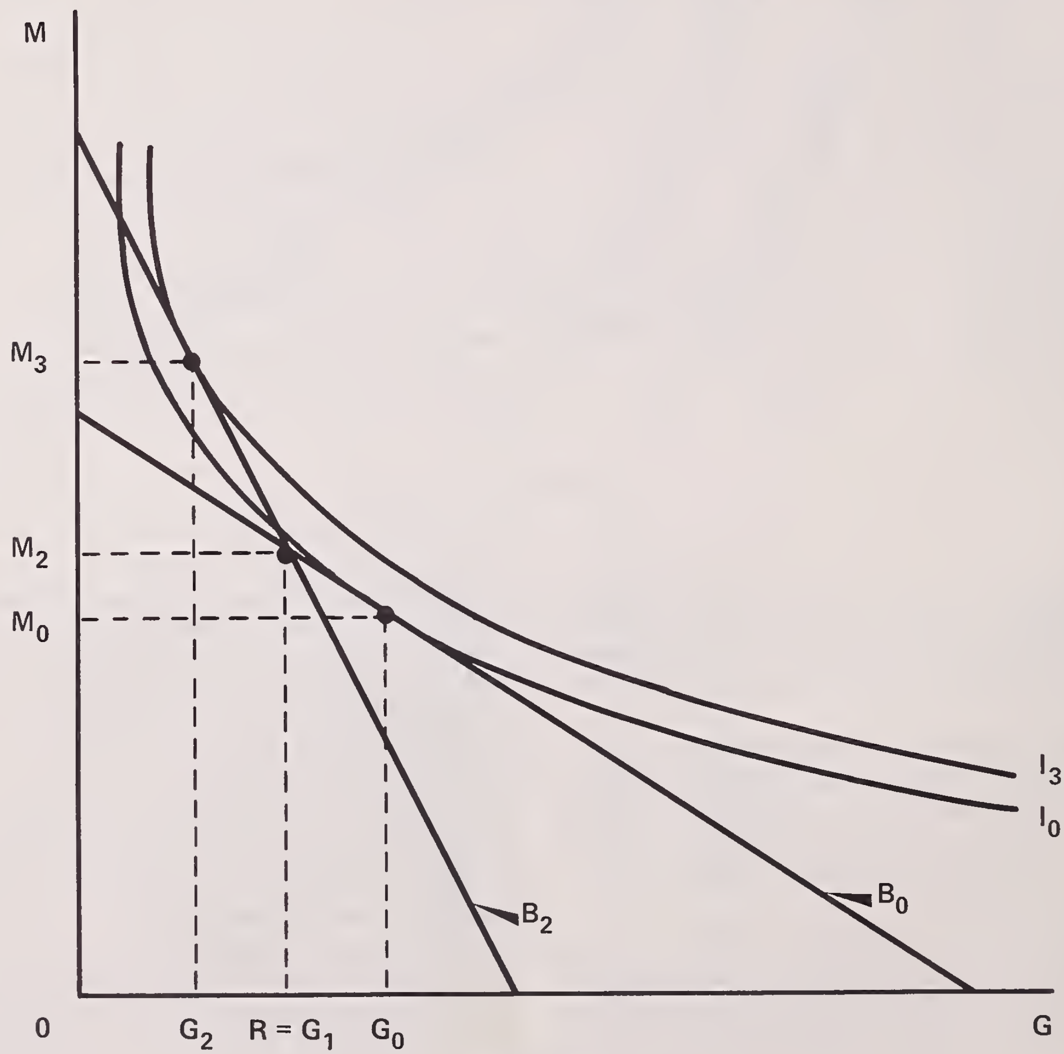

Figure 4

alternative income levels. Neisser (*16*) addresses the question of the conditions under which the lowest income classes would benefit from rationing at the cost of the rest of the population. He suggests the outcome depends in part on the overall income distribution, on the percent that the value of the rationed item is of the individual's total purchases, and on whether the rationed allowance exceeds the quantity the individual consumed before rationing. If the income elasticity of demand for gas is positive, we might expect to find a higher income person using more gas than R and a lower income person using less, although the number of gallons rationed (R) is the same for both consumers.

Figure 5 shows the possibility of the lower income person becoming relatively better off from the realization of added cash through the sale of coupons, while the higher income person finds his utility reduced under rationing. This is not to say that the program necessarily helps low-income families at the expense of those with higher incomes, but there does appear to be such a general tendency. The income effect is proportionately larger for the lower income consumer. A family with two licensed drivers and an income of $3,000 per year will find the market value of the coupons received to be around 10 percent of income. For a family earning $30,000 per year, the income effect of the program would be only 1 percent of income. Hence the

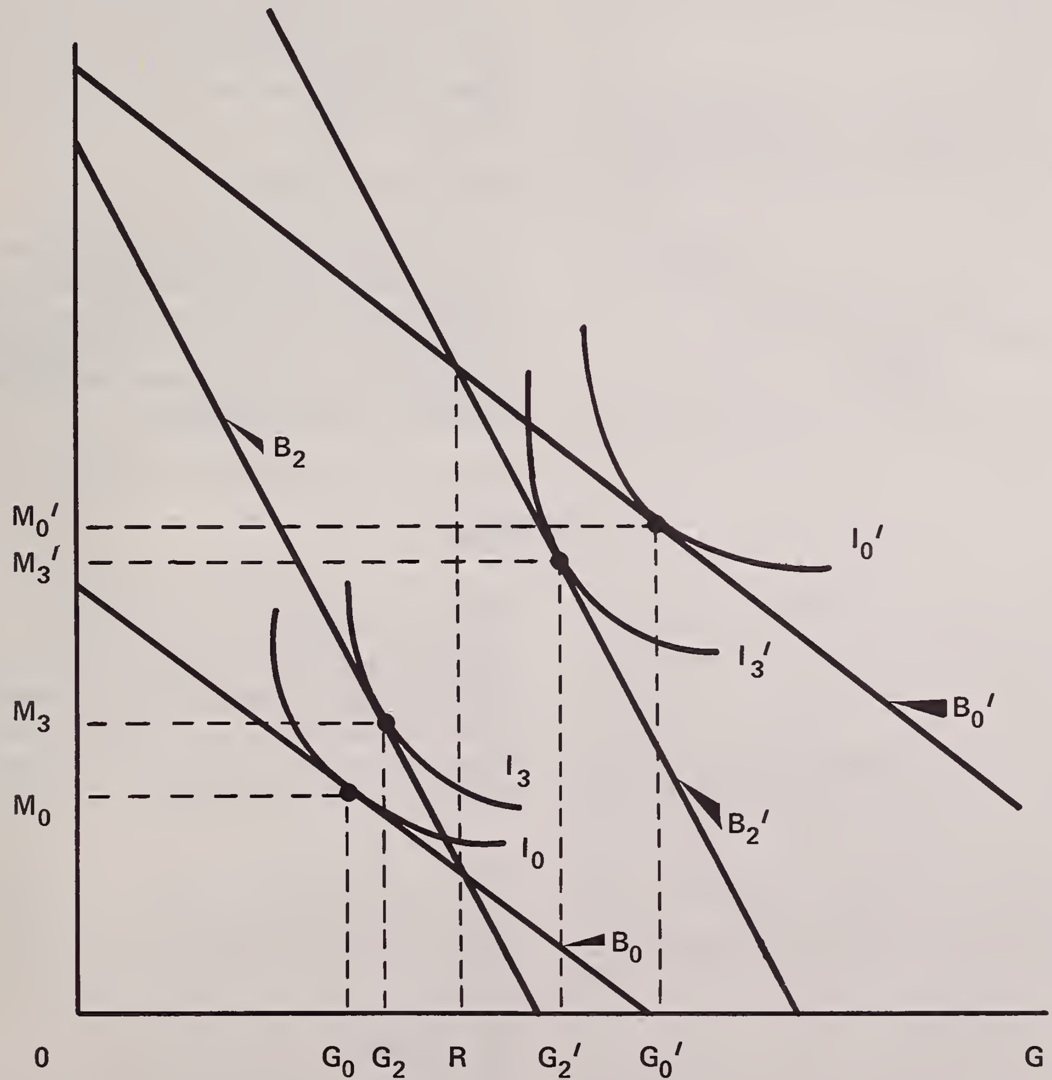

Figure 5

income distribution effect of the exchangeable coupon rationing program is progressive.

The lower income person's gain depends on a well-ordered market for coupons. If he sells coupons for $0.05 or $0.10 a gallon to someone who will resell them for $0.40 or $0.50 to a desperate user, then the income transfer is to the broker rather than to the low-income seller or the desperate buyer. Under a well-ordered coupon market, the regulated pump price plus the market price of coupons $(p + q)$ is the relevant choice indicator regardless of consumer psychology or income level.

It may be expected that the market will develop a bid-ask system of pricing. For example, a driver with a few extra coupons might sell them to a retailer for $0.25 each and a customer might come along a few minutes later and buy them for $0.30.

On the consideration that the consumer can acquire A coupons in the market at price q_a or sell S coupons at price q_s, it is useful to restate the consumers' problem as follows: Maximize

(1) $U = f(M, G)$

subject to

(4) $M = I - pG - q_a A + q_s S$

where

(5) $G = R + A - S$

(6) $AS = 0$

(7) $A \geqslant 0$

(8) $S \geqslant 0$

(9) $q_a \geqslant q_s$

The marginal condition for maximizing utility in this situation is a pair of inequalities:

(10) $(p + q_a) \frac{\partial U}{\partial M} \geqslant \frac{\partial U}{\partial G} \geqslant (p + q_s) \frac{\partial U}{\partial M}$

Now if the consumer is buying coupons, then $A > 0, S = 0$, and

(11) $(p + q_a) \frac{\partial U}{\partial M} = \frac{\partial U}{\partial G}$

which says that coupons and gas are acquired up to the point at which the utility of one more gallon of gas equals the utility of the money represented by $(p + q_a)$. If the consumer is selling coupons, then $A = 0, S > 0$, and

(12) $(p + q_s) \frac{\partial U}{\partial M} = \frac{\partial U}{\partial G}$

which says that coupons are sold and gas is acquired up to the point at which the utility of one more gallon equals the utility of the money represented by $(p + p_s)$. If the consumer is neither buying nor selling coupons, then the utility of a gallon of gas lies below the utility of $(p + q_a)$ but above the utility of $(p + q_s)$.

If the price for which a consumer can sell coupons is below the price at which he can buy them, a kink appears in the budget constraint B_2 as in figure 6. The intersection of this kink with the indifference map allows for corner solutions which increase the likelihood that the utility maximizing quantity of gas precisely equals the ration $(R = G_1)$.

The Theory of the Firm

From the point of view of an individual firm, the problem may be regarded as one of seeking to maximize profits (π) from the production of a single product (Y) using a variable resource (X) and gasoline (G) with an exchangeable coupon ration (R). That is, maximize

(13) $\pi = P_y Y - P_x X - pG + q(\mathrm{R} - G)$

subject to

(14) $Y = f(X, G)$

where P_y and P_x are the price of the product and variable factor respectively, p is the price of gas, q the exchange value of a coupon, and R the ration of coupons. The marginal condition with respect to optimal use of X is

(15) $P_y \frac{\partial Y}{\partial X} = P_x$

and that for gas is

(16) $P_y \frac{\partial Y}{\partial G} = p + q$

which says the condition for using X is that the marginal value product equals the factor price,

