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THE IMPACT OF FLUCTUATING GRAIN AND SOYBEAN PRICES ON LIVESTOCK PRODUCERS AND CONSUMERS IN THE U.S.

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Introduction

Feed ingredient prices have been extremely unstable over the past decade and are likely to remain so during the 1980s according to the view of most agricultural economists (see for example O'Brien). Such instability has had a profound effect on the incomes of corn and soybean producers, land prices in the midwest, the incomes of livestock feeders, and the prices paid by consumers for livestock products. On two occasions in the 1970s, the U.S. government decided to impose export restrictions on sales of grain and soybeans in an attempt to damp down domestic inflation and to provide some relief for livestock feeders. This, in turn, led importing countries to try to diversify sources of supply and to reduce their dependence on imports by promoting food self-sufficiency. Thus, when confronted with sharply rising grain prices, the U.S. must decide whether to restrict (or tax) exports and risk losing potential markets, or to permit unrestricted exports and thereby impose additional costs on livestock feeders and consumers.

The research results reported in the following pages deal with the potential costs to livestock feeders and consumers of unrestricted exports. A simulation model has been developed for this purpose. It is based on what happened to livestock production in the 1970s when feed ingredient prices changed dramatically. To provide the coefficients for the simulation model, three sets of relationships were estimated. First, regression procedures were employed to determine the relationship between corn and soybean prices and livestock feed ingredient prices. This was done in an attempt to determine how rapidly and to what extent changes in grain prices are reflected in the prices of poultry, hog, dairy and cattle feed. Second, a model was developed to assess how rapidly and to what extent livestock production falls as feed prices rise. These relationships were then used to determine how long it takes before livestock prices rise by an amount sufficient to offset the impact of higher feed costs, or to put it another way, how long the incomes of livestock producers are likely to remain depressed as a result of a given increase in feed ingredient costs. Finally, the historical relationship between changes in livestock output (by sectors) and retail meat and livestock product prices was estimated in order to provide a basis for assessing the potential impact of changes in livestock output on consumer food costs.

Previous feed-livestock models have been based mainly on annual rather than quarterly data. These models have been used principally to estimate the ultimate effect on output of changes in feed costs without tracing through the intermediate effects on livestock producers and consumers. The models developed for this study are designed to fill this gap by providing empirical estimates of lags in response to changing price relationships and consequently the sequence of events that is likely to occur as the effects of higher grain prices are transmitted through the livestock sector to consumers.

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* The author is especially grateful to Professor K. L. Robinson for his invaluable comments and suggestions.

The sources of data, models employed and the empirical results for each of the subparts of the model are summarized in the following sections. To test the model the empirical results were used to simulate livestock output and prices for the 1970s. The model is then used to project what might happen during the 1980s assuming approximately a 40 per cent increase in corn and soybean meal prices from the levels prevailing in 1979.

Feed Price-Ingredient Cost Relationships

The feed price-ingredient cost relationships are based on first order differences. Quarterly changes in the price of feed are specified as a function of current and previous quarterly changes in the prices of corn and soybean meal. The general form of the estimated relationship is as follows:

$$\Delta P_t = a + b\ \Delta PC_t + c\ \Delta PC_{t-1} + d\ \Delta PS_t + e\ \Delta PS_{t-1} + \mu_t$$

where

ΔP_t = the change in the price of the livestock feed from the preceding quarter;

ΔPC_t = the change in the price of corn from the preceding quarter;

ΔPS_t = the change in the price of soybean meal from the preceding quarter;

μ_t = the error term.

A positive relationship between changes in the price of feed and changes in the cost of feed ingredients was expected. First order difference analysis was employed because of the poor results obtained when quarterly feed prices were regressed against ingredient prices. These poor results were mainly a consequence of multicollinearity between quarterly prices of corn and soybean meal. When the actual prices of feed and feed ingredients were used in the analysis, the estimated feed price-ingredient cost relationships also had low Durbin-Watson statistics.

All the relationships in this study were estimated using quarterly data for the period starting in the first quarter of 1970 and ending in the third quarter of 1979. The data used for this part of the analysis were obtained from U.S.D.A.'s publication "Agricultural Prices, Annual Summary."

Table 1 shows the increase in the prices of the various livestock feeds ($/ton) resulting from an increase in the price of corn and soybean meal by $1/ton. Most of the adjustment to a change in feed ingredient costs takes place within one quarter after the change occurs. The small adjustment taking place in the second quarter is basically a result of the initial change in the price of corn. Dairy feed prices appear to be less sensitive than the prices of the other livestock feeds to changes in corn and soybean meal prices. The main reason for this is that dairy feeds contain lower proportions of corn and soybean meal and more by-product feeds than poultry, hog and beef feeds. The increase in beef feed refers to the price of beef supplement. The beef supplement provides all the required protein for growing

Table 1. Increase in the Price of Feed ($/ton) Resulting From an Increase in the Price of Corn and Soybean Meal by $1/ton

Period	Livestock Feed for Beef	Hogs	Broilers	Laying Hens	Dairy Cows
	$/ton				
Increase End of 1st Quarter	0.43	0.71	0.76	0.68	0.52
Increase End of 2nd Quarter	0.24	0.20	0.15	0.14	0.09
Total Increase	0.67	0.91	0.91	0.82	0.61

calves and is mixed with corn at a ratio of 1:4 to 1:6, depending upon the age of the animals. If the total beef ration is considered (including the amount of whole grain normally fed) the increase in price was calculated to be around $0.90 for each $1 increase in the price of corn and soybean meal.

Livestock Production-Feed Cost Relationships

Relationships between feed costs and livestock production are recursive in nature because of the important time lags involved in livestock production. Thus, production in any quarter is strongly influenced by the number of animal units already born, or by breeding plans in previous periods, which in turn are influenced by past and anticipated relationships between feed and livestock prices. Changes in production plans in the current period influence output in the current and succeeding periods.

The feed-livestock relationships in this study are based on quarterly data. This makes it possible to identify the timing of changes in production in response to changes in feed prices more precisely than if annual data were used. The timing and magnitude of this adjustment depends upon the particular type of livestock fed and is influenced mainly by biological factors. For example, broiler growers can adjust their production within one quarter much more easily than pork producers because of the shorter biological cycle which characterizes broiler production.

Empirical estimates of the relationship between livestock output and feed prices (or feed/livestock product price ratios) were obtained using current and lagged feed and livestock prices. Specifically, the model used to estimate livestock output for each sub-sector (beef, pork, broilers, etc.) was as follows: 1/

$$Y_t = a + \sum_{i=0}^{n} b_i P_{t-i} + \sum_{j=0}^{m} c_j P_{t-j} + \sum_{k=1}^{3} d_K D_K + e T + \mu_t$$

where

Y_t = production for a particular livestock sector;

P_t = the price of the livestock product;

R_t = the price of the livestock feed;

D_1, D_2, D_3 = seasonal dummies;

T = the time trend;

μ_t = the error term.

The price of the livestock product in the current quarter is treated as an endogenous variable, influenced mainly by the level of livestock production while the price of feed is an exogenous variable. Hence, the model used in this study can be considered as a "quasi reduced form" model because, in addition to the exogenous variables, it contains an endogenous variable, namely, the price of the livestock product.

Johnston (pp. 408-420) explains in detail the advantages and disadvantages of using a structure versus a reduced form model. The choice between the two methods seems to depend primarily on the purpose of the model. Structural equations describing the livestock sector were not estimated in this study

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1/ In the case of egg and milk production, the ratio of the price of feed to the price of the livestock product was used as an explanatory variable. Fed beef production was estimated using a two-step procedure. First, the number of cattle on feed was estimated as a function of current and lagged feed and livestock prices. Second, production of fed beef in the current quarter was estimated using current feed costs and number of animals on feed during the current and previous quarters as explanatory variables.

because the purpose of the model was to forecast changes in livestock production resulting from changes in feed prices. The results of several comparative studies do not provide any clear evidence of the superiority of one model over the other for forecasting purposes (Johnston, p. 419); however, the reduced form does have the advantages of simplicity and economy in computation.

If annual data had been used it would have been more appropriate to use a simultaneous equation model because livestock production and livestock prices are determined, to a significant extent, within the same year.

The problem when estimating livestock supply relationships using ordinary least squares is that, because of multicollinearity among the lagged independent variables, the values of the estimates will be imprecise and their standard errors will be large. This may lead to the misspecification of the model if variables are omitted which may in fact be important (see Koutsoyiannis, p. 297).

Alternative distributed lag models have been proposed to overcome the previously mentioned multicollinearity problem. All these models impose various restrictions on the parameters of the livestock supply relationship. These restrictions, depending on how appropriate they are in each application, introduce a potential bias in the estimated parameters. On the other hand, by imposing these restrictions, standard errors may be reduced, thus improving the precision of the estimates.

The model used in this study for the estimation of the livestock supply relationships was the Almon lag model. The Almon model is based on the Weierstrass theorem, which specifies that the coefficients of the lagged variables can be approximated by a polynomial of appropriate degree. 2/ The length of the lag in the supply response was not restricted. Lagged variables were added as long as their estimated coefficients were significant and had the expected sign. The sensitivity of the estimated coefficients was examined for small changes in the degree of the polynomial and the length of the lag.

Empirical results based on the Almon lag model are shown in Table 2.[3/] The coefficients express the percentage change in output that occurs within each time period resulting from a 10 per cent increase in feed costs. From this table it is clear that the most sensitive sectors to changes in the price of feed are beef and pork while the least sensitive are milk and eggs.

2/ A description of the Almon model and the reasons why it was selected for use in this study can be found in Spathis, pp. 18-28.

3/ Data on livestock production were obtained from the following U.S.D.A. publications: Livestock and Meat Statistics, Meat Situation and Outlook, Poultry and Egg Situation, and Dairy Situation.

Table 2. Percentage Change in Production by Livestock Sector Resulting From a 10 Percent Increase in Feed Prices[a/]

	Livestock Sector											
	Fed Beef		Non-fed Beef		Pork		Broilers		Eggs		Milk	
Period	% Impact Within Each Period	Cumulative % of Total Impact	% Impact Within Each Period	Cumulative % of Total Impact	% Impact Within Each Period	Cumulative % of Total Impact	% Impact Within Each Period	Cumulative % of Total Impact	% Impact Within Each Period	Cumulative % of Total Impact	% Impact Within Each Period	Cumulative % of Total Impact
0-4 quarters	-13.5	100	17.2	29	- 9.3	36	- 8.5	47	- 0.4	3	- 0.4	9
4-8 quarters			24.8	70	- 5.1	56	- 9.5	100	- 6.5	49	- 3.4	81
8-12 quarters			18.0	100	- 8.3	89			- 6.3	94	- 0.9	100
12-16 quarters					- 2.8	100			- 0.8	100		
Total impact on production	-13.5		60.0		-25.5		-18.0		-14.0		- 4.7	

a/ In the case of milk and eggs, changes in production are based on changes in the price ratios rather than the price of feed alone.

The impact of a change in the price of feed varies greatly among livestock sectors both as to timing and magnitude. The longest lags in the adjustment of livestock production to changes in the price of feed were found in the case of eggs (16 quarters), pork (12 quarters) and non-fed beef production (12 quarters). Fed beef and broilers exhibited the shortest lags with all the adjustment occurring by the end of the 4th and 6th quarters respectively. In the case of milk production, most of the adjustment occurs in the second year following the price increase, although some additional adjustment occurs in the third year.

Around 90 percent or more of the total adjustment in production takes place in all sectors by the end of the third year. By the end of the second year all the adjustment appears to have occurred in the case of broilers and fed beef while approximately 80% has occurred in the case of milk, 70% in the case of non-fed beef, 56% in the case of pork and 49% in the case of eggs.

The length of the adjustment process is influenced by biological constraints. The expansion phase of each livestock sector is limited by the time it takes to increase breeding stock and the gestation period. The downward phase of all livestock cycles can be considerably shorter than the expansion phase because livestock can be slaughtered immediately in response to unfavorable price relationships. Keeping in mind this distinction, it appears that the estimated length of the production response lag in the case of broilers and pork is more appropriate for the expansion than the contraction phase of the production cycle. The estimated lag in egg response is even longer than one would expect even for the expansion phase in egg production. The estimated total impact on egg production also seems considerably greater than one would expect based on the results of previous studies (see for example, Egbert, et al).

Further analysis indicated that the long lag in egg production reflected in the results shown in Table 2 may occur because the coefficient attached to the egg/feed price ratio is picking up the effects of a persistent downward trend in egg production which is correlated with the egg-feed price ratio.

Non-fed beef production moves counter to the change in pork, fed beef and broiler production in response to an increase in feed ingredient prices. Based on relationships prevailing in the 1970s, the regression results indicate that a 10 per cent increase in feed costs is associated with a 60 per cent increase in non-fed beef supplies over a three-year period. This occurs as a result of marketing cattle directly rather than selling them to feed lot operators when feeding margins are squeezed. The liquidation of cattle thus helps to compensate for the decline in fed beef, pork and broiler supplies and, as will be noted in a subsequent section, tends to moderate the price impact on consumers of higher feed costs.

The decision to use the Almon lag model clearly influenced the results. In the case of both pork and eggs, the magnitude of the response and its distribution over time differed when ordinary least squares estimation procedures were used. Results also were influenced by the degree of polynomial used in the analysis and the length of the lag which was assumed. The coefficient expressing the relationship between feed prices and non-fed beef production is large because it picked up the effects of a sharp reversal in the beef cycle which occurred during the late 1970s. The rise in feed costs in the mid 1970s triggered the reversal which persisted for several years. Had the beef cycle not been at an historic high, there would have been many fewer animals to liquidate.