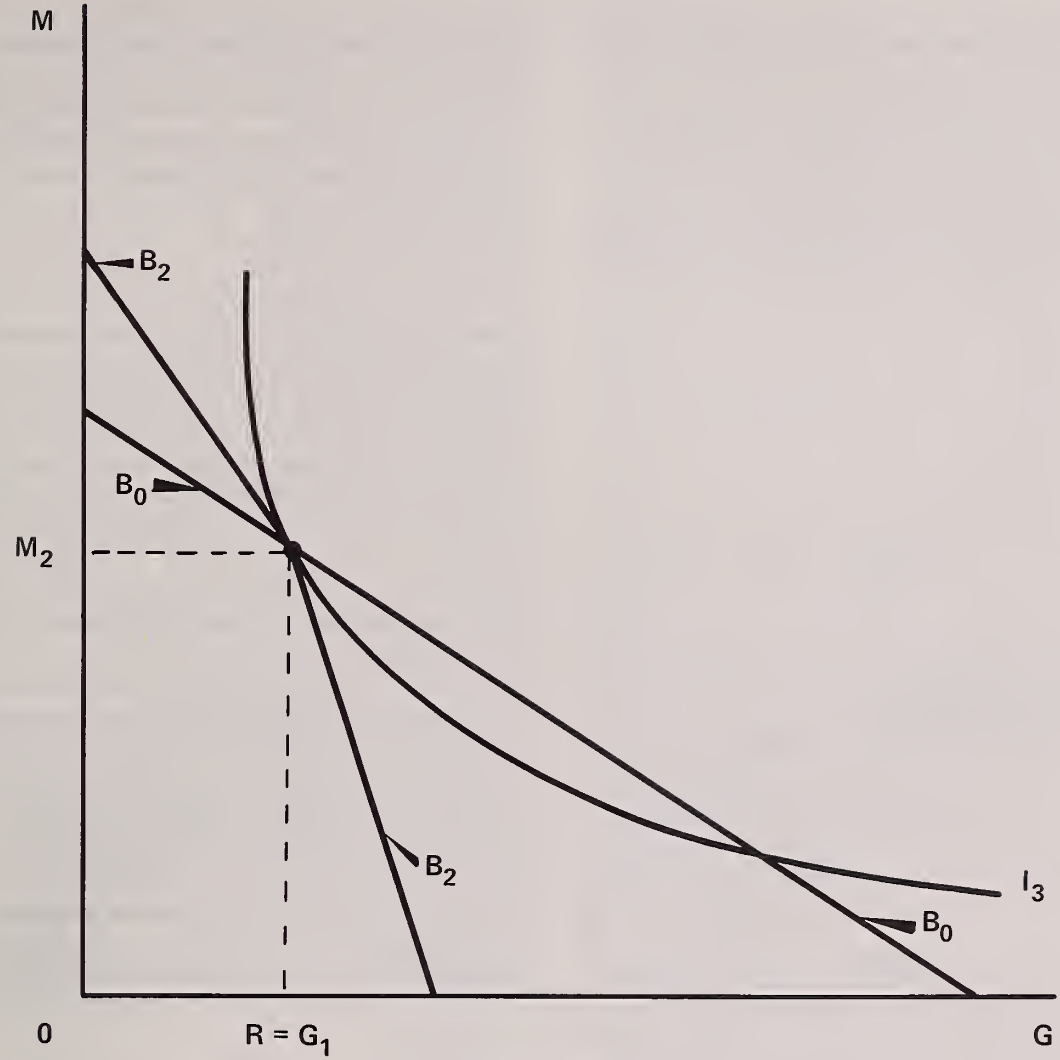

Figure 6

while the condition for using gas is that the marginal value product of gas equals the pump price of gas plus the market value of the exchangeable coupons. These two conditions imply

$$(17)\quad \frac{\partial X}{\partial G} = \frac{p + q}{P_x}$$

which says the marginal rate of substitution equals the ratio of the pump price plus coupon price to the price of X. Thus as q becomes larger, less gas relative to X will be used in order to make the marginal rate of substitution larger. In terms of factor-factor substitution, higher coupon prices (q) encourage firms to use relatively less gas and more of other resources subject to the technical possibilities of conserving gasoline. In addition, this line of thinking leads one to suspect that, as q rises, the final product mix of the economy under rationing is likely to reflect an increased proportion of commodities which require relatively less gas in their production and distribution.

The level of gas consumption by the firm is analyzed by reference to the demand in the factor market as measured by the marginal value product. In figure 7, G_0 is the amount of gas the firm uses at price p. Suppose the ration R is less than G_0. The firm can exchange coupons plus money for gas up to point R. If, at this juncture, the marginal value product of gas exceeds the opportunity cost $p + q$, as assumed in figure 7, the firm will buy coupons on the market and maximize profits with G_1 units of gas. Figure 7 shows the incentive for a firm to buy coupons on the market when $MVP_g > (p + q)$ at $G = R$.

On the other hand, if $MVP_g < (p + q)$ at $G = R$, the firm will have an incentive to sell coupons as shown in figure 8. From figures 7 and 8 it becomes apparent that $p + q$ is the choice indicator of how much gas to use, and the size of R has no direct relation to the optimal level of G. However, the firm prefers a large R to a small one because of the income transfer effect. The monetary value of the transfer is qR, indicated by the shaded area in figures 7 and 8.

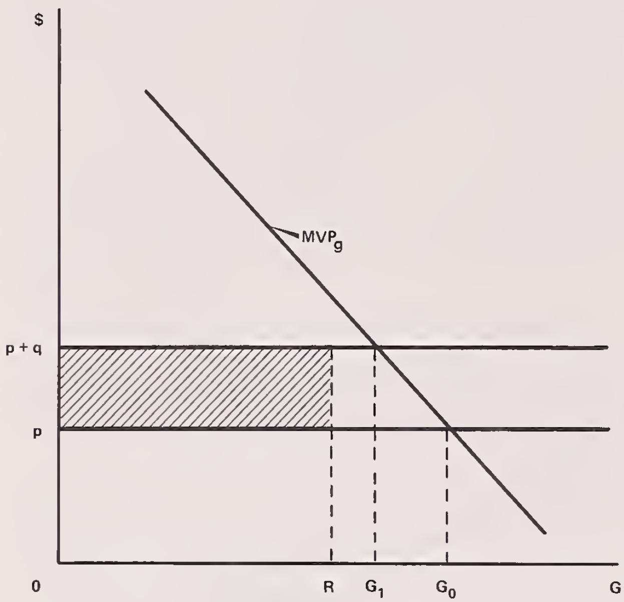

Figure 7

In the event that a bid-ask pricing system obtains for coupons, the marginal condition for optimal use of gas by the firm is

$$(18) \quad (p + q_a) \geqslant MVP_g \geqslant (p + q_s)$$

The case for which MVP lies between these bounds, and both inequalities hold, is shown in figure 9. The firm will maximize profits by using exactly the ration of gas, R, in this instance. Should the demand for gas by the firm shift to the right, the firm will buy gas for $p + q_a$; should it shift to the left, the choice indicator becomes $p + q_s$.

The Coupon Market: Aggregate Supply and Demand

Individual actions of firms and households in response to a distribution of exchangeable gas rationing coupons will lead to a market for coupons as described above. This section addresses the question of the probable monetary value of a coupon. If we start from an initial price and quantity, and assume a gas shortage, an estimate of the price impact depends upon an estimate of the price elasticity of demand for

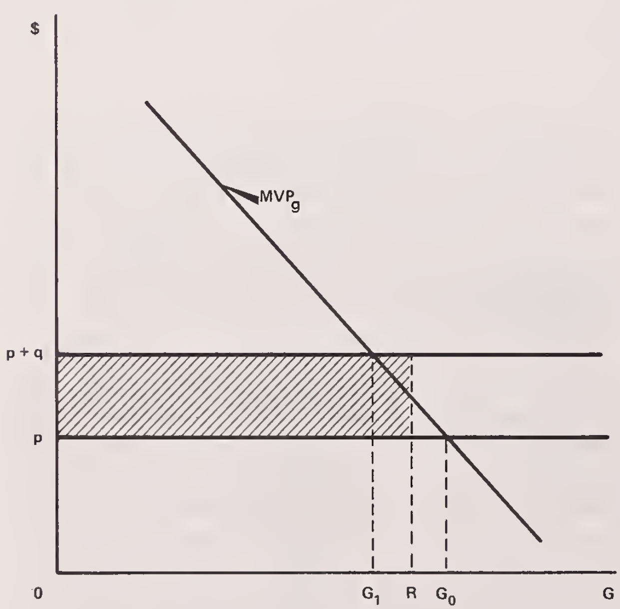

Figure 8

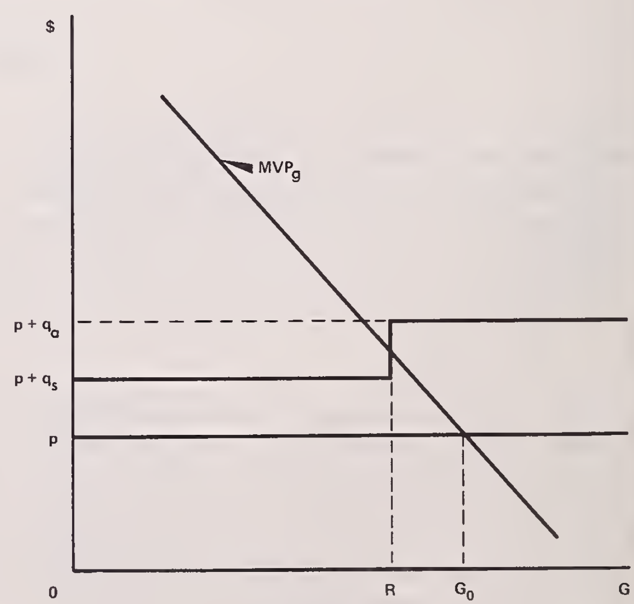

Figure 9

gas. There are a number of difficulties involved in answering this empirical question. Some estimates of short- and long-run elasticities are available, but none drawn from a set of statistically satisfying situations paralleling the recent experience. The number of observations of price hikes in the range of 10 to 50 percent per year is not sufficient for a statistical estimate. And there is little statistical evidence as to the importance of probable shifters in the price-quantity relationship such as population, income per capita, tastes, and prices of related goods. But in a practical situation one works with what one has. Various statistical analyses point to a short-run price elasticity between −0.10 and −0.25, confirming the notion that the market for gasoline is inelastic. An elasticity of −0.20 would suggest that the 38 percent price rise from the spring of 1973 to the spring of 1974 was sufficient to curtail use by around 7 percent. Inasmuch as use was estimated around 12 percent below unconstrained demand at preshortage prices, and the remaining 5 percent could easily be explained by voluntary conservation practices and by continuing evidence of upward pressure on prices, it does not appear unreasonable to use −0.2 for illustrating the price effects of a gasoline shortage with implications for the exchange market price of coupons.

A price elasticity of −0.2 implies, under appropriate assumptions, a price flexibility of −5. Thus a shortage of 10 percent in gas supplies may induce a 50 percent increase in prices, resulting in a gain in total revenue to the industry of 35 percent. The relationship between price, quantity, and total revenue when the price flexibility equals −5 is shown in table 1. The way this market behavior may translate into a price of coupons can be traced in table 2.

Table 1. Changes in price per gallon and total value of gasoline when price flexibility is − 5 and supply declines by specified percentages

Change in quantity	Change in price	Change in pQ
Percent	*Percent*	*Percent*
−1	5	3.95
−5	25	18.75
−10	50	35.00
−15	75	48.75
−20	100	60.00

Suppose the economy is in equilibrium with 105 billion gallons of gas selling for $0.60 per gallon, and a total revenue of $63 billion to the industry, when a 10 percent shortage in supplies arises. Then only 94.5 billion gallons of gas are available. One way to induce consumers to demand no more than the reduced supply of gas is to raise the price. With a price flexibility of −5 and a shortage of 10 percent, the resulting increase in price would be 50 percent. The price of gas would increase to $0.90 from $0.60. The total revenue to the oil industry would increase by 35 percent to $85 billion, a gain of $22 billion (table 2).

Rationing with exchangeable coupons and with the pump price of gas frozen at $0.60 would create a coupon exchange market. The exchange price of a coupon would be bid up by users who value gas at more than the pump price. This market would reallocate the fixed

Table 2. Market value of gas and of coupons under alternative assumptions when supply declines by specified percentages

Change in quantity	Quantity per year	Free market price of gas, p_f	Value of gas, p_fQ	Price of a coupon, q, at p = 0.60	Value of coupons, qQ	Value of gas at p = 0.60
Percent	*Billion gallons*	*Dollars*	*Billion dollars*	*Dollars*	*Billion dollars*	*Billion dollars*
0	105.00	0.60	63.0000	0.00	0.0000	63.0000
−1	103.95	.63	65.4885	.03	3.1185	62.3700
−5	99.75	.75	74.8125	.15	14.9625	59.8500
−10	94.50	.90	85.0500	.30	28.3500	56.7000
−15	89.25	1.05	93.7125	.45	40.1625	53.5500
−20	84.00	1.20	100.8000	.60	50.4000	50.4000

Source: Table 1.

quantity of gas among users so that the value of gas at the margin to the user is equal to the opportunity cost of the pump price plus the coupon price. Coupons at $0.30 to ration 94.5 billion gallons of gas would generate a $28 billion coupon market (table 2). This is a measure of the income transfer to firms and households from the oil industry. With a market price of $0.90 for gas, the oil industry would gross $85 billion. But with $0.60 gas and $0.30 coupons, firms and households receive $28 billion, and the oil industry grosses only $57 billion. Hence the $28 billion gain to individuals is accompanied by a $6 billion loss to the oil industry (table 2).

The oil industry could avert this loss by seeking an increase in the pump price to $0.67. This would hold the industry gross (including taxes) at $63 billion. Then coupons would reach equilibrium at $0.23 per gallon and the gross value of the coupon market would be $22 billion per year (table 3).

Table 3. Total value of coupons, price per coupon, and price per gallon of gas required to hold industry revenue constant at $63 billion, when gasoline supply declines by specified percentages

Change in quantity	Value of coupons	Price of a coupon	Price of gas
Percent	*Billion dollars*	*Dollars*	*Dollars*
0	0	0.0	0.6000
−1	2.4885	.0239	.6061
−5	11.8125	.1152	.6348
−10	22.0500	.2333	.6667
−15	30.7125	.3441	.7059
−20	37.8000	.4500	.7500

Source: Table 2.