Lags in the Response of Livestock Prices to Changes in Feed Costs

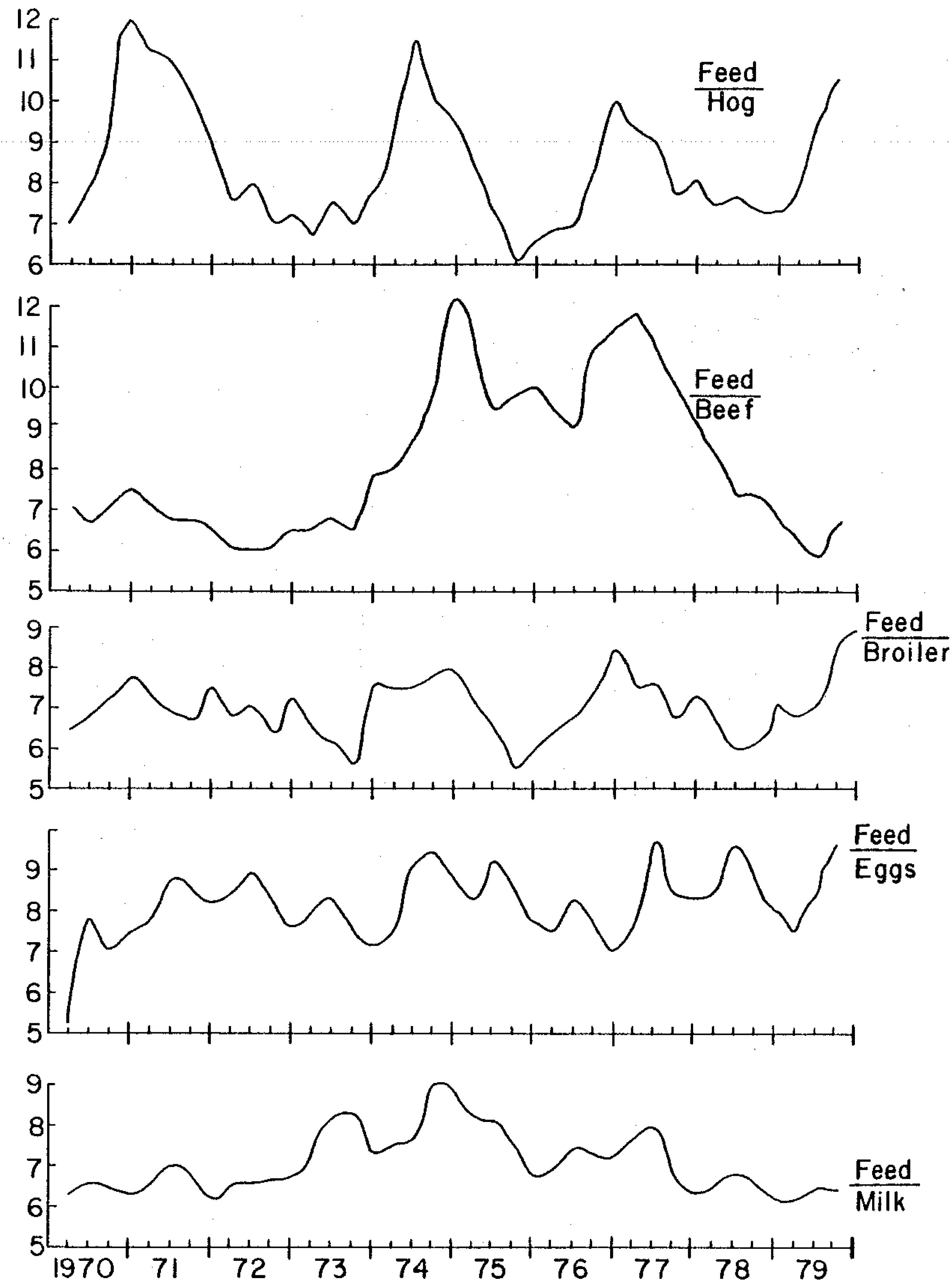
The immediate impact on livestock feeders of an increase in feed ingredient costs is to reduce the profitability of livestock feeding. Subsequently, this leads to a reduction in livestock output, which then tends to reverse the previous increase in the ratio of feed prices to those of livestock products. Among the objectives of the study were to estimate how long it takes following an increase in feed ingredient prices for livestock prices to move up sufficiently to compensate for the increase in feed costs. One way to do this would be to look at the financial records of livestock feeders. It is difficult to obtain data of this type, however, and therefore the analysis was confined to an examination of the behavior of feed-livestock price ratios. An estimate of the time required to restore profitability to the level prevailing before the rise in feed costs occurred can be obtained simply by observing how long it took during the 1970s (following the jump in feed ingredient prices) for feed-livestock price ratios to decline to the level prevailing in 1972 or early 1973.

The behavior of feed livestock product price ratios for each of the major livestock sectors is shown in Figure 1. All the feed-livestock price ratios rose in 1974 from the level prevailing in 1972 and 1973, but the precise timing and magnitude of this increase in the ratio and the subsequent decline were far from uniform among livestock sectors. It took less than two years after 1973 for the feed-hog ratio to return to the level prevailing in 1973, while for beef, it was not until 1979 (5 years later), that the feed-beef ratio declined to the level prevailing in the early 1970s. The period during which dairymen suffered from unfavorable price relationships was nearly as long. Profitability, as measured by the feed-livestock product price ratio, was restored for both egg and broiler producers within about two years.

The rise in feed costs in 1973 was compensated for by an increase in the prices of most livestock products during the last half of that year. For broilers and eggs, the feed-livestock price ratio actually declined despite a sharp rise in feed costs. This was due to an even greater rise in egg and broiler prices which occurred following the lifting of price ceilings in July of 1973. The prices of broilers and eggs nearly doubled during this period. Milk prices, which were strongly influenced by the support program, failed to rise significantly and consequently the feed-milk price ratio rose in contrast to what happened to the corresponding price relationships for broilers and eggs.

By late in 1973, the prices of most livestock products had begun to decline, while feed prices remained high. As a result the feed-livestock price ratios began to rise and generally reached a maximum in 1974 or early in 1975. A short grain crop in 1974 led go a further boost in grain prices

Figure 1. Feed-Livestock Product Price Ratios, United States, 1970-79



SOURCE: U.S.D.A., Agricultural Prices, Annual Summaries.

late in 1974 and early in 1975. This was followed by cut-backs in pork, fed beef and broiler production. A larger grain crop in 1975 combined with rising livestock prices helped to restore the ratio for most livestock sectors (except fed beef) to the level prevailing before the export boom. In the four year period following 1975, the price ratios for broilers, eggs and hogs continued to fluctuate in a manner not unlike that prevailing before the shock in grain prices. During this period, changes in grain prices were much smaller than those which occurred in 1973 and 1974.

Differences in the timing and magnitude of changes in feed-livestock product price relationships which occurred during the early and mid 1970s are summarized in Table 3. The largest percentage increase in feed prices occurred between the third quarter of 1972 and the third quarter of 1973. During this period, feed costs rose a minimum of 50 percent for beef and milk producers and as high as 65 per cent (owing to the greater increase in soybean meal prices) for broiler growers. Note that the sharp rise in feed costs during this period did not lead to a corresponding increase in the feed-product price ratio in 1973, except for milk. As pointed out earlier, most livestock product prices also rose by enough during this period to compensate for the increase in grain prices. But this was not true in 1974. By the third quarter of 1974, the feed-livestock product price ratio for beef feeders was 58 per cent higher than it had been in the third quarter of 1973. Thus, beef feeders were severely squeezed. Between 1972 and 1974, the feed-product price ratio rose 47 per cent for pork producers, 36 per cent for dairymen, 24 per cent for broiler growers, but only 16 per cent for egg producers. By the third quarter of 1975, the ratio had declined to about the level prevailing in late 1972 for pork, egg and broiler producers (or substantially below in the case of broilers); however, price relationships were still moderately unfavorable for dairymen and extremely unfavorable for beef producers owing to wholesale liquidation of beef herds which depressed beef prices.

Table 3. Percentage Changes in Feed Prices and Feed-Livestock Product Price Ratios, Selected Periods, 1972-75

Livestock Sectors	Percent Change in the Price of Feed III 72 - III 73*	% Change in Feed-Product Price Ratio*		
		III 72-III 73	III 72-III 74	III 72-III 75
Beef	+51	+ 7	+58	+58
Pork	+58	0	+47	- 7
Broilers	+65	-15	+24	-15
Eggs	+61	-10	+16	+ 7
Milk	+50	+24	+36	+12

* Roman numerals refer to the quarter used as the beginning or ending period.

SOURCE: U.S.D.A., Agricultural Prices, Annual Summaries.

The behavior of feed-livestock product price ratios during the 1970s was influenced by a decrease in grain prices in 1975 and 1976 as well as by changes in livestock prices induced by the rise in feed costs in 1973-74. One cannot tell from looking at the ratios which element is causing the ratio to fluctuate; that is, changes in feed costs, changes in livestock prices, or some combination of the two. Regression analysis helps to sort out the effect of the initial grain shock from subsequent changes in grain prices, but clearly there are confounding factors which make it difficult to do this. Price signals confronting livestock feeders tend to change before the full effects of the initial price change have had time to manifest themselves. The evidence does suggest that even very large price increases for grains will not result in unfavorable price relationships persisting for more than about two years. Increases in grain production and decreases in livestock output following the initial increase in grain prices will tend to restore more favorable price relationships for most livestock feeders within a two year period. The principal exceptions to this generalization are likely to be fed beef and milk. The time it takes for price ratios to recover depends to some degree on the stage in the livestock cycle at which the initial price change occurs.

Livestock Production-Retail Price Relationships

The relationship between changes in livestock output and retail prices was estimated for each major livestock sector in order to determine the effects of changes in livestock output, induced by changes in feed costs, on consumers. To assess the longer-run effects of an increase in feed costs on livestock output, it also is necessary to take account of the change in farm prices for livestock products that occurs as a result of the fall in livestock production. Thus, to trace through the full effects, estimates are required of the relationship between changes in the output of livestock products and both farm and retail prices. Price changes induced by the initial rise in feed costs tend to be damped down over time as a result of the rise in livestock product prices which tends to encourage expansion.

Livestock production within any one quarter is largely predetermined by previous prices and the availability of animals available for feeding. Wholesale and retail prices for livestock products within a particular quarter are thus determined mainly by the level of marketings and factors which influence consumer demand including population, income and seasonal preferences. For this reason, the model used in estimating livestock production-retail price relationships assumed that price was the dependent variable. Specifically, the price variable employed in the analysis was the index of retail prices for beef, pork and dairy products compiled by the U.S. Department of Agriculture. Each index is a weighted average of the prices of cuts of meat commonly purchased by consumers, or a typical combination of dairy products. The use of index numbers to represent changes in livestock product prices makes it easier to calculate the effect of changes in feed ingredient costs on the Consumer Price Index (CPI) than if actual prices of livestock products were used in the analysis.

Explanatory variables used in the analysis included quarterly estimates of per capita production (quantity sold) of livestock products, per capita storage stocks, per capita production of substitute products, per capita disposable income, an index of inflation, and dummy seasonal variables. The general form of the model used to estimate the relationship between livestock production and retail prices is as follows:

$$P_t = a + b\,S_{t-1} + cY_t + dY_{t-1} + eX_t + fI_t + gF_t + \sum_{i=1}^{i=3} h_i D_i + U_t$$

where

P_t = the U.S.D.A. retail price index for the livestock product,

S_t = per capita storage holdings of the livestock product,

Y_t = per capita production (marketings) of the livestock product,

X_t = per capita production of a substitute product,

I_t = per capita disposable income in current dollars,

F_t = the GNP implicit price deflator for non-durable goods (1972=100)

D_1, D_2, D_3 = seasonal dummies,

U_t = the error term.

All variables are based on quarterly data. Both current and lagged values of livestock marketings were included in estimating the price-quantity relationships because of the time required for livestock products to move through the processing and distribution system. Supplies of substitute products were included in the price flexibility equations whenever these variables were found to be statistically significant.

Storage holdings of the livestock product at the end of the previous quarter were included in the price-dependent equations because they influence the supplies of the product available for consumption in the current period. Per capita disposable income and the implicit price deflator for non-durables were included as shift variables. Seasonal dummies also were included when they were found to be statistically significant.

The empirical results, based on data for the period 1970-79, are shown in Table 4. The coefficients are in the form of price flexibilities, that is the average percentage change in the price (or price index) associated with a 1 percent change in marketings or production. Technically, the price flexibility coefficients reported in Table 4 apply only at the mean level of output and prices. Percentage relationships, which the flexibility coefficients represent, change as the quantity marketed increases or decreases. This is a function of having estimated the slope coefficients assuming linear price-quantity relationships.

Table 4. Retail Price Flexibilities for Various Livestock Products Calculated at Mean Values of the Data

Retail Price of:	Effects of a 1% Increase in Marketings on Retail Prices Beef	Pork	Broilers	Eggs	Milk
Beef (index)	-1.34	-0.13			
Pork (index)	-0.16	-1.37			
Broilers			-2.17		
Eggs				-2.04	
Dairy Products (index)					-0.044

Price flexibilities differ among the various livestock products. The beef and pork coefficients are of a similar order of magnitude, but considerably less than the coefficients for broilers and eggs. This implies that the demand for broilers and eggs is less elastic (or more inelastic) than the demand for red meat. The flexibility coefficient for broilers is higher than that reported by other price analysts (see for example, George and King). It is possible that in this case the price flexibility coefficient is picking up the effect of a persistent downward trend in real broiler prices that prevailed during the 1970s. The low price flexibility coefficient for dairy products probably reflects the support program which strongly influenced the wholesale prices of dairy products and for fluid milk during that period.

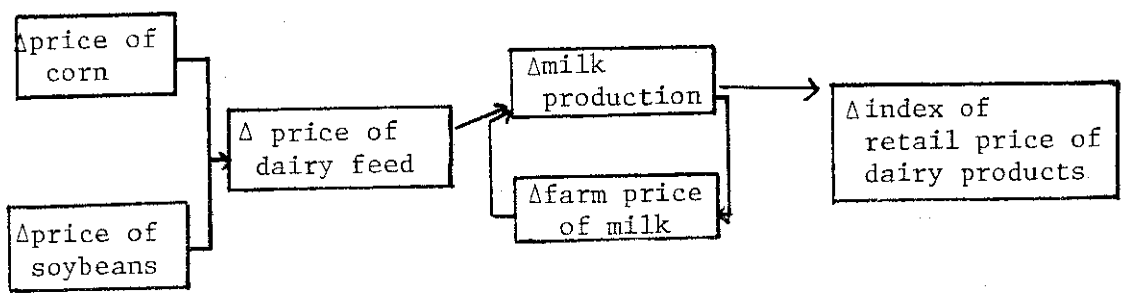
Corresponding equations were estimated to determine the effect of changes in the output of livestock products on farm prices; however, some of the variables used in the retail analysis did not produce satisfactory results when included in the farm level equations. For this reason, storage stocks, per capita income and the GNP implicit price deflator were not used as explanatory variables in the farm price equations. A time trend was substituted for the deleted variables and this gave more reasonable results. The dependent variable for each of the farm-level equations was the average farm price reported for the quarter by the U. S. Department of Agriculture.

Simulation Results

Simulation techniques were used for the purpose of evaluating the model and for examining the impact on livestock production and livestock product prices of a large increase in the price of corn and soybean meal. Simulation was used in these two cases in order to take into account the interaction between farm prices and production. Because of the relatively long lags involved in the adjustment of livestock production, it was expected that changes in livestock prices, induced by changes in feed prices, would modify to a considerable extent the impact caused initially by the change in the cost of feed.

A schematic diagram of the model for the dairy sector is shown in Figure 2. Similar models were developed for the other livestock sectors. Beef and pork linkages are more complex because of the significant degree of substitutability which exists between these two products. Production and prices interact in a recursive way and thus determine, within each time period, both production and prices.

Figure 2. Linkages Between Feed Ingredient Prices and Retail Prices for Dairy Products



Evaluating the Model

Components of the model were first evaluated to see how closely they were able to capture the changes in production that occurred during the period 1973-79 which included the years used to estimate the coefficients. Each livestock sector model was then used to forecast production in 1980 and in some cases 1981, one or two years beyond the estimation period. Endogenous variables used in the analysis included the price of feed, per capita income, the price deflator, a trend variable and seasonal dummies. Farm level and retail livestock product price relationships had to be estimated in order to take account of the effect of these price changes on subsequent output. The simulation period was not the same for each livestock sub-sector owing to differences among livestock products in the length of the lag in production response. A number of observations preceding the beginning of the simulation period are necessary to calculate the lagged values of the endogenous variables. In general, the simulation period beyond the data base begins with the 4th quarter of 1979 and ends with the 4th quarter of 1981; however, for both fed and non-fed beef, the results could be compared only through 1980 because data for 1981 were not available at the time the simulation runs were being made.