Conclusions

Gasoline rationing using exchangeable coupons and ration banking has several properities quite different from other forms of rationing or allocation. Highlights of some of the properties discussed in this paper, plus a few added considerations, follow:

1. When supplies are below unconstrained demand at present prices, possible solutions are to (a) increase supplies, (b) encourage voluntary reduction in demand, (c) impose a tax or surcharge, (d) raise prices, or (e) ration. This paper focuses on implications of the last two.

2. Each of the above alternatives can bring demand into balance with supply. But the alternatives differ with respect to their impacts on the allocation of scarce gasoline among alternative ends, and also on the distribution of income. The chief difference between raising prices, raising gas taxes, and exchangeable coupon rationing is the effect on income distribution. Raising prices transfers income to the oil industry; raising taxes transfers income to the Government; and coupon rationing transfers income to households and firms. Allocative rationing with priorities set by the Government may result in a different distribution of gasoline among uses than the other alternatives.

3. The magnitude of the income transfer associated with a 10 percent shortage is estimated in the neighborhood of $28 billion per year.

4. Prices at the pump must be frozen below the market level if coupon rationing is to be useful. If prices rise, the value of coupons falls accordingly and may become less on the resale market than the cost of operating the program.

5. The relevant choice indicator that firms and households will use in deciding how much gas to allocate among alternative uses under exchangeable coupon rationing is the sum of the pump plus the coupon price. Hence, if the pump price is $0.60 per gallon and a coupon is $0.30 per gallon, the choice indicator is $0.90.

6. It follows that the size of the ration to a firm or household does not affect the quantity of gas used, but only affects the income distribution. Hence, if one group is rationed at 100 percent of need and another group at 80 percent, the effect is simply to give a subsidy to the former group. Both groups will allocate gas on the basis of whether an additional gallon is worth $0.90 to them.

7. Gas rationing as a means of allocating a scarce resource and avoiding hardship is worthwhile. But, through the income redistribution effects, gas rationing with exchangeable coupons also becomes a welfare program. It may prove less efficient at meeting the latter objective than other welfare institutions. Insofar as the former goal of allocating a scarce resource without hardship is uppermost, coupon rationing may be worth the expense and effort. But if the latter goal of welfare is seen to be paramount, other,

more efficient institutions should be considered.

8. Exchangeable coupon gas rationing creates a new market institution likely to do a business worth $28 billion per year. The institution would be uncertain and imperfect. Some might take advantage of others in this situation. It is a responsibility of the Government when it creates such an institution to watch it, help it, and be sure it works fairly. For example, the Government may help make an efficient market by buying and selling coupons in very small lots. And the Government may collect coupon price information daily and disseminate it as a market news service.

9. The coupon resale market introduces a degree of flexibility in gasoline allocation among alternative ends that allocative forms of rationing don't have. But it doesn't solve all the administration problems. The coupon creates a price-protected market possibly $0.30 per gallon above the pump price. Efforts to circumvent this protection would give rise to black market and other illegal operations. Experience with illegal actions such as price gouging during the gasoline shortage in early 1974 suggests that gasoline rationing regulations with exchangeable coupons must provide adequate audit and enforcement procedures.

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Statistical Decision Theory in a Macro Simulation Model: Feed Grain Sector

By Fred C. White and W. C. McArthur

A method for taking uncertainty into account when formulating aggregate agricultural policies is applied to the feed grain program. The impact of alternative feed grain programs on net farm income, Government payments, and feed grain production in the Southeastern Coastal Plains is shown. A model is developed to explain planted acreages of the major competing crops. The effects of alternative feed grain programs are evaluated using Monte Carlo simulation to account for random variation. Confidence intervals are placed on estimates of income and production resulting from selected feed grain programs.

Keywords: Agricultural policies, Farm income, Methodology, Production, Simulation, Uncertainty.

Policymakers have at their disposal a wide array of policy instruments capable of affecting U.S. agricultural production and farm income. Considerable progress has been made in constructing aggregative models which can be used to forecast production changes resulting from use of these policy instruments. Results of these models have been severely limited by the nature of their forecasts. For a given combination of expected prices and Government programs, these models provide a single estimate of expected production response. Although this estimate is an important ingredient in decisionmaking, other valuable information is ignored.

More specifically, risk and uncertainty have not been incorporated into these models. As a result, no estimate is made of the distributions of production or farm income. Such distributions would show the probability of obtaining a specified level of production or income. Information on such probability distributions could aid policymakers in choosing among alternative policies. For instance, programs with similar expected levels of net farm income may have different probabilities of producing an unacceptably low level of net farm income.

Objectives

This study illustrates a method for developing distributions for aggregate production response and aggregate farm income and reports some empirical results of application of the method to feed grain production in the Southeastern Coastal Plains. The procedure for developing these distributions is as follows:

(1) Develop a system of simultaneous equations which can explain the production response of feed grains and competing crops to policy alternatives.

(2) Develop distributions of aggregate feed grain production and farm income under specified policy alternatives and expected price alternatives. Specifically, the impact of alternative levels of Government diversion requirements upon feed grain production, farm income, and cost of Government programs is analyzed.

Study Area

The Southeastern Coastal Plains are characterized by a diversified agriculture. Major crops include cotton, corn, soybeans, peanuts, and tobacco. The area also includes a substantial acreage of wheat and oats. Barley acreage is relatively small. Pasture crops and several minor crops occupy the rest of the cropland in this area.

Determinants of Farm Income

Net farm income derived from feed grains and related crops depends on planted acreage, yields, prices, Government payments, and production costs.

Yields and prices determine per acre gross income derived from farm marketings. Economic, technological, and institutional factors are responsible for any major trends in yields. Expected yields are based on these trends. Much of the year-to-year variation in yields is due to influences of weather. Expected prices used in this analysis are based on estimates developed for supply response research by the Aggregate Production Analysis Team (APAT) in the former Farm Production Economics Division, now the Commodity Economics Division, ERS. Actual price may deviate from expected price for any reason that shifts supply and demand of the various crops.

Economic and institutional forces which affect farmers' planting plans are major factors that determine number of acres to be planted. Certain other factors, such as weather at time of planting, may be largely responsible for deviations from expected planted acreage. A major portion of this analysis involves construction of an econometric model to explain economic factors which influence acreage planted. The nature of this model is discussed in the next section.

Government payments constitute an important component of net farm income for this area. Since these payments are based on projected yields, market price, and parity, there is considerable leeway for adjustments in the rate. Requirements to participate in the program can vary over a wide range of values. Payments may also be made for voluntary diversion above minimum requirements. Thus, there are many policy alternatives which can have an effect on net farm income.

Cost of production for different crops also influences net income. Budgets by enterprise and size of farm have been estimated for the area (*3*). These costs were assumed to apply throughout the analysis.

Planted Acreage Model

Almost all feed grain in the area is produced on commercial farms which have several alternative enterprises for which the cropland can be used. Therefore, it seems likely that farmers would respond to economic factors which change their income situation. It is hypothesized that farmers would respond to higher expected net returns by increasing their planted acreage. Actual response is restricted by the availability of land, labor, and capital.

Present Government programs for cotton, tobacco, and peanuts make these crops more profitable than feed grains.[1] Their acreage, however, is fairly well determined by Government programs. Soybeans, wheat, barley, and oats compete with feed grains for the remaining cropland acreage. As net returns from these competing crops rise, substitution for feed grain acreage is expected to occur.

[1] Budgets developed by McArthur (*3*) show relative profitability of alternative enterprises.

The Variables

Notations included in the planted acreage model are as follows:

Variables associated with commodity i:

A_i = number of acres planted
Y_i = yields in bushels per acre
P_i = expected price per bushel
PC_i = variable production cost per acre
NR_i = net returns to overhead, management, and fixed resources per acre excluding Government payments ($P_i \times Y_i - PC_i$)
DP_i = Government diversion payment rate for feed grain set-aside
VP_i = Government voluntary diversion payment rate for set-aside above minimum requirement
MN_i = minimum proportion of allotted base which must be set aside to participate in Government program

Subscripts (commodity):

FG = feed grains
SA = feed grain set-aside
SB = soybeans
WH = wheat
NP = nonprogram commodities (barley and oats)
TL = combined acreage of feed grains, soybeans, wheat, nonprogram crops, and feed grain set-aside

The Six-Equation Model

Equations fitted:

$$(1)\quad A_{FG} = f(A_{SA}; NR_{FG}, NR_{SB}, NR_{WH}, NR_{NP})$$

$$(2)\quad A_{SA} = f(A_{FG}; MN_{FG}, DP_{FG}, VP_{FG}, NR_{SB})$$

$$(3)\quad A_{SB} = f(A_{FG}, A_{SA}; NR_{SB}, NR_{WH}, NR_{NP})$$

$$(4)\quad A_{WH} = f(A_{SA}; NR_{WH}, NR_{FG}, NR_{SB}, NR_{NP})$$

(5) $A_{NP} = f(A_{SA}; NR_{NP}, NR_{FG}, NR_{SB}, NR_{WH})$

These equations depict the interrelationships hypothesized to exist in the feed grain planted acreage model. Endogenous relationships are expected to exist (1) among feed grain and soybean acreages and feed grain set-aside acreage and (2) among feed grain set-aside acreage and wheat and nonprogram commodity acreages. In addition, planted acreage of a commodity is expected to be related to net returns of that commodity and major competing commodities. Set-aside acreage is expected to be exogenously related to Government policy alternatives.

Equation (6) is an identity which constrains the system on planted acreage.

(6) $A_{TL} = A_{FG} + A_{SA} + A_{SB} + A_{WH} + A_{NP}$

Total acreage is equal to cropland in the area, excluding acreage of peanuts, tobacco, cotton, and set-aside acreage in nonfeed grain programs. Thus, it is the sum of acreages in feed grains, soybeans, wheat, nonprogram crops, and feed grain set-aside.

Data for the Planted Acreage Model

Data from linear programming results were used to estimate the parameters of the planted acreage model. The linear programming model used in the analysis is an aggregate crop production model designed primarily to make estimates of the impact of Government commodity programs and commodity price changes on the acreage and production of major crops for 1 or 2 years in the future. The units of analysis include aggregates of two farm-size situations within the geographic production area.

The basic linear programming model was made up of a set of expected prices for 1971 and the 1971 feed grain program. Solution of this model showing planted acreage of each commodity was used as one observation in the regression analysis. Then the expected price of one commodity was incremented by $0.05 over a range applicable to that commodity. The solution obtained with each new price produced an additional observation on planted acreages by commodity to be used in the regression analysis. In turn, expected prices were incremented for each commodity. While any one price was varying, every other price was held constant at its expected level.

In addition, observations for the regression analysis were generated from linear programming by incrementing Government policy parameters. Program alternatives underlying the analysis include a required set-aside of 25 to 30 percent of the feed grain base and 85 percent of the wheat allotment. Barley was excluded from the feed grain program. Voluntary diversion of up to 20 percent of the feed grain base and 75 percent of the domestic wheat allotment was allowed. Set-aside rates used in the analysis were $0.25 to $0.40 per bushel for feed grain and $1.66 per bushel for wheat. The analysis also included variable payment rates for voluntary feed grain set-aside ranging from $0.20 to $0.52 per bushel.

Twenty-eight observations for the regression analysis were produced from the linear programming model. Each observation showed estimates of equilibrium values for planted acreages of feed grain, soybeans, wheat, and nonprogram commodities and feed grain set-aside acreage given a specified set of expected prices and specified Government feed grain program.

Statistical Estimates of the Planted Acreage Model

Table 1 shows the planted acreage equations estimated statistically by two-stage least squares. Most coefficients are significantly different from zero, and all signs of the coefficients are those predicted by theory. These equations explained from 56 to 98 percent of the variation in the sample data on planted acreages.

The following conclusions can be drawn from the equation of feed grain acreage response. First, an increase in expected net returns of feed grains has a statistically significant effect in increasing feed grain acreage. Second, a decrease in net returns of soybeans and wheat is associated with an increase in feed grain acreage. A given decrease in net returns of soybeans is associated with a larger increase in feed grain acreage than the same reduction in net returns of wheat. Finally, the Government's feed grain program also has a significant influence on feed grain production. As feed grain set-aside acreage increases, feed grain production decreases.

Set-aside acreage under the feed grain pro-

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Table 1. Simultaneous equations explaining planted acres of feed grains, soybeans, wheat, and nonprogram crops and acres of feed grain set-aside

Variable	Planted acres of feed grains	Acres of feed grain set-aside	Planted acres of soybeans	Planted acres of wheat	Planted acres of nonprogram crops
Constant	1,332.0	168.0	2,512.0	242.4	169.9
Endogenous variables:					
Acres of:					
Feed grains		– 0.087	– 0.799		
		[a](– 2.189)	(– 24.01)		
Feed grain set-aside	– 0.457		– 0.7252	– 0.1006	– 0.043
	(– 1.637)		(– 11.32)	(– 1.795)	(– 1.821)
Exogenous variables:					
Net revenue of:					
Feed grains	8.341			– 1.098	– 0.223
	(5.881)			(– 3.873)	(– 1.874)
Soybeans	– 8.605	– 3.742	2.074	– 0.798	– 0.353
	(– 4.126)	(– 6.233)	(5.181)	(– 1.196)	(– 2.015)
Wheat	– 0.331			0.089	
	(– 1.360)			(1.669)	
Nonprogram crops				– 0.481	1.642
				(– 1.448)	(12.94)
Minimum requirement for feed grain set-aside		782.0			
		(5.764)			
Payment rate for feed grain set-aside		631.1			
		(6.799)			
Voluntary diversion payment rate for feed grains		148.5			
		(6.757)			
R^2	0.721	0.879	0.979	0.564	0.891

[a]Numbers in parentheses are *t*-values.

gram depends on program payments and requirements and on profitability of not participating. Larger set-aside payments per acre result in more set-aside acreage. An increase in the proportion of feed grain base required for set-aside to participate in the Government program results in a net increase in set-aside acreage. An increase in Government payments for voluntary diversion above the minimum requirement for participation results in an increase in set-aside acreage. Highly profitable soybean or feed grain production outside Government programs results in less participation in the feed grain program.

Each equation explaining planted acreage of soybeans, wheat, and nonprogram commodities shows a positive relationship between planted acreage of the commodity and its net returns. In other words, an increase in the net returns of a product relative to net returns of product substitutes results in an increase in production of the commodity in question. Acreages of all three commodities are endogenously related to feed grain set-aside acreage. In addition, soybean acreage is endogenously related to feed grain acreage. Acreages of wheat and nonprogram commodities are competitive with one another, as well as with feed grains and soybeans.

The planted acreage model, equations (1) to (6), forms the basis for estimating variability of production and farm income. The following section describes how the planted acreage model is combined with other information to develop probability distributions for production and farm income.

Monte Carlo Simulation

Because of the interaction of many variables and the complexity of the system, it is extremely difficult to develop distributions of net farm income, feed grain production, and feed grain set-aside acreage by standard analytical techniques.[2] However, Monte Carlo—stochastic simulation—methods can be used to determine these distributions.

[2]The study by White and Eidman (*5*) presents one method for developing these distributions by standard analytical techniques.

Simulating Outcomes

Simulated statistics are generated by supplying sets of random numbers (Z) into the system under study (*4*). Statistics simulated by use of these sets of random numbers can possess desired characteristics of specified means, variances, and covariances. Through repeated sampling of system outcomes from input of these random numbers, behavior of the system can be analyzed. More specifically, distributions of the desired statistics can be developed.

Generation of a series of m outcomes (prices and yields) for n events (commodities) for a given mean vector and variance-covariance matrix may be described by the following equation:

$$X_i^* = \overline{X} + CZ_i \qquad i = 1 \text{ to } m$$

where X^* is an $(n \times 1)$ vector of generated outcomes, $\overline{X}$ is an $(n \times 1)$ vector of expected outcomes, C is an $(n \times n)$ matrix of coefficients, and Z is an $(n \times 1)$ vector of random normal deviates. The C matrix, derived from the variance-covariance matrix, insures the correlation of events at the desired level. Development of the C matrix is presented in the appendix.

Using the procedure for correlating events given above and historical data, many prices and yields were generated for each commodity so that the effect of various Government policies could be studied. Since the correlating procedure used historical data, the correlation matrices for generated prices and yields were similar to the correlation matrices for the historical data.[3] Generated prices and yields of feed grains, soybeans, wheat, and nonprogram crops were used to determine production and farm income. Mean and variance-covariance matrices for the specified commodities derived from 1962-71 data are shown in table 2. The only negative relationship in yields has been between feed grains and wheat. Yields of wheat and nonprogram commodities have historically been closely related. Also, prices of feed grains and soybeans have been closely related.

The system of simultaneous equations in table 1 can be solved to determine planted acreage of each crop and set-aside acreage of feed grain. In using this system of equations for analytical purposes, the standard procedure is to insert values for the predetermined variables within the system and to simultaneously estimate all the endogenous variables. Methods for solving systems of equations are presented in Friedman and Foote (*2*, pp. 81-85).

For this analysis, planted acreages of the various commodities are the endogenous variables, while expected net returns and Government program options are considered as predetermined variables. In addition, the error terms are considered to be predetermined variables. The first step in solving this system is the substitution of the identity, equation (6), into one of the other equations. Then solution of the

[3] Since this analysis is concerned with only one area within the United States, prices and yields are assumed to be independent of each other. Techniques developed in this paper could easily take into consideration the relationship between prices and yields on a national basis.

Table 2. Means, variances, and covariances for the analysis

Commodity	Means	Variance-covariance matrices			
		Feed grain	Soybeans	Wheat	Nonprogram crops
Yields:					
Feed grain (bu/acre)	43.64	84.852	7.732	– 0.368	6.034
Soybeans (bu/acre)	20.17		10.955	6.102	6.807
Wheat (bu/acre)	30.80			23.547	24.939
Nonprogram crops (bu/acre)	39.57				32.443
Prices:					
Feed grain ($/bu)	1.30	0.045	0.045	0.005	0.002
Soybeans ($/bu)	2.60		0.075	0.014	0.002
Wheat ($/bu)	1.50			0.010	0.001
Nonprogram crops ($/bu)	0.82				0.001

condensed five-equation model ensures that estimates of acres devoted to the various crops will equal total acres available.

The error terms were generated using the random number generator discussed above. For each observation, error terms were generated for equations (1) through (5). This procedure was repeated m times. The variance-covariance matrix developed from the residuals of estimated acreage equations was used in generating the error terms. Thus, the correlation between any two error terms using generated data was similar to the correlation between the respective residuals.

Results of Monte Carlo Simulation

Given expected prices for 1971,[4] it is possible to examine the impact of alternative feed grain programs. Table 3 presents distributions of aggregate net farm income, feed grain production, and feed grain set-aside acreage for alternative payment rates for participation in the feed grain program. The table is designed so that for a given level of expected prices, policymakers can compare income (or production) distributions associated with alternative programs.

To derive this table, m was set equal to 300. Thus 300 observations of prices, yields, and equilibrium acres were calculated and used to estimate net farm income. Net income from the sale of commodity i is the difference between value of production and variable cost:

$$NI_i = (Y_i^* P_i^* - PC_i) A_i^*$$

where NI is net income, Y^* is generated yield, P^* is generated price, PC is variable production cost, and A^* is the generated number of planted acres. This calculation is made for net farm income from feed grains, soybeans, wheat, and nonprogram commodities. Summation of net farm income from the various commodities yields one observation of net farm income for the area.

This procedure is repeated 300 times to give 300 values of net farm income, feed grain production, and feed grain set-aside acreage. The 300 values of net farm income are ranked in ascending order. The probabilities of achieving various levels of net farm income are estimated from this ordered array. This scheme is used to derive the values of net farm income in table 3. The various columns of the table are found by using the above procedure and the specified participating requirements for the feed grain program and the specified expected prices. The information on feed grain production and feed grain set-aside acreage in table 3 is also estimated from the respective ordered arrays.

Results in the first data column of table 3 are interpreted as follows. This column presents the probability distributions for net farm income, feed grain production, and feed grain set-aside acreages, assuming that the set-aside requirement for feed grains is 25 percent of the feed grain base and expected prices are those prices projected for 1971. Under these conditions, there is a 5 percent probability that aggregate net farm income for the study area will be less than $1.77 million and a 10 percent probability that it will be less than $18.85 million. At the other end of the probability distribution, there is a 90 percent probability that net farm income will be less than $122.91 million and a 95 percent probability that it will be less than $138.74 million. The expected value of net farm income is $68.21 million. Expected feed grain production is 60.75 million bushels with a 5 percent probability that feed grain production will be less than 42.91 million bushels. Other columns can be interpreted in a similar manner.

This table presents two policy alternatives under two sets of expected prices. For 1971 expected prices, the two policy alternatives in data columns (1) and (3) represent alternative programs that a policymaker might actually have under consideration. The first variables that he might wish to compare are the expected values of net farm income, Government payments, and feed grain production. Average net farm income is $68.2 million and $70.5 million with set-aside requirements of 0.25 and 0.30, respectively. The higher net farm income associated with the higher set-aside requirement results from the aggregate relationship between lower volume and higher price for the United States. However, for the area under analysis, there appears to be little difference in feed grain production under the two options. Even though diverted acreage

[4] Expected prices per bushel for 1971, which were developed by APAT and used in this analysis, were $2.24 for soybeans, $1.35 for wheat, $0.78 for nonprogram commodities, $1.18 for feed grains with 0.25 set-aside requirement, and $1.23 for feed grains with 0.30 set-aside requirement.

Table 3. Distribution of net farm income, feed grain production, and feed grain set-aside acreage and expected value of Government payments by alternative set-aside requirements for participation in the feed grain program and alternative feed grain prices

Probability of obtaining smaller value	Set-aside requirements for feed grain program			
	0.25 with feed grain price at—		0.30 with feed grain price at—	
	Base	Base plus 10¢	Base	Base plus 10¢
	Net farm income (million dollars)			
.05	1.77	6.52	4.06	8.93
.10	18.85	23.13	20.56	25.23
.20	35.47	40.54	37.71	42.25
.50	67.80	73.98	70.00	76.64
.80	102.94	110.97	105.39	113.58
.90	122.91	131.71	125.39	134.39
.95	138.74	148.79	141.57	151.83
Expected value	68.21	74.82	70.45	77.23
	Government payments (million dollars)			
Expected value	20.95	20.83	19.80	19.68
	Feed grain production (million bushels)			
.05	42.91	44.89	43.14	45.13
.10	47.13	49.24	47.38	49.48
.20	51.19	53.48	51.46	53.74
.50	60.65	63.38	60.97	63.69
.80	69.73	72.74	70.09	73.09
.90	75.65	78.96	76.03	79.35
.95	80.96	84.50	81.38	84.91
Expected value	60.75	63.45	61.07	63.77
	Feed grain set-aside acreage (thousand acres)			
.05	488.88	484.71	527.50	523.32
.10	490.37	486.19	528.98	524.79
.20	493.35	489.17	531.96	527.78
.50	498.12	493.94	536.73	532.55
.80	501.89	497.71	540.50	536.32
.90	503.41	499.23	542.02	537.84
.95	504.40	500.22	543.01	538.82
Expected value	497.54	493.36	536.15	531.97

increased substantially under the higher set-aside requirement, much of the increased diversion came at the expense of commodities other than feed grains because feed grains experienced an increase in price.

In addition to expected values, the policy-maker might wish to examine the probabilities of obtaining a specified net farm income for feed grain production. He may be unwilling to support a policy that has a 0.10 probability of providing less than $20 million in net farm income from farm marketings. If so, he would prefer the set-aside requirement of 0.30 with 1971 expected prices.

Thus far, attention has been focused on the probability of obtaining a net farm income, etc., that is less than a stated value. However, a policy decisionmaker may also be interested in the probability of other interval estimates, such as the interval around the expected value of net farm income. A confidence interval can be used to state the chance that an observation will fall in a given range. The results in table 1 can easily be converted to confidence intervals as follows:

$$P(Z_L - Z - Z_U) = (1 - \alpha_L - \alpha_U)$$

where α is probability, L is lower, and U is upper.

Such a method can best be described by means of a particular example. Given expected prices and Government programs used in deriving column (1) of table 3, 90 percent of the time net farm income will be between $2 million and $139 million. The choice of 90 percent is arbitrary; we could have selected a 60 percent or 80 percent confidence interval. With a longer interval, the probability is higher that the observation will fall within the interval. However, a large interval does not offer much precision. In comparison with the 90 percent interval, 60 percent of the time net farm income will be between $35 million and $102 million.

Comparison of Simulation and Linear Programming Results

Since the simulation model is based on results from linear programming, it appears useful to compare results of the two methods. Although simulation estimates of net farm income were consistently above those from linear programming (see table 4), the effects of changing a policy variable were very similar in the two models. Note that with 1971 expected prices and 0.25 set-aside requirement, estimates of expected net income were $68.21 million with simulation and $67.94 million with linear programming. With an increase in expected feed grain price of $0.10 per bushel, simulation results showed average net farm income would increase $6.61 million, compared with $6.32 million with linear programming.

Some differences between simulation and linear programming can be accounted for by the restrictions in the linear programming formulation. Although any appropriate restrictions can be incorporated in the simulation model, the present analysis did not consider such restrictions.

Summary and Conclusions

This study developed a simultaneous equation model to explain planted acreages of feed grains, wheat, soybeans, and nonprogram crops. The statistical model quantified the impact of expected prices, yields, and production costs on planted acreages of the various crops. The impacts of selected Government program alternatives were also estimated.