The results obtained from the simulation model are shown for fed beef and non-fed beef in Figures 3 and 4. The results for fed beef are not entirely satisfactory. Actual production deviated substantially from the simulation results in 1975, 1977 and again in 1980. Apparently the model was unable to capture fully the seasonal pattern of changes in production which actually occurred. The overall performance of the non-fed beef production model was quite satisfactory although actual production in 1980 exceeded by a substantial margin the simulated production in that year. Thus, the ability of the model to make accurate projections beyond the period from which the data are drawn is suspect.

Corresponding results for pork, broilers and eggs are shown in Figures 5, 6, and 7. The pork model performed well for the period from 1973 through first quarter of 1979, but rather poorly thereafter. Other forecasting models also failed to predict the high levels of pork production that were maintained during this period. Thus, it is not surprising that the simulation model produced forecasts that were far below actual production in 1980 and 1981.

The broiler production model likewise failed to predict production accurately in 1980 and 1981 despite its excellent performance in tracking actual production from 1972 through the first quarter of 1979. The egg simulation model performed in a similar fashion. Thus, it is not clear that the coefficients derived from data covering the period 1970-79 can be used in a simulation model to produce reliable production forecasts beyond that period.

The production and price coefficients previously derived also were used to simulate the behavior of prices. Forecasts of prices for 1980 and 1981 proved to be too high because production forecasts, as previously noted, were generally below the levels of output that prevailed during those two years. The model performed better at predicting milk prices than milk production. Milk prices were relatively easy to predict throughout the 1970s because they were closely linked to support prices, which in turn were indexed and consequently moved up with the general rate of inflation.

One method of evaluating the performance of simulation models is to calculate the percentage root mean square error. 4/ This was done for each of the livestock subsectors for both the production and price simulation

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4/ The percentage root mean square error is simply the root mean square error (RMSE) divided by the mean and multiplied by 100. The RMSE is defined as follows:

$$\text{RMSE} = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (X_i - \hat{X}_i)^2}$$

where X_i = the actual observation, and

$\hat{X}_i$ = the corresponding forecast.