The planted acreage model served to develop probability distributions for farm income and production. For a given Government program and set of expected prices, a sample of planted acreages was simulated. In addition, simulated prices and yields were combined with the

Table 4. Net farm income estimates using simulation and linear programming

Item	Set-aside requirements for feed grain program			
	0.25 with feed grain price at—		0.30 with feed grain price at—	
	Base	Base plus 10¢	Base	Base plus 10¢
	Million dollars			
Simulation:				
Net farm income	68.21	74.82	70.45	77.23
Net farm income above base column (1)		6.61	2.24	9.02
Change in net farm income from 10¢-per-bushel increase in feed grain price		[a]6.61		[b]6.78
Linear programming:				
Net farm income	67.94	74.24	69.60	76.29
Net farm income above base column (1)		6.32	1.66	8.35
Change in net farm income from 10¢-per-bushel increase in feed grain price		[a]6.32		[b]6.69

[a]Estimate is calculated by subtracting net farm income in data column (1) from net farm income in data column (2).

[b]Estimate is calculated by subtracting net farm income in data column (3) from net farm income in data column (4).

simulated planted acreages to determine an array of simulated farm income observations. These income observations represent a sample of possible values for the farm income variable which takes into consideration the historical interrelationships between prices, yields, and planted acreages. These income observations were then used to estimate the probability of obtaining a specified level of farm income. Thus the results introduce an additional dimension—variation of production and income—to conventional evaluations of policy alternatives.

Statistical decision theory provides tools to deal with the interaction of variables and with risk and uncertainty in a way that greatly increases the ability to manage complex systems such as aggregate feed grain production. By providing policymakers with information on the distribution of farm income and production, statistical decision theory will improve their understanding of the consequences of various policy alternatives. Thus they will be better prepared to choose among the alternatives according to how they perceive public preferences. Extension of procedures outlined in this study should aid income stability by improving policy decisionmaking.

This analysis did not attempt to evaluate the effectiveness of the linear programming results in predicting planted acreages. However, the variation between actual and predicted planted acreages could be incorporated in the model. This extension would improve the accuracy of the farm income and production estimates.

Since this study was concerned with production in only one region of the United States, price and quantity of a commodity were assumed to be unrelated. However, further research could extend the analysis to account for interrelationships among various price and quantity variables. Once production (per acre yields and planted acreage) is simulated, it could be inserted in an estimated demand model to determine price. This procedure could take into account current levels of such exogenous variables as per capita income and foreign demand.

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Appendix

Let V be the variance-covariance matrix of X. Clements, Mapp, and Eidman (*1*) reported that:

$$(1)\quad V = E(CZZ'C')$$

where C is lower triangular. Since ZZ' is composed of random normal deviates with expected value of zero and variance of one, the expected value of equation (1) gives the following expression of the variance-covariance matrix:

$$(2)\quad V = CC'$$

To obtain C from V, the so-called "square root method" can be used. This method provides a set of recursive formulas for the computation of the elements of C (*3*).

$$c_{i1} = \frac{\sigma_{i1}}{\sigma_{11}^{1/2}}, \qquad 1 \leqslant i \leqslant m$$

$$c_{ii} = \left(\sigma_{ii} - \sum_{k=1}^{i-1} c_{ik}^2\right)^{1/2} \qquad 1 < i \leqslant m$$

$$c_{ij} = \frac{\left(\sigma_{ij} - \sum_{k=1}^{j-1} c_{ik}c_{jk}\right)}{c_{ij}} \qquad 1 < j < i \leqslant m\,.$$

Demand for Feed Ingredients by U.S. Formula Feed Manufacturers

By Karl D. Meilke[1]

In 1969, formula feed manufacturers utilized 23.1 percent of all the feed grains and wheat fed to livestock. Estimates of aggregate demand by the mixed feed industry for corn, oats, barley, grain sorghum, and wheat are presented. As expected, all of the feed grains have elastic demands. Grain sorghum has the highest direct price elasticity (–5.42), followed by corn (–4.81), oats (–3.82), and barley (–2.75). The direct price elasticity of wheat is estimated to be –0.85. The location of feed manufacturers is found to play an important role in the demand for feed ingredients.

Keywords: Barley, Corn, Demand, Demand elasticity, Demand functions, Feed grains, Grain sorghum, Livestock feeding, Oats, Wheat.

Use of feed grains by formula feed manufacturers in the United States has been increasing for at least the past 20 years. In 1949, 10.2 million tons of feed grains and 1.3 million tons of wheat were utilized by the formula feed industry (*8*). This represented less than 11 percent of the total feed grains and wheat fed in 1949. By 1969 (the latest year for which these data are available) the formula feed industry was consuming 31.5 million tons of feed grains and 0.8 million tons of wheat, or 23.4 percent of the total feed grains and wheat fed to livestock (*6*). The total amount of the individual feed grains fed and the percentages used in formula feed for 1949 and 1969 are shown in table 1.

The mix of feed grains used by formula feed manufacturers has also changed since 1949 when 6.9 million tons of corn, 0.6 million tons of grain sorghum, 0.8 million tons of barley, 1.9 million tons of oats, and 1.3 million tons of wheat were used in manufactured feeds (*8*). By 1969, 19.8 million tons of corn, 7.6 million tons of grain sorghum, 2.4 million tons of barley, 1.7 million tons of oats, and 0.8 million tons of wheat were utilized in formula feeds (*6*, p. 17). The use of corn and barley tripled while the use of grain sorghum increased 10 times and the use of oats held steady.

There are three basic types of formula feeds, each with different requirements for ingredients. They are complete feed, supplement feed, and premix (*6*, p. 2). Complete feeds contain all the nutrients needed in the nonroughage portion of an animal's diet. Complete feed is the major user of feed grains and is the dominant type of feed manufactured in States deficit in the production of feed grains. Supplement feed is combined with other feed ingredients to improve the nutritive balance in an animal's diet. Supplements are produced heavily in feed grain surplus States where they are mixed with farmers' home-grown grain. Supplements contain large amounts of high protein ingredients as well as vitamins and minerals. Premixes are formulations of one or more microingredients, such as vitamins, trace minerals, or drugs, mixed with a carrier. The premix is used to distribute microingredients evely throughout a formula feed. Premixes are heavy users of all the microingredients, and their production is centered in the Corn Belt.

Feed manufacturers are expected to be more responsive than individual livestock producers to changes in the price of individual ingredients. This is because the large amounts of feed mixed by feed processing firms enables them to expend considerable resources in the assessment of the relative prices of the various ingredients and of interstate price differentials. Also, the individual livestock producer is unlikely to sell home-grown grain and then repurchase some other feed grain unless relative prices are very favorable.

Linear programming has been widely adopted by the formula feed industry and is used to

[1] I would like to acknowledge the encouragement and assistance given by Dale C. Dahl, Department of Agricultural and Applied Economics, University of Minnesota, and the two journal referees. Valuable insights into the data collection procedures were provided by George Allen and Earl Hodges, ERS, and Fred Thorp, SRS, USDA.

Table 1. Use of feed grains and wheat by U.S. formula feed manufacturers, 1949 and 1969

Crop	Crop year 1949			Calendar year 1969		
	Total amount fed	Amount used in formula feed	Formula feed use/ total feed use	Total amount fed	Amount used in formula feeds	Formula feed use/ total feed use
	Mil. tons	*Mil. tons*	*Percent*	*Mil. tons*	*Mil. tons*	*Percent*
Corn	79.4	6.9	8.7	99.8	19.8	19.8
Grain sorghum	1.8	0.6	33.3	17.6	7.6	43.2
Oats	19.1	1.9	9.9	11.6	1.9	16.4
Barley	3.3	0.8	24.2	5.6	2.4	42.8
Wheat	3.3	1.3	39.4	5.8	0.8	13.8
Total	106.9	11.5	10.7	140.4	32.5	23.1

Sources: *The Formula Feed Industry, 1969: A Statistical Summary*, U.S. Dept. Agr., Statis. Bul. 485. *Feed Consumed by Livestock: Supply and Disposition of Feeds, 1949-50 by States*, U.S. Dept. Agr., Statis. Bul. 145.

determine least-cost rations. With the aid of linear programming, feed processors can vary the composition of their mixed feeds within limits set by nutritional constraints. As early as 1956, Mighell pointed out that the expansion of the formula feed industry would have a stabilizing influence in feed grain markets by tending to keep the prices of alternative feeds more nearly in line with their marginal feed substitution values (*13*).

A large formula feed industry has two implications for grain marketing. First, an increase in the level of substitution between grains reduces the extent to which the price of a single grain can be set independently of the prices of other feeds, should this ever be desirable from a policy point of view. Second, geographic variations in the prices of ingredients could result in considerable increases in interstate grain shipments.

This model is an attempt to show how the aggregate feed manufacturing industry reacts to changes in the prices of the major feed ingredients. Linear programming can indicate how a cost-minimizing firm should adjust its ingredient use to obtain a least-cost ration under a certain set of specific nutritional constraints, but it cannot indicate how industry demand will change, given the different types of formula feed produced.

This study has at least two purposes. They are (1) to indicate the relative degree of substitution among the feed grains, and (2) to show how price variations may affect the ingredient needs of the formula feed industry under different ingredient price and growth assumptions.

Objectives

This study provides estimates of the demand by formula feed manufacturers for corn, oats, barley, grain sorghum, and wheat. The study answers the following types of questions:

(1) What are the direct and cross price elasticities among the different feed grains?

(a) What effect would a high price for one of the major feed grains, perhaps as the result of a poor crop, have on the demand for it and the other feed grains?

(2) What effect does location play in the demand for feed grains?

(3) How will the expansion of the formula feed industry affect the demand for feed ingredients?

(4) Do different types of formula feed have different ingredient needs?

There is no published information available that estimates the aggregate response of feed manufacturers to ingredient price changes. Likewise, although the feed grains have always been assumed to be very close substitutes, no one has been able to estimate the relevant cross elasticities of demand. This study should fill a part of this knowledge gap.

Data

The quantity data used in this analysis come from a survey of feed mills conducted by the Economic Research Service (*6*). The survey was an attempt at a complete census of all U.S. feed mills producing over 1,000 tons of formula feed

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in 1969. The survey was conducted under the authority of the Defense Production Act of 1950, as amended, and response to the questionnaire was mandatory. Of the feed milling establishments surveyed, 7,267 produced over 1,000 tons of formula feed in 1969. The sample was expanded by approximately 9 percent to allow for unusable questionnaires and firms that may have been missed by the survey. Therefore, the final compilation of data represented the responses of 7,917 feed processing establishments.

Feed ingredient usage was reported by 4,833 firms that mixed some primary feed in 1969. A primary feed is defined to be a feed processed from the ground up, although it may contain a premix used at a rate of less than 100 pounds per ton of finished feed (*6*, p. 2).

Prices paid for feed ingredients were not collected along with the quantity data in the survey of feed mills. Therefore, before any demand analysis can be undertaken, prices have to be obtained. The only comprehensive set of price data collected, by State, is published by the Statistical Reporting Service and relates to the prices received by farmers for feed grains (*20*). The farm price in different States reflects the transportation differentials between States and any premium or dockage due to quality differences. The farm price for the feed grains is calculated by taking a simple average of the monthly prices received by farmers during calendar year 1969. The monthly prices reflect the cost of storing grain from one month to the next. Feed manufacturers purchase grain steadily throughout the year and do not store ingredients for long periods. Data in the feed mill survey indicate that feed manufacturers maintain slightly more than 30 days inventory of grain (*6*, p. 45). Hence, it is not necessary to weight prices more heavily in some months than others in computing average farm prices.

A study by the U.S. Department of Agriculture also indicated that seasonality in the production of manufactured feed was not great. Production varied from a peak of 8 percent above average in April to 6 percent below average in August (*23*, pp. 30-34).

Since the price data are collected at the farm level, the published prices have to be adjusted to reflect the wholesale price. The margin between the prices received by farmers (farm price) and the prices paid by feed manufacturers (wholesale price) includes charges for handling, assembling, and blending of the grain ingredients. The farm prices of feed grains are adjusted to reflect wholesale prices by adding a margin for the assembly function. The margin is computed from data collected by the U.S. Department of Agriculture on the cost of handling grain at country and terminal elevators in six regions of the United States (*16*).[2]

For some States, prices received by farmers for feed grain are not reported. In these States estimates of the prevailing wholesale prices during 1969 were obtained from private trade sources.[3]

The Model

A single-equation demand function for each of the feed ingredients is estimated using ordinary least squares. Identification of the demand curve is possible, using single-equation methods, if we assume that feed manufacturers consider the major feed ingredient prices as fixed. If feed manufacturers consider feed grain prices fixed, the supply facing a particular firm is perfectly elastic and the regression of quantity on prices provides parameter estimates of the demand curves (*10*, p. 509).

The demand curves for the feed ingredients are obtained using cross section data collected from feed manufacturers for 47 States for calendar year 1969 (*6*, pp. 16-20). None of the major feed ingredients were used in all of the 47 States surveyed. The number of observations for a particular ingredient varies from 45 for corn and oats to 43 for barley, 39 for wheat, and 32 for grain sorghum.

[2] In computing the marketing margin, grain received at the feed mill by truck is assumed to come from a country elevator where it is also received by truck. Eighty percent of the grain received at a feed mill by rail is assumed to originate from a country elevator, and 20 percent from a terminal market where the grain is received by rail from a country elevator. The margin between farm and wholesale prices varies from a low of 3.8 cents per bushel in North Dakota to a high of 6.8 cents per bushel in several Northeastern States.