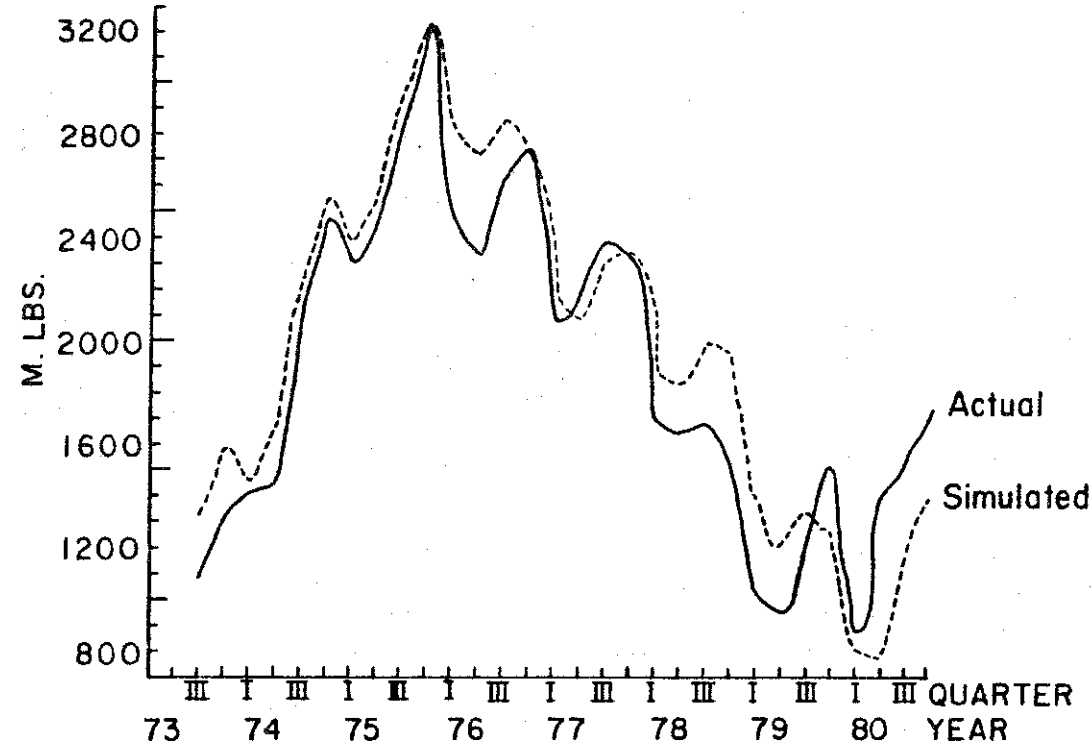

Figure 3. Non-fed Beef Production

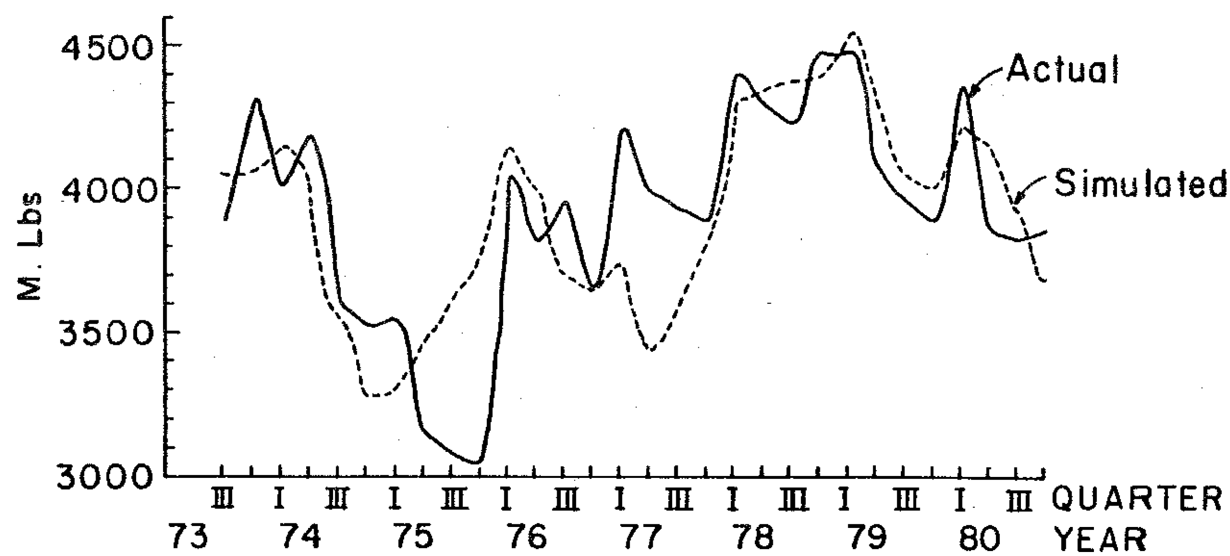

Figure 4. Fed Beef Production

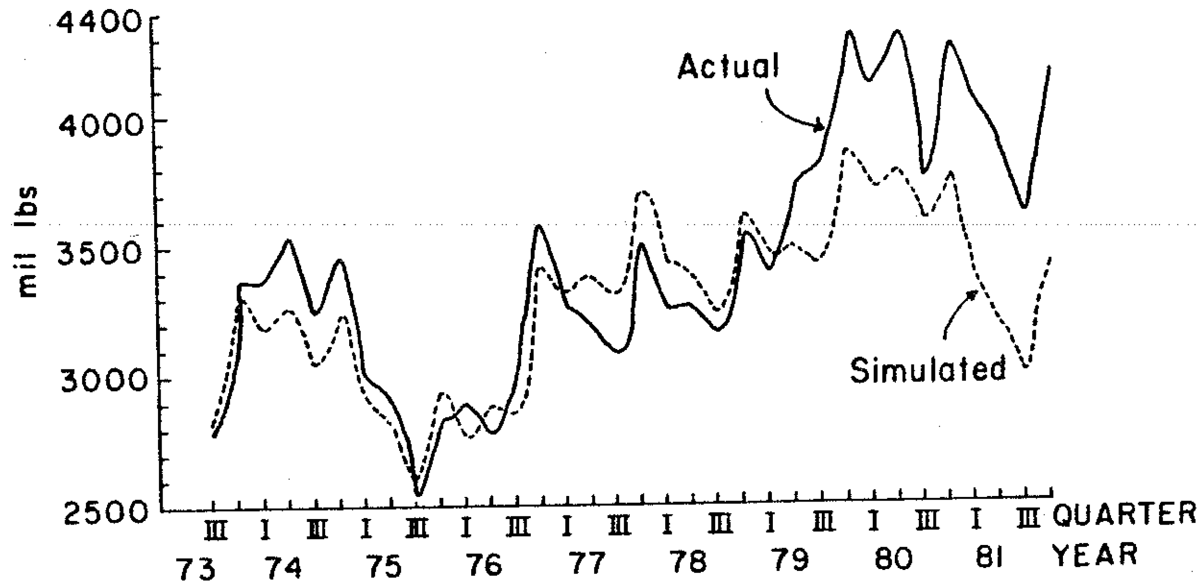

Figure 5. Pork Production

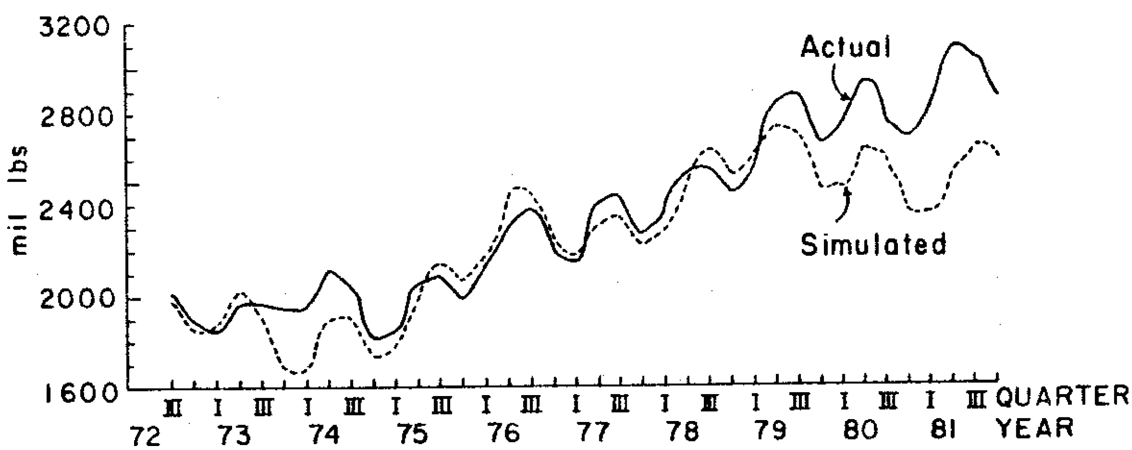

Figure 6. Broiler Production

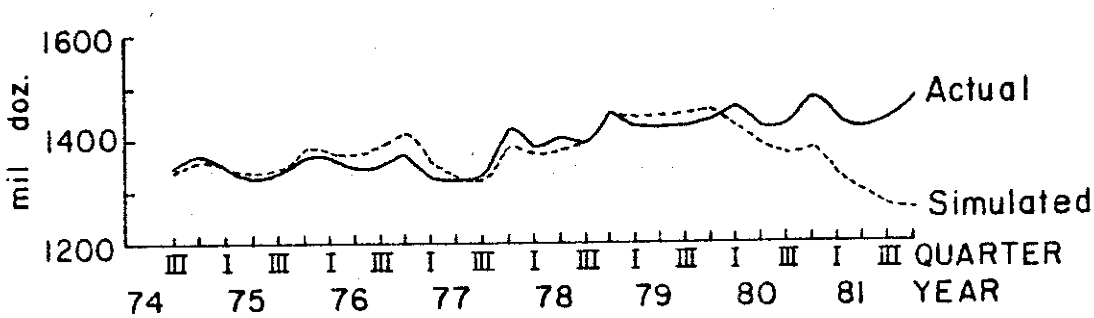

Figure 7. Egg Production

models covering the period 1973-79. The percentage root mean square errors for the production simulation models are shown in Table 5. The values ranged from only 1.5 per cent for eggs to 12.1 per cent for non-fed beef. The retail price simulation model errors were less than those calculated for the production simulation model only for milk and beef.

Table 5. Percentage Root Mean Square Errors of Simulated Production and Retail Prices*

	Production	Retail Price
Fed Beef	6.8	6.6
Non-fed Beef	12.1	
Pork	4.8	6.5
Broilers	5.5	11.5
Eggs	1.5	7.4
Milk	8.2	2.5

* Based on the period 1973-79 except for eggs which includes only 1974-79.

Production Effects of Higher Feed Ingredient Prices

The individual livestock subsector models were used to assess the potential impact on livestock production and retail livestock product prices of a large increase in feed ingredient prices. The feed ingredient price assumptions were selected arbitrarily; the subsector models were run assuming an increase of $1 per bushel in the price of corn and $5 per hundredweight in the price of soybean meal. These prices represent increases of 40 to 50 per cent from the level of prices prevailing in the early 1980s. Coefficients of the feed ingredient-livestock feed model were used to convert these increases into equivalent changes in feed costs. The production and retail price simulation models were then run for each subsector to obtain estimates of how much livestock output and retail livestock product prices might be expected to change, given the assumed changes in feed ingredient prices. The other exogenous variables, including per capita income, stocks of livestock products, inventories of breeding stock, and all other prices were held at the level prevailing in 1979. The endogenous variables are livestock output (by subsectors) and both farm and retail prices. The model takes account of the feed-back effect of higher livestock prices early in the simulation period on subsequent production. No changes in feed ingredient prices were permitted once the initial increase was factored into the model. The model was run for whatever number of years was required to reach a new equilibrium.

The cumulative effects of the increase in feed prices on the endogenous variables are reported for each of the four years following the assumed price increase. This time period was considered appropriate for the following reasons: First, the empirical evidence presented earlier indicates that all the major adjustments in production to an increase in feed prices takes place within a four year period. Second, from a policy perspective, the impacts within this period are likely to be more important than the impacts in subsequent years. Third, the liquidation of the beef breeding herd, which is implied by the non-fed beef supply response, cannot be assumed to continue for more than 4 to 5 years.