[3] It is well known that if the independent variables in a multiple regression analysis contain measurement error, the ordinary least squares estimates of the coefficients are biased and inconsistent. In this portion of the study, the chance of measurement error in the price variables is fairly high. For this reason, the estimates of the demand parameters should be interpreted as providing only estimates of the general magnitude for the true demand parameters. J. Johnston, *Econometric Methods* (New York: McGraw-Hill, 1963), pp. 148-176.

The same two basic demand equations are estimated for each of the feed grains. They are:

$$(1)\quad \log Q_i = \log a + b \log P_i + c \log PF_i + d \log CF_i + e \log L_i + f\, CC_i/CF_i + u$$

and

$$(2)\quad \log Q_i = \log a + b \log (P_i/PF_i) + c \log CF_i + d \log L_i + e\, CC_i/CF_i + u$$

where

Q_i = quantity of feed ingredient Q used in State i

P_i = price per ton of feed ingredient Q in State i

PF_i = weighted average price per ton of the other feed grains used in State i

CF_i = quantity of complete formula feed mixed in State i

L_i = a ten-one variable used to indicate the location of State i

The choice of variables to include in each equation is based on derived demand theory and data limitations. The theory of derived demand for feed inputs is developed by King (*9*) and will not be reproduced here. In general the demand for an input depends on the price of the input, the price of other inputs, and the price of the output. In this study the inputs are the feed grains and the output is complete formula feed. Unfortunately it is impossible to calculate a representative price for formula feed in each State. Therefore the quantity of complete formula feed mixed in each State is included as an independent variable in each equation. This variable performs two roles: (1) it accounts for differences in feed grain usage, because of the size of the formula feed industry in each State, and (2) it picks up some of the influence of the excluded price variable assuming price and quantity move in an inverse relationship.[4] The inclusion of the quantity puts certain restrictions on the estimated elasticities. In particular, the demand for each ingredient is estimated assuming the quantity produced, rather than the price of the output, remains constant.

Theoretically, we would expect the sign of the coefficient on P_i to be negative and the sign on PF_i to be positive. We would expect both the direct and cross price elasticities to be greater than one because of the availability of close substitutes.

The sign of CF_i should be positive and close to one. A coefficient of one implies that the use of a feed ingredient varies in direct proportion with the amount of feed produced. In some equations the coefficient for CF_i is constrained to equal one.

For most ingredients, the increased production of certain types of formula feed has a greater impact on their use than the increased production of other types of feed. For this reason the proportion of cattle feed produced in each State is used as a demand shifter. Multicollinearity between CC_i/CF_i and CF_i was not a problem.

L_i is a location variable that indicates whether a State is in the Eastern, Western, or Midwestern region of the United States. Figure 1 indicates the boundaries of the three regions. In general, the West contains States that are deficit in the production of corn but surplus in the production of one or more of the other feed grains. The Midwest contains the Corn Belt States, which are all surplus corn-producing States. The East contains States that are generally deficit in the production of all the feed grains, although there are a few exceptions. For example, North Carolina is a surplus corn-producing State. The location variable is included in the analysis to pick up two possible influences. First, feed manufacturers may be reluctant to use ingredients that are unfamiliar to their customers. This is especially true if the formula feed is sold with an "open label."[5] Second, the location variables may pick up some of the nonfeed costs of using ingredients shipped long distances. For example, North Carolina feed manufacturers may not use barley because delivery from the Northwest is uncertain and because of the extra cost involved in locating distant sources, even though the price of barley, including transportation charges, may be slightly cheaper than corn.

Equation (2) is similar to equation (1) except that relative prices are used instead of absolute prices. This form of the equation constrains the

[4] The use of the quantity of feed mixed in the demand equation can be compared to using the number of animal units in a demand function for all feed grains. For example see, R. J. Foote (*5*).

[5] An open label lists the ingredients included in the formula feed.

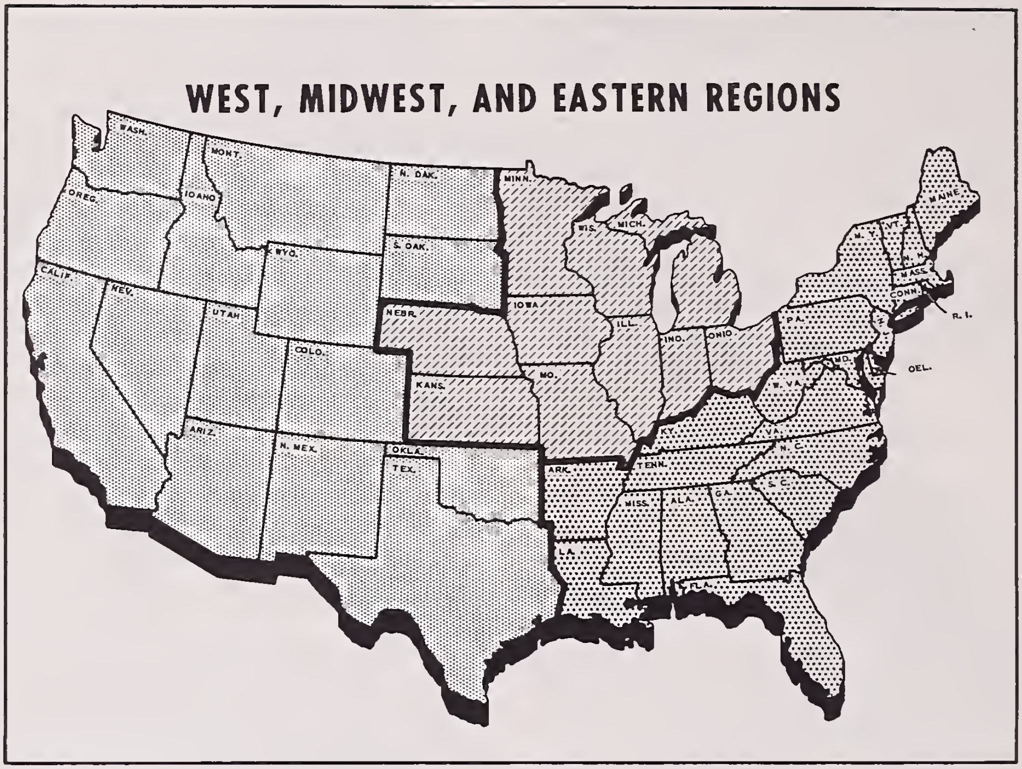

Figure I

direct and cross price elasticities to be equal.

All of the demand equations are estimated using data converted to logarithms, except for the ratio of CC_i to CF_i. Logarithmic equations are preferred when (1) the relationships between the variables are believed to be multiplicative rather than additive; (2) the relations are believed to be more stable in percentage than in absolute terms; and (3) the unexplained residuals are believed to be more uniform over the range of the independent variables when expressed in percentage rather than absolute terms (*4*, pp. 37-38). In this analysis it is felt that the independent variables affect the dependent variables jointly, rather than additively; therefore, log-log demand curves are estimated. If an additive relationship is used for the prices of the various grains in the demand equation, it implies that the effect of a change in the price of corn, for example, on the quantity of corn used would be independent of the price of other feed grains. It seems more realistic to assume that the effect of a change in the price of corn is greater when the prices of the other grains are relatively high and their usage low than when the other grains are relatively cheap and their usage high. This amounts to assuming a declining marginal rate of substitution between corn and other grains. It is one way of arguing for the constant elasticity assumption which is implicit in a multiplicative model.

A word of caution should be given concerning the interpretation of the elasticities calculated in this study. The estimates given below are based on geographic variation in grain prices. This price variation, over space, allows the estimation of cross demand effects that are impossible to detect in time series data, because of the tendency of feed grain prices to move together over time.[6] Therefore the ceteris paribus assumption imposed in estimating the demand curves, namely that the price of one feed grain varies while the prices of the other feed grains are constant, is not likely to be met over time. Hence, the demand elasticities for any individual feed are much larger when holding the prices of

[6] For a discussion of the problem of estimating the cross demand relationships among the feed grains using time series data, see K. W. Meinken (*12*).

other feed grains constant than when allowing the prices of all feed grains to vary together.[7] Consequently, the elasticities calculated in this study are most applicable in determining how the use of a particular feed ingredient will vary when a change in freight rates or cropping patterns makes it more or less expensive relative to other feed grains in a State.

Empirical Analysis: Feed Grains and Wheat

Corn. In 1969, 96.8 percent of the 4,717 feed establishments that used some feed grain reported using corn (*6*, p. 16). Corn is the feed grain against which all other feed grains are measured. It is unexcelled in feeding poultry, and because of its net energy value, corn is one of the best feeds for use in broiler rations. A large percentage of corn is included in most of the high energy mashes for broilers. It is an excellent feed for dairy cattle but is generally used as only a part of the concentrate mixture, frequently being mixed with oats. Corn is also a good beef cattle feed and unsurpassed for growing and fattening pigs (*15*, pp. 415-522).

The statistical estimates of the demand for corn are presented below. The *t* values of the estimated coefficients are in parentheses below the coefficients. Since all of the variables have been converted to logarithms, the coefficients can be interpreted directly as elasticities.

$$(3)\quad QC_i = 2.8 - \underset{(5.13)}{7.01}PC_i + \underset{(4.67)}{5.01}PFC_i + \underset{(11.01)}{1.05}CF_i$$

$$R^2 = 0.77$$

$$(4)\quad QC_i = 5.3 - \underset{(4.71)}{4.81}PC_i + \underset{(2.04)}{1.47}PFC_i + \underset{(18.00)}{0.99}CF_i - \underset{(9.40)}{0.59}\,West - \underset{(3.10)}{0.26}\,Mwst$$

$$R^2 = 0.93$$

$$(5)\quad QC_i = -0.57 - \underset{(4.50)}{5.14}PC_i/PFC_i + \underset{(10.70)}{1.06}CF_i$$

$$R^2 = 0.74$$

[7] For a detailed analysis of the demand for feed grains over time, see K. D. Meilke (*11*).

where

QC_i = quantity of corn used in State i (1,000 tons)
PC_i = price per ton of corn in State i
PFC_i = average price per ton of all feed grains except corn in State i
CF_i = quantity of complete formula feed mixed in State i (1,000 tons)
$West$ = a zero-one variable equal to one for Western States and zero for all other States
$Mwst$ = a zero-one variable equal to one for Midwestern States and zero for all other States

Equation (3) is the simplest formulation of the demand curve for corn. All of the coefficients are significant at the 5 percent level, and the equation explains 77 percent of the variation in the dependent variable. The direct price elasticity in equation (3) is −7.0, and the cross price elasticity is 5.0. Equation (3) predicts a 1 percent change in the use of corn in response to a 1 percent change in the production of complete formula feed.

Equation (4) is the same as equation (3) except that two location variables have been added. The major effect of this adjustment is to lower the direct and cross price elasticities to −4.81 and 1.47, respectively. Holding all other variables constant, States will use less corn than those in the Midwest or the East. According to equation (4) a change in the price of corn will have about three times the effect on the quantity of corn used as will a similar change in the average price of the other feed grains.[8]

In equation (5) the two elasticities are constrained to be equal, and the estimated elasticity is found to be −5.14.[9]

Grain sorghum. Grain sorghum was utilized by 62.0 percent of the feed processing firms

[8] Due to the close correlation among the location variables and the type of feeds mixed in the different regions, it was difficult to determine whether the different rates of use were due to the difference in the type of feed mixed or location. If the difference is due to the type of feed mixed, then increases in the production of poultry feed will have a much larger effect on the use of corn than increases in the production of other types of feed.

[9] If the location variables are added to equation (5), the estimated elasticity falls to approximately one-half of that found in equation (5).

reporting ingredient usage in 1969 (*6*, p. 16). Grain sorghum is well liked for fattening cattle and produces nearly as rapid gains as corn. The feeding value of grain sorghum is close to that of corn for poultry, when used in well balanced rations. If a large proportion of grain sorghum is used in a broiler ration, it will produce white skinned and shanked birds. Grain sorghums are excellent in feeding swine (*15*, pp. 453-456).

Four demand curves for grain sorghum were fitted statistically and are presented below:

(6) $$QGS_i = -4.98 - \underset{(2.32)}{7.50}PGS_i + \underset{(2.10)}{9.12}PFGS_i + \underset{(3.42)}{0.93}CF_i + \underset{(2.60)}{0.87}Mwst + \underset{(5.55)}{1.64}West$$

$$R^2 = 0.61$$

(7) $$QGS_i = -2.42 - \underset{(2.35)}{7.48}PGS_i + \underset{(3.91)}{0.99}CF_i + \underset{(2.78)}{0.76}Mwst + \underset{(5.65)}{1.60}West$$

$$R^2 = 0.60$$

(8) $$QGS_i = -\underset{(1.53)}{4.90} - \underset{(1.53)}{5.42}PGS_i + \underset{(1.46)}{6.77}PFGS_i + \underset{(3.71)}{1.04}CF_i + \underset{(1.35)}{0.88}CC_i/CF_i + \underset{(1.92)}{0.68}Mwst + \underset{(2.65)}{1.18}West$$

$$R^2 = 0.63$$

(9) $$QGS_i = -2.78 - \underset{(1.54)}{5.35}PGS_i/PFGS_i + \underset{(4.21)}{1.09}CF_i + \underset{(1.41)}{0.90}CC_i/CF_i + \underset{(2.00)}{0.59}Mwst + \underset{(2.65)}{1.14}West$$

$$R^2 = 0.63$$

where

QGS_i = quantity of grain sorghum used by formula feed manufacturers in State i (1,000 tons)

PGS_i = price per ton of grain sorghum in State i

$PFGS_i$ = average price per ton of all feed grains except grain sorghum in State i

$West$ = a zero-one variable equal to one for the Western States and zero for all other States

$Mwst$ = a zero-one variable equal to one for the Midwestern States and zero for all other States

CC_i/CF_i = cattle feed produced as a percentage of total complete feed mixed in State i

CF_i = quantity of complete formula feed manufactured in State i (1,000 tons)

All of the coefficients in equations (6) and (7) have the correct sign and the *t*-values for all of the variables are over 1.64, the critical value for a one-tailed test of significance at the 5 percent level.

The direct and cross price elasticities for grain sorghum are both quite high, indicating the demand for grain sorghum is very elastic. This seems reasonable since the price of grain sorghum is such that it can compete with corn in the Midwest and barley in the West. The cross price elasticities are slightly larger than the direct price elasticities in equations (6) and (8).

The coefficients on the location variables show that grain sorghum is used more intensively in the West and Midwest than in the East.

All of the equations indicate that the demand for grain sorghum will increase about 1 percent for every 1 percent increase in the production of complete formula feed. An increase in the proportion of complete cattle feed mixed, holding total production constant, will also cause the demand for grain sorghum to increase.

Oats. Oats were utilized by 86 percent of the formula feed manufacturers in 1969 (*6*). Oats can be used as a part of the ration for swine, but because of a high fiber content, they are too bulky to be the chief concentrate. Oats are very desirable in poultry rations because of certain special characteristics, such as the tendency to prevent picking and cannibalism. Oats also improve the growth and feather development of chicks while helping to prevent mortality. Oats have a higher value for dairy cows in comparison with corn than would be expected on the basis of total digestible nutrients. Dairymen commonly include some ground oats in the concentrate mixture for dairy cattle (*15*, pp. 427-431).

Equations (10) through (13) are the demand curves estimated statistically for oats.

$$(10)\quad QO_i = \underset{}{3.76} - \underset{(2.63)}{3.82PO_i} + \underset{(0.50)}{0.85PFO_i} + \underset{(8.75)}{0.83CF_i} + \underset{(2.60)}{0.65CC_i/CF_i} - \underset{(2.15)}{0.34West} + \underset{(0.51)}{0.08Mwst}$$

$$R^2 = 0.75$$

$$(11)\quad QO_i = -1.24 - \underset{(2.05)}{3.07PO_i/PFO_i} + \underset{(8.19)}{0.81CF_i} + \underset{(2.40)}{0.63CC_i/CF_i} - \underset{(1.05)}{0.15West} + \underset{(2.96)}{0.34Mwst}$$

$$R^2 = 0.72$$

$$(12)\quad QO_i = 3.51 - \underset{(2.93)}{4.32PO_i} + \underset{(0.69}{1.21PFO_i} + 1.0CF_i - \underset{(2.68)}{0.69CC_i/CF_i} - \underset{(2.29)}{0.37West} + \underset{(0.20)}{0.03Mwst}$$

$$R^2 = 0.43$$

$$(13)\quad QO_i = -1.76 - \underset{(2.35)}{3.57PO_i/PFO_i} + 1.0CF_i + \underset{(2.48)}{0.67CC_i/CF_i} - \underset{(1.19)}{0.17West} + \underset{(2.56)}{0.30Mwst}$$

$$R^2 = 0.36$$

where

QO_i = quantity of oats used by formula feed manufacturers in State i (1,000 tons)

PO_i = price per ton of oats in State i

PFO_i = average price per ton of all feed grains except oats in State i

West = a zero-one variable equal to one for the Western States and zero for all other States

Mwst = a zero-one variable equal to one for the Midwestern States and zero for all other States

CC_i/CF_i = cattle feed produced as a percentage of total complete feed mixed in State i.

All of the variables in equations (10) through (13) have the correct signs, and equation (10) explains 75 percent of the variation in the dependent variable. The coefficient on the *PFO* variable in both equations (10) and (12) is not statistically significant.

The estimated cross demand elasticities of 0.85 in equation (10) and 1.21 in equation (12) are much smaller than the cross demand elasticities estimated for corn or grain sorghum. This is probably due to the fact that the price of oats, in most States, is much higher in relation to feeding value than the prices of other feed grains. Just the same, oats are utilized in nearly every State because of the special characteristics mentioned earlier. To make it profitable to use oats as a major item in livestock ratios, the price of other feed grains would have to increase considerably. All of the equations indicate that complete cattle feed is a heavy user of oats.

Equations (12) and (13) differ from (10) and (11) in that the coefficient of CF_i is constrained to equal one. This change increases the estimates of the demand elasticities.

Wheat. Wheat was used by 68 percent of the feed manufacturing establishments in 1969 (*6*). In only three States did the amount of wheat used by formula feed manufacturers account for more than 10 percent of the total grain used in the State. Wheat is about equal in feeding value to corn for dairy cows and a good substitute for corn or barley in fattening cattle. It is slightly superior to corn in feeding swine. Poultry prefer wheat to all other grains, and a limited amount is often included in poultry rations to increase their palatability and to furnish variety (*15*, pp. 437-440).

Presented below are the estimated demand curves for wheat.

$$QW_i = -6.70 - \underset{(0.43)}{0.85}PW_i + \underset{(2.49)}{3.27}PFW_i + \underset{(6.57)}{0.90}West + \underset{(4.47)}{0.66}Mwst + \underset{(6.16)}{0.76}CF_i \quad (14)$$

$$R^2 = 0.69$$

$$QW_i = -1.83 - \underset{(2.20)}{2.72}PW_i/PFW_i + \underset{(6.73)}{0.80}CF_i + \underset{(6.68)}{0.92}West + \underset{(4.39)}{0.58}Mwst \quad (15)$$

$$R^2 = 0.67$$

$$QW_i = -4.63 - \underset{(0.92)}{1.83}PW_i + \underset{(2.31)}{3.15}PFW_i + 1.0CF_i + \underset{(7.48)}{1.00}West + \underset{(4.19)}{0.65}Mwst \quad (16)$$

$$R^2 = 0.65$$

$$QW_i = -2.46 - \underset{(2.24)}{2.83}PW_i/PFW_i + 1.0CF_i + \underset{(7.54)}{1.00}West + \underset{(4.44)}{0.60}Mwst \quad (17)$$

$$R^2 = 0.65$$

where

- QW_i = quantity of wheat utilized by formula feed manufacturers in State i (1,000 tons)
- PW_i = price per ton of wheat in State i
- PFW_i = average price per ton of all feed grains except wheat in State i
- *West* = a zero-one variable equal to one for Western States and zero for all other States
- *Mwst* = a zero-one variable equal to one for Midwestern States and zero for all other States.

The estimate of the direct price elasticity from equation (14) for wheat is −0.85, while the cross price elasticity is estimated to be 3.27. The reason for the large cross price elasticity in comparison with the direct price elasticity can be partially explained by the fact that wheat prices have often been supported at levels that remove it from competition with the feed grains. Consequently, wheat prices are probably not included in many feed manufacturers' linear programming models unless the price of feed grains is very high.

When the price of feed grains increases, the cost of the feed manufacturer's rations also increases. This signals the feed processor to try to find alternative nutrient sources that are cheaper, and wheat will probably be considered. On the other hand, when the price of wheat falls into the range where it is competitive with the feed grains, there is no increase in the cost of the manufacturer's output to signal the need for action. Hence, the feed manufacturer may not shift from feed grains to wheat as quickly in response to a change in the price of wheat as he would to a change in the price of feed grains. More wheat is fed in the West and Midwest than in the East, as evidenced by the large coefficients on the location variables.

In equations (16) and (17) the coefficient of the *CF* variable is constrained to equal one. This modification results in a somewhat higher direct price elasticity of −1.83 and a cross price elasticity of approximately the same size as that found in equation (14). When the relative price of wheat is used in the demand functions, the estimated elasticity is approximately −2.80.[10]

Barley. In 1969 the use of barley as a feed ingredient was reported by 67 percent of the feed manufacturing establishments (*6*). The use of barley is especially important in the Western States. Feeding trials have shown that fattening cattle will gain just as rapidly on ground barley, fed as the only grain, as on shelled corn. For dairy cattle, barley is as good as corn when composing 40 to 60 percent of the ration. Barley is a good feed for hogs, but it needs to be ground where corn does not. For poultry, barley is less palatable than corn, and due to the hulls, the growth of chicks is decreased if more than 30 percent of ground barley is used in a chick starter or more than 15 percent in a ration for broilers (*15*, pp. 446-450).

Four demand equations are fitted statistically for barley.

[10] The CC_i/CF_i variable was included in the demand equation in preliminary runs. Its estimated coefficient was not statistically significant, and its exclusion caused only a small change in the estimated elasticities.

(18) $QB_i = -3.33 - 2.75PB_i + 3.88PFB_i +$
$\quad\quad\quad\quad(1.48) \quad\quad (1.96)$

$0.64CF_i + 0.93CC_i/CF_i + 0.95West$
$(4.78) \quad\quad (2.90) \quad\quad\quad (6.16)$

$R^2 = 0.75$

(19) $QB_i = -1.45 - 3.13PB_i/PFB_i + 0.64CF_i +$
$\quad\quad\quad\quad(1.73) \quad\quad\quad (4.76)$

$0.90CC_i/CF_i + 0.95West$
$(2.82) \quad\quad\quad (6.18)$

$R^2 = 0.74$

(20) $QB_i = -4.55 - 2.59PB_i + 3.81PFB_i +$
$\quad\quad\quad\quad(1.30) \quad\quad (1.78)$

$1.0CF_i + 0.96CC_i/CF_i + 1.02West$
$\quad\quad\quad (2.79) \quad\quad\quad (6.23)$

$R^2 = 0.75$

(21) $QB_i = -2.54 - 3.00PB_i/PFB_i + 1.0CF_i +$
$\quad\quad\quad\quad(1.54)$

$0.93CC_i/CF_i + 1.02West$
$(2.70) \quad\quad\quad (6.25)$

$R^2 = 0.74$

where

QB_i = quantity of barley used in feed manufacturing in State i (1,000 tons)

PB_i = price per ton of barley in State i

PFB_i = average price per ton of all feed grains except barley in State i

$West$ = a zero-one variable equal to one for Western States and zero for all other States

CF_i = quantity of complete formula feed manufactured in State i (1,000 tons)

CC_i/CF_i = cattle feed produced as a percentage of total complete feed mixed in State i.

Equations (20) and (21) differ from equations (18) and (19) in that the coefficient of the CF_i variable is constrained to equal one. In general, this constraint has little effect on the estimated coefficients. All of the variables in the demand functions have the correct signs, but the PB variable in equations (18) and (20) and the price variable in equation (21) are not statistically significant at the 5 percent level.

The estimated direct and cross price elasticities from equation (18) are −2.75 and 3.88, respectively. If the two elasticities are constrained to be equal, as in equation (19), the estimated elasticity is −3.13. The demand for barley is much stronger in the West than in the rest of the country. Barley demand also increases when the percentage of cattle feed mixed increases. The estimated equations explain about 75 percent of the variation in the amount of barley used in formula feeds.

Summary

Statistical information gathered about corn, oats, barley, sorghum, and wheat is summarized in table 2 and table 3.

According to the analysis, the use of grain sorghum is the most responsive to changes in its own price and to changes in the price of the other feed grains. In terms of direct price elasticities, corn, oats, barley, and wheat follow grain sorghum in degree of responsiveness to changes in their own price. The cross price elasticity of grain sorghum use with respect to

Table 2. Direct and cross price elasticities calculated for corn, oats, barley, grain sorghum, and wheat

Commodity	Equation number	Elasticity with respect to:	
		Own price	Price of all other feed grains
Corn	(4)	– 4.81	1.47
Grain sorghum	(8)	– 5.42	6.77
Oats	(10)	– 3.82	0.85
Wheat	(14)	– 0.85	3.27
Barley	(18)	– 2.75	3.88

Table 3. Estimated elasticities when the direct and cross demand elasticities are constrained to be equal

Commodity	Equation number	Price elasticity
Corn	(5)	– 5.14
Grain sorghum	(9)	– 5.35
Oats	(11)	– 3.07
Wheat	(15)	– 2.72
Barley	(19)	– 3.13

the price of other feed grains is nearly twice as large as that for barley and wheat. The cross price elasticity of corn is lower than that of wheat and barley but is still greater than one. Oats are the only feed grain with a cross price elasticity of less than one.