The reported change of an endogenous variable during a specific quarter of the four year period is relative to the value of the same variable during the quarter preceding the change in the price of feed. Thus, the impacts reported in Tables 5 and 6 are cumulative impacts on the endogenous variables relative to the equilibrium values of the same variables which prevailed immediately before the increase in the price of feed ingredients. 5/

The results based on the foregoing assumptions are summarized in Table 6. The most sensitive sectors to changes in feed prices are beef and pork. At the end of sixteen quarters following the increase in feed prices, both fed beef and pork production are approximately 30% below the initial levels. Fed beef production, however, changes considerably more than pork production during the first eight quarters. Broiler production declines by 10-14% over the four year period following the increase in feed prices.

Table 6. Impact of a $1/bu. Increase in the Price of Corn and $5/cwt. in the Price of Soybean Meal on Livestock Production a/

Time Period (Quarter after Increase)	Percent Change in Production						
	Fed Beef	Non-fed Beef	Pork	Broilers	Total Meat	Eggs	Milk
After 4 quarters	-25	41	-14	-14	-9	-1	2
After 8 quarters	-22	159	-16	-14	-6	-10	-3
After 12 quarters	-26	238	-27	-10	5	-18	-5
After 16 quarters	-29	228	-29	-13	1	-16	-4

a/ The impacts are cumulative relative to 1979. In the case of egg production the change is calculated on the basis of 1,410 million dozen per quarter while in the case of milk on the basis of 29,657 million pounds per quarter.

5/ In the case of beef, pork and broilers, the estimated supply relationships contain the price of feed and the price of the livestock product as separate explanatory variables as opposed to eggs and milk in which the ratio of feed to livestock prices was used as the explanatory variable. For the livestock sectors which belong to the first category, the results do not depend upon the particular starting values of the variables. Thus, in the case of beef, pork and broilers, the cumulative impact on livestock production and prices can be considered relative to the 1979 values of the same variables expressed on a quarterly basis.

By the end of the four-year period, non-fed beef production increases by over 200 per cent. This large increase in non-fed beef production offsets to a great extent the decrease in fed beef, pork and broiler production. As a result, total meat production declines very little during the first two years following the increase in feed costs. It falls 9 per cent during the first year and by 6 per cent during the second year following the increase in feed prices. During the third and fourth years meat production actually increases by 5 per cent and 1 per cent respectively.

The impact on total meat production depends to a great extent on the phase of the cattle cycle when the increase in the price of feed occurs. When the size of the beef breeding herd is large, as during the period 1973-75, the amount of non-fed beef available for sale also is very large. If these animals are sold, the increased quantity of non-fed beef will help to compensate for reduced supplies of fed beef, pork and broilers. The change in non-fed beef marketings undoubtedly would have been less if the increase in the price of feed had occurred during a period when the size of the beef herd was small.

The length of the liquidation period also depends on the size of the beef breeding herd. The coefficients used in the simulation model are based on what happened during the liquidation phase of the cattle cycle which occurred in the 1970s and lasted from 1974 through 1978. The initial runs of the simulation model reflect the situation which prevailed in the mid 1970s, thus making it possible to increase non-fed cattle marketings during each of the four years following the assumed increase in feed ingredient costs.

In an attempt to ascertain what might happen if the beef cycle were at a low point and feed ingredient prices rose, a second simulation run was made assuming no net reduction in cattle numbers. Under such circumstances, the increase in the number of non-fed cattle slaughtered would just equal the reduced number of cattle going into feed lots. If no liquidation in the beef herd is permitted, fed beef production declines, as one would expect, but this is still offset by an increase of approximately 90 to 95 per cent in marketings of non-fed beef. This is less than half the 230 per cent increase which occurs if there is a large stock of animals available for liquidation. Total meat production, which rises in the third and fourth year under the initial assumptions, as shown in Table 6, would decline slightly if no liquidation of the total beef herd were permitted.

The impact on milk production of a substantial increase in feed costs, according to the simulation model, is likely to be relatively small. The maximum decrease in milk production is 5 per cent and it occurs twelve quarters after the increase in feed prices. Egg production decreases very little the first year following the increase in feed prices, but during the third and fourth year it declines 16 to 18 per cent.

One way of checking on the reasonableness of the results obtained with the simulation model is to compare the changes in livestock output derived from the model with the changes which actually occurred following the sharp rise in feed costs in the mid 1970s. The rise in ingredient costs during that period was of a similar order of magnitude as that assumed in making the simulation runs. Between 1972 and 1975, fed beef production declined

31 per cent, pork production declined 20 per cent, and non-fed beef marketings increased 170 per cent. These changes do not differ greatly from those generated by the simulation model during the first three years following the assumed increase in feed ingredient costs. Production of milk also declined about 4 per cent during this period, about the same as the change projected by the simulation model; however, the model projected a much greater decline in egg production and a moderately larger decline in broiler production than actually occurred during the mid 1970s. Egg production fell only 8 per cent (compared to a projected decline of 18 per cent at the end of the third year for the simulation model) and less than 1 per cent for broilers (compared to a projected decline after 12 quarters of 10 per cent). This evidence suggests that one should not accept uncritically the results obtained from the egg simulation model.

Consumer Price Effects of Higher Feed Ingredient Prices

The livestock subsector models were used to simulate retail prices of livestock products as well as production, again assuming an increase of $1 per bushel in the price of corn and $5 per hundredweight in the price of soybean meal. The results of these simulation runs are summarized in Table 7. During the first year following the rise in ingredient prices, beef, pork and broiler prices increase significantly, but there is little impact on the prices of eggs and milk. Thereafter, non-fed beef supplies increase to such an extent that beef prices decline. At the end of the 4th year they are still nearly 25 per cent below the initial level. In sharp contrast to beef prices, pork and broiler prices remain above the level of prices prevailing before the assumed jump in feed ingredient prices, even during the third and fourth years. Egg prices also continue to rise in the second and third year, and remain well above the initial level of prices in the fourth year. Thus, except for beef prices, which fall because of the large increase in marketings of non-fed beef, the effect of a substantial rise in feed ingredient prices is to cause retail prices of meat to rise by anywhere from 10 to 30 per cent and to remain high for the remainder of the four year simulation period.

Table 7. Impact of an Increase of $1/bu. in the Price of Corn and $5/cwt. in the Price of Soybean Meal on Retail Livestock Product Prices a/

	Percent Change in Retail Prices				
Time Period	Beef	Pork	Broilers	Eggs	Milk
(Quarter after Increase)					
After 4 quarters	10	12	32	2	≠
After 8 quarters	-12	6	31	17	≠
After 12 quarters	-27	10	21	28	≠
After 16 quarters	-23	18	29	26	≠

a/ Impacts are relative to 1979 retail prices.

≠ Change of less than 1 percent.

One of the effects of higher feed prices clearly is to alter relative meat prices. Broilers and pork become much more expensive relative to beef than in the base period. This is consistent with what actually happened to relative meat prices during the late 1970s; however, the divergence between beef and other meat prices implied by the simulation results is not likely to persist, given the substitutability that is possible among meat products. One of the weaknesses of the model may be that it fails to take full account of substitution relationships. Cross elasticity (or cross price flexibility) coefficients estimated on the basis of data for the period 1970-79 were either weak or non-significant in most cases.

The impact of the increase in feed ingredient costs on milk prices is insignificant. This is due to the insensitivity of milk production to changes in feed prices and to the existing government support program for dairy products.

The final step in the analysis of the impact of a substantial rise in feed ingredient prices on consumers was to estimate the effects on the overall rate of inflation. The simulation model, as indicated above, traces through the consequences of higher feed prices on livestock output and retail prices of livestock products. Once these price changes have been estimated, it is relatively easy to calculate their effects on the Consumer Price Index using the CPI weights assigned to each of the major livestock products. If all other prices are held constant, the net effect of the assumed increase in feed ingredient costs on the CPI is very modest, amounting to a rise of less than 1 per cent. Based on the simulation results, the CPI is projected to increase by only 0.5 per cent during the first year following the increase in feed ingredient prices. Owing to the increase in total meat supplies in subsequent years (which is the result of added marketings of non-fed beef), retail meat prices are projected to decline slightly in the third and fourth years following the rise in feed ingredient costs. Again the results are strongly influenced by the assumption that sufficient numbers of beef animals are available to offset the price impact of reduced output of other livestock products.