The elasticity estimates in this study provide an upper bound for the true direct and cross price elasticities for the total feed use of the individual grains and wheat. The typical livestock producer, especially one who produces his own feed, will not be as responsive to price changes as formula feed manufacturers.

Location plays an important role in the demand for all of the feed grains. Grain sorghum, wheat, and barley are used more intensively in the West than in the Midwest or East. More oats are utilized in the Midwest and more corn in the East than would be expected on the basis of interstate price differentials.

The demand for barley, oats, and grain sorghum is affected by the proportion of total complete feed production accounted for by cattle feed. When location and total production are held constant, an increase in the proportion of cattle feed mixed will increase the demand for barley, oats, and grain sorghum.

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Book Reviews

Postwar Productivity Trends in the United States, 1948-1969

By John W. Kendrick. National Bureau of Economic Research, Inc., 261 Madison Avenue, New York, N.Y. 10016. 369 pages. 1974. $15.

Productivity as a subject for research and policy attention has not been given its due in agriculture. There have been a few notably good studies and some good dissertations written on factor productivity in farming and in the food industry, but productivity is not one of the more common topics for research or teaching. This is true for the agricultural economics profession at large and, the work of a few stalwarts aside, for the Economic Research Service in particular, where in recent years there has been a paucity of resources assigned to this topic.

The meager resources assigned to productivity research in agriculture are in contrast to the rising concern for agricultural productivity. The National Academy of Sciences has expressed concern over purported evidence that productivity in some parts of agriculture is already in decline. A committee in the Academy has been studying this subject. The White House Commission on Productivity recently had a special task force review productivity problems in all sectors of the food industry, including farming. In the setting of inflation and scarcities, many observers are expressing concern that we have about exhausted our sources of easy gain in agricultural productivity and that we are not making the necessary new investments in research to assure new sources of productivity gains in the future. In response to these recent concerns, one may perceive faint signs of some resurgence of interest among economists in agricultural productivity research issues.

Economists interested in productivity will find John Kendrick's update of his earlier *Productivity Trends in the United States* a valuable addition to their reference shelves. The data assembled in the nearly 150 pages of "basic tables" (part III of the appendix) are alone enough to assure that the book will be well thumbed. But the book will also be valuable for its readability and because of the interesting results of Kendrick's years of research on productivity trends.

Kendrick's earlier book, published in 1961, traced the productivity story for the U.S. economy and its major industry divisions from 1889 to 1957. The current study focuses on postwar productivity trends, by industry groupings, for 1948-66 with preliminary estimates through 1969.

Kendrick devotes a chapter to a review of concepts of productivity and its component variables, plus a summary of methods and sources of estimation. His index numbers of "total factor productivity" are based on ratios of net output (real product) to weighted averages of the human (labor) and nonhuman (capital) tangible factor inputs. The weights represent the shares of factor income accruing to each of the two major factor classes in successive base periods. Labor input is measured in terms of man-hours worked. Capital is assumed to move proportionately to the real stocks of tangible capital assets. In addition to total factor productivity, Kendrick includes the more conventional measures relating output to man-hours and to capital individually.

Few economists agree on how to measure productivity. Kendrick acknowledges the disagreement over his measures. He is especially sensitive to the charge that his use of tangible factor inputs does not reflect changes in quality of inputs so that changes in the ratios of output to input may be interpreted as reflecting all the diverse forces that affect the quality or "productive efficiency" of the factors. A number of other economists have undertaken studies designed to narrow the residual attributable to productivity increases by expanding the inputs to include various qualitative elements, such as rising educational levels of the work force, and the assumed increase in man-hour output occasioned by declines in the average number of hours worked per week. However, Kendrick defends his measures of tangible factor inputs, unadjusted for quality changes, as a useful point of departure for analysis of growth and change in economic aggregates and structure.

The results of Kendrick's exhaustive investigations of productivity movements are summarized in four chapters. The first deals with national productivity trends during the postwar period. A major conclusion is that there has been no significant acceleration in the trend rate of growth in total factor productivity since World War II, at 2.3 percent per year, compared with the earlier period beginning around the time of World War I. Output per unit of labor, however, has shown further acceleration because of a faster rate of increase in capital per unit of labor input than prevailed during the interwar period.

Kendrick also notes that in the postwar period there is less year-to-year variation in productivity, and interprets this lesser variability as reflecting a broader and more persistent rate of technological advance.

Another chapter examines the relationship between national productivity and economic growth. Kendrick finds that since World War I gains in total factor productivity have accounted for more than half of aggregate economic growth. Since 1948 the trend rate for total factor productivity has been 2.3 percent a year and the trend rate for economic growth has been 4.1 percent a year. Even more interesting is the conclusion that from 1948 to 1966, gains in total factor productivity accounted for almost all the increase in "planes of living," as measured by real net national product per capita, which rose at an average rate of 2.4 percent a year. During the postwar period total input per capita rose only fractionally, as substantial increases in capital input relative to population did little more than offset a persistent decline in labor input per capita. Kendrick concludes this chapter by hypothesizing that the chief determinant of the rate of growth in total factor productivity is the rate of growth in the real stocks of intangible capital embodied in the tangible factors. These intangible investments enhanced the quality or productive efficiency of labor and capital.

Yet another chapter deals with patterns of productivity change by industry groups. Here one can examine and compare productivity trends in seven major industry segments and 34 industry groups. Farming appears as a major industry segment and foods, beverages, tobacco, textiles, and apparel appear as industry groups under manufacturing. Interestingly, no industry group for which estimates were constructed showed declines in total factor productivity. Farming had a better than average showing (3.3 percent for the postwar period) but the air transportation industry outstripped all others in productivity gains (8 percent per year).

In the final chapter Kendrick examines the interrelationships among rates of change in productivity, output, and a number of associated variables. For 1948-66 there is a significant positive correlation between rates of change in productivity and in output. Since there was no significant correlation of productivity changes with input price movement, productivity gains were negatively correlated with price changes in output. Thus, the productivity gains of the postwar period have been a significant factor in reducing potential rates of inflation.

More than half the book is devoted to an appendix on sources and methods which cover the national economy (part I), industry groups (part II) and basic tables (part III).

In part II, Kendrick makes an interesting observation on the measurement of productivity in farming. He shows that the ratio of intermediate costs to the total value of farm output in real terms rose from about 35 percent in 1948 to 44 percent in 1966. This trend reflects the transfers of various activities from the farm to nonfarm sectors and the increasing use of various nonfarm inputs required to farm. If we adjust the gross output of the farm sector for the increasing proportion of intermediate products used, the rate of increase in real farm product is significantly smaller than the rate of increase in gross output. Kendrick argues that gross output in farming should be related not only to factor inputs, but to total inputs inclusive of intermediate inputs as well. This would reduce the apparent rate of productivity advance in farming. In most industries gross output is used as a proxy for real product output and is related only to factor inputs to measure productivity. In farming, however, it is clear that gross output has a persistent upward bias as a proxy for real product and cannot be so interpreted.

Kendrick's book is not the place to go for an exhaustive review of alternative productivity concepts. That would be a rather large book in itself. Kendrick's measures of productivity are not perfect or complete, but they are very useful. Certainly, few people have studied productivity as exhaustively as Kendrick. The results of his efforts make interesting reading.

John E. Lee, Jr.

Land Policy in Buganda

By Henry W. West. African Studies Series No. 3. Cambridge University Press, New York, N.Y. 10022. 244 pages. 1973. $19.50.

In 1900, the commissioner of the British Protectorate of Uganda assigned 8,000 square miles of agricultural land to 1,000 Buganda chiefs and their more important followers. Buganda, a part of the protectorate, was a long established kingdom whose king, the Kabaka, was presumed to own all the land because of his paternal sovereignty over everything in the kingdom. The immediate objectives of the land partition were to consolidate British overrule and to settle the strife between feuding factions, but inadvertently, it also had long-lasting complex effects on the future social and economic life of Buganda. The land of the 1900 agreement was distributed in square mile units, and for this reason, was called "mailo" land, from the African pronunciation of the English word "mile." It included virtually all land in Buganda suitable for crops.

This book is a study of the developments in the ownership and tenancy of the mailo land. It investigates the character of the proprietary rights of both mailo owners and tenants. Five sample surveys taken in the midsixties provide information on the number, position, size, and orientation of the holdings, and on the nature of land use in five areas ranging from rural to semiurban and urban.

The number of land owners in Buganda increased from 4,000 in 1905 to 112,000 in 1967. Undoubtedly, landownership became possible for a large number of farmers, and some of these were able to break away from the traditional subsistence agriculture and farm commercially. Another volume in this series (*Subsistence to Commercial Farming in Present Day Uganda, An Economic and Anthropological Survey*, edited by Audrey I. Richards, Ford Sturrock, and Jean M. Fortt, Cambridge University Press, New York) tells the story of the successful commercial farmers on mailo land. The present study shows the pessimistic side of the picture. The original grants measured in square miles have been subdivided so drastically by inheritance that the average area inherited by beneficiaries in 1962-64 had shrunk to only about 24 acres. This is because families are large, and women can inherit land on equal terms with men. If this trend to smaller and smaller holdings continues, it will hamper the development of commercial agriculture.

Another factor that tended to perpetuate the number of subsistence holdings was a law promulgated in 1928 to improve the conditions of the tenant farmers on mailo land. This law abolished crop shares and pegged the money rent at a low level. At the same time, it made it difficult for the owner to evict the tenant. It provided the necessary security of tenure to encourage tenants to plant a long-surviving crop like coffee. The law also helped thousands of tenants to become owners, but in thousands of other cases, it discouraged the mailo owner from investing capital in the farm.

In the last chapter, the author discusses future policy. How can the market-oriented farmer, with a secure and negotiable title to an economically viable piece of land, replace the present subsistence cultivator? The companion volume suggests that the change to commercial farming occurs only when the peasant sees the possibility of a dramatic improvement in his position. Many peasants made this jump successfully. These included some who inherited the land and others who purchased it, but they are only a minority. For the majority to become commercial farmers, it is important that further subdivision by inheritance must stop. Yet the rural population keeps increasing at such a rapid rate that there is no way in the near future to find a place for them in other sectors. The solution seems to be some device which will prevent further division of properties, but which will provide a place in agriculture for the increasing population.

There is much more in this book, all well-documented with profuse footnotes. An extensive bibliography lists almost 100 government reports plus an equal number of special studies and general works. A large map shows land tenure in Buganda in 1966. Twelve smaller maps present details on such topics as land occupancy, land values, land use, ownership by clans, and more.

Herbert Steiner

You Can Profit from a Monetary Crisis

By Harry Browne. Macmillan Publishing Company, Inc., New York, N.Y. 10022. 397 pages. 1974. $8.95.

Many economists and financial writers predict difficult times for the economy, at least in the near future. None, however, has taken such an extreme position as Harry Browne, the author of this book. On the basis of his successful prophetic advice, published in his previous book in 1970, *How you Can Profit from the Coming Devaluation*, he evidently feels compelled to offer a broad strategy to the public for keeping on top of the eroding economies of the world.

The author concludes that because of the current state of the economy and the mistakes of Government financial policies, this Nation will experience the worst depression in its history. He predicts business conditions will get worse in the 1970's leading perhaps to financial collapse.

To offset the consequences, one must radically change his habits of investing; one must move away from traditional investments in securities, real estate, savings accounts,.etc., and invest in the supreme commodity, gold, or things that are backed by gold, such as strong foreign currencies and stocks in gold companies. The author's reasoning is simply that paper money, not based on gold and subject to increasing inflationary pressures, will continue to lose its value as inflation proceeds—and there will be no letup of the inflationary push.

The author even suggests drastic measures as selling your home, car, and valuables, and storing up a retreat far away from any urban area to sit out the trouble. One would think that he is predicting an impending atomic bomb attack rather than a financial crisis. Our Nation has experienced economic reversals in the past—albeit not as severe as France in 1790 or Germany in 1923—and has managed to survive intact, indeed has gone on to greater economic heights.

Perhaps this is all right for the author, who is unattached, lives out of the country, relaxes on his couch, and listens to records (classical). But for the rest of us who have a vested interest in what material things we have acquired through work and who are conditioned to our routine of day-to-day enjoyment of life, it would be hard to give up so much on the basis of $8.95 worth of advice.

Despite everything, this book is worth reading if only because of the perspective and education one gets regarding this Nation's economy.

Jack Ben-Rubin

U.S. GOVERNMENT PRINTING OFFICE: 1974 O - 555-999

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AGRICULTURAL ECONOMICS RESEARCH

Is a quarterly publication of the Economic Research Service, U.S. Department of Agriculture. Use of funds for printing this publication approved by the Director of the Office of Management and Budget, February 12, 1970.

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. 65 cents a single copy, $2.60 a year domestic, $3.25 foreign.