Time Required to Restore Profitability in Feeding Livestock

A major part of the burden of adjustment to rising grain prices obviously falls on livestock feeders. The immediate impact of higher grain prices is to reduce the profitability of feeding. Eventually, of course, feeding margins will recover as output is cut back and livestock prices rise (assuming they are not controlled). In the 1970s, as pointed out earlier, relative prices moved strongly against livestock feeders in 1974, but then recovered to the level prevailing before the rise in feed ingredient costs within a period of three years owing to a decline in grain prices (following 1974) and a rise in livestock product prices. The subsequent decline in grain prices was one of the principal factors helping to restore profitability in feeding livestock during the late 1970s, but this sequence of events will not necessarily be repeated in the future. For this reason, the simulation model was used to estimate how long it would take for feed-livestock product price ratios to recover to the level prevailing before the assumed increase in feed ingredient costs. A further assumption made in conducting this part of the analysis is that feed costs do not decline in subsequent years, but remain at the new and higher level.

Under the foregoing assumptions, recovery in the feed-livestock price ratio for an individual livestock sector is contingent on reducing output by enough to raise prices to whatever level is necessary to compensate for the rise in feed costs. The time required for this to occur for each of the major livestock sub-sectors is shown in Table 8. Neither the beef-feed nor the milk-feed price ratio recovers to the initial level during the 16 quarters (4 year period) following the assumed rise in ingredient costs. The failure of beef prices to rise by enough to offset the effects of higher feed costs is a function of the large-scale liquidation of beef herds which keeps beef prices depressed; however, with lower prices for replacement cattle going into feed lots, feeding margins still could improve despite weak prices for fed cattle. In the case of milk, output does not decline by enough to raise milk prices above the support level, and consequently there is insufficient price increase to compensate for the higher feed costs.

Pork and broiler production decline more promptly in response to higher feed prices than milk or beef production, and for this reason, price ratios are restored to their former level within one year. According to the simulation model it takes about two years for egg prices to rise by enough to bring the egg-feed ratio to the level prevailing before the assumed increase in feed ingredient costs.

Table 8. Number of Quarters After Initial Price Increase for Feed-Livestock Price Ratios to Recover

	Time (in quarters) Required for Ratio to Recover
Beef	≠
Pork	3
Broilers	3
Eggs	7
Milk	≠

≠ Does not recover within 16 quarters.

Summary and Conclusions

The research described in the foregoing pages was undertaken to provide information which would enable those involved in making policy decisions to assess the potential impact on the livestock economy and on consumers of allowing unrestricted exports of grain and soybean products during periods of short supplies and rising prices. A simulation model was developed for the purpose of tracing through to consumers the consequences of a substantial increase in feed ingredient prices. The coefficients incorporated in the simulation model are based on what happened to livestock production and prices during the period from 1970 to 1979.

The lag between changes in the prices of corn and soybean meal and feed costs is very short. Almost all the increase in the price of feed ingredients is reflected in feed prices during the quarter in which the change in ingredient prices occurs. The prices of poultry and hog feeds are the most sensitive to changes in the prices of corn and soybean meal. Dairy feed is least sensitive owing to the fact that the proportion of by-product feed ingredients used in dairy rations is greater than in poultry and hog feed.

Both the timing and magnitude of adjustments in production to changes in feed costs vary among livestock sectors. Pork, broiler and fed beef production are the most sensitive of the livestock subsectors to changes in feed costs. Empirical evidence, based on what happened in the mid 1970s, suggests that most of the adjustment in fed beef production occurs within one year of the rise in feed costs, while the impact of higher feed costs is spread over two years for broilers and over three to four years for pork production. The Almon lag model, which was used to determine the length of the adjustment period, suggests that the impact of changes in feed costs is likely to be spread over a much longer period for egg production than for broilers. Milk production appears to be the least responsive of any livestock product to an increase in feed ingredient prices.

A simulation model using coefficients based on the response of production to price changes in the 1970s was used to estimate the impact on each major livestock product and on retail livestock product prices of a simultaneous increase of $1 per bushel in the price of corn and $5 per hundredweight in the price of soybean meal. These price changes are equivalent to a 40 to 50 per cent increase in the cost of feed ingredients from the level of prices prevailing in the early 1980s.

Increases in feed ingredient costs of this magnitude were projected to reduce fed beef production, over a four year period, by 29 per cent. Nearly all of the decrease in fed beef production occurs within the first year. Pork production also declined by 29 per cent, but the effects are distributed over a longer period. The projected decrease in broiler and egg production was somewhat less, ranging from 13 to 16 per cent and milk production still less, amounting to less than 5 per cent.

The simulation runs produced surprisingly small changes in total meat production in response to higher feed ingredient prices. This is attributable to a large increase in marketings of non-fed beef, made possible by reducing the size of the beef herd. The model accurately reflects what happened to beef supplies in the mid 1970s. The rise in feed ingredient costs at that time triggered a reversal of the cattle cycle. Increased slaughter of non-fed cattle, provided there are sufficient numbers to make this possible, helps to compensate for reduced supplies of pork, fed beef and broilers. If the increase in feed costs occurs at a time when the inventory of beef cattle is relatively small, total meat supplies obviously would decline much more.

Relative livestock product prices change dramatically in response to the projected changes in production. Retail beef prices were projected to decline by as much as 27 per cent as a result of the large increase in marketings of non-fed beef, while pork and broiler prices rose 18 and 32 per cent respectively. Milk prices proved to be the least sensitive to changes in feed ingredient costs owing to the small change in production projected by the model and the influence of the dairy support program which largely dictates the level of retail prices for dairy products.

The impact of higher grain prices on consumers is distributed over a relatively long period owing to lags in response of livestock feeders to changes in feed costs. The overall effect on inflation, as measured by the Consumer Price Index, also is relatively small. The assumed 40 per cent increase in grain prices produced a net increase of less than one per cent when the price changes projected for each of the major livestock products were weighted according to their relative importance in the CPI.

The simulation model developed for this study can be used to project the consequences of a sequence of price changes for feed ingredients as well as a one-time increase in prices. In practice, corn and soybean prices are not likely to remain stable. This was demonstrated during the late 1970s when prices changed (in this instance they declined) before the full effects of the initial price increase had been transmitted through the various livestock sectors and on to consumers. Fortunately, the cost of a single simulation run is modest, amounting to only about $5 per run. Thus, it is possible to use the model to project the consequences of a wide range of alternative scenarios at very low cost.

The principal limitation of the study is that the results are strongly influenced by the experience of the 1970s. The model performed very well in tracing changes in livestock output and prices during that period, but much less well in forecasting production in the two years beyond the period used to derive the coefficients. Structural changes may have occurred in recent years that make the relationships between changes in feed ingredient costs and livestock output during the 1970s inappropriate for forecasting changes in the 1980s. The results also are influenced by the model used to estimate the length of the adjustment period and the magnitude of the response identified for each livestock sector. The Almon lag model, which was selected for this purpose, appears to pick up trend effects where they are present, as in the case of eggs. This led to incorporating a longer adjustment period for eggs in the simulation model than one can justify on logical grounds or the results of other studies. Finally, the results, as previously emphasized, are strongly conditioned by the stage in the cattle and hog cycles at which the change in ingredient prices occurs.

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