A Quarterly Econometric Model of United States Livestock and Feed Grain Markets and Some of Its Policy Implications

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This paper discusses the structural equations, forecasting properties, dynamic characteristics, and economic policy implications of a quarterly econometric model of U.S. livestock and feedgrain markets. Quarterly, semi-annual, and annual endogenous variables are incorporated by allowing individual structural equations to be estimated and to enter into the solution of the model with different periodicities. Commodity prices are determined by market equilibrium conditions rather than by autoregressive and other time-series techniques. Dynamic multipliers give the effect of changes in corn exports, beef imports, government grain stocks, corn yield, consumer income, and the support price for corn on producer and retail prices and acreage planted.

Key words: econometric model, economic policy, U.S. agriculture.

This paper presents a quarterly econometric model of the United States livestock and feed grain markets and analyzes some of its policy implications. The econometric model is designed to provide quarterly forecasts for such variables as livestock and grain production and prices, the retail-producer price spreads for meat products, and consumer demand for meat. The forecasts are conditional upon assumed values of such exogenous variables as disposable personal income, government policy with respect to the livestock and feed grain markets, and certain other developments in the economy.

Some of the principal features of the model are as follows: Quarterly, semiannual, and annual endogenous variables are incorporated by allowing individual structural equations to be estimated and to enter into the solution of the model with different periodicities. Thus the endogenous annual corn harvest enters into the solution of the model only in the fourth quarter of each year. Feed grain production, consumption, and prices are endogenous so that the dynamics of the interaction of the livestock and feed grain markets may be analyzed.[1] The microeconomic market supply and demand specification is retained as far as possible. Commodity prices are determined by market equilibrium conditions rather than by autoregressive and other time-series techniques.

The organization of this paper is as follows. The second section discusses the estimated structural equations; the third analyzes the solution of the model and evaluates its forecasting accuracy; the fourth examines dynamic characteristics and utilizes the multipliers of the model to analyze a number of policy issues; and, finally, the fifth section summarizes the main findings of the paper.

The Structural Equations

The econometric model consists of forty-two equations of which five are market clearing equations and fourteen are identities. These equations explain the demand and supply for five commodities (fed and nonfed beef, pork, chicken, and the principal feed grain—corn)

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The authors gratefully acknowledge financial support from the C. W. Cook Center for Food Policy Studies of Columbia University and valuable comments from Giulio Pontecorvo and *Journal* referees.

[1] The most complete econometric study of the livestock sector is that of Freebairn and Rausser. However, their model is annual and treats grain prices as exogenous. Previous studies focusing on partial aspects of the livestock sector are Crom, Hayenga and Hacklander, and Langemeier and Thompson. Meilke modeled the grain sector. Models of the Canadian livestock sector are Kulshreshtha and Wilson and Tryfos. Aggregate models of the U.S. agriculture focusing on its interrelation with the rest of the economy but not developing the livestock production process include Fox and Chen.

and the role of prices in clearing the market for each commodity.

Table 1 identifies variables and table 2 presents the estimated structural equations.[2] In addition, measures of the goodness of fit and serial correlation of the residuals, the estimator utilized, the sample period, and the periodicity of the equation are listed. Some equations are estimated annually (10) and (11) or semiannually (16) due to data limitations, while other structural equations represent decisions or events that essentially occur only annually—see (22) and (23) dealing with planting and harvesting of grain. Structural equations not characterized by simultaneous determination of endogenous variables are estimated by ordinary least squares and all other equations by (truncated) two-stage least squares (Fair 1970, 1973). The list of instrumental variables is given in the notes to table 2.

A linear functional specification has been adopted for the structural equations of the model. The primary justification for this structure is the desire to simplify the data requirements, estimation, and analysis of the model (Arzac and Wilkinson). Dummy variables are introduced in quarterly demand and supply equations to allow for seasonal effects such as holidays and weather on demand (Logan and Boles) and biological growth patterns of livestock on supply. Explanatory variables with the expected signs have been retained in the structural equations even when the estimated standard errors are large relative to the point estimate of the coefficient.

The structural equations may be arranged into the following blocs:

Bloc	Equation Numbers
I. Consumer demand for meat	(1)–(4)
II. Retail and producer price relations	(5)–(8)
III. Livestock production, inventory, and supply relations	(9)–(19)
IV. Demand and supply of feed grain	(20)–(23)
V. Market clearing equations and identities	(24)–(42)

[2] The data were obtained from the following sources: USDA *Livestock and Meat Statistics, Feed Situation, Livestock and Meat Situation, Hogs and Pigs, Agricultural Statistics, Poultry and Egg Situation, Crop Production*, and worksheets; U.S. Department of Commerce, *Business* and *Employment and Earnings*.

Table 1. Variable Definitions

	Endogenous Variables		
*AP*1	Acreage planted for corn (thou. a.)	*Mi*	Retail-producer price spread, $i = 1, \ldots, 4$ (¢/cwt.). See equ. (23)–(27).
AU	Animal units on feed (m. hd.)	*PFi*	Producer price of meat, $i = 1, \ldots, 4$ (¢/cwt.)
DSC	Change in prior calf slaughter, see equ. (29)	*PF*5	Price of feeder steers (¢/cwt.)
*EC*4	Prior exports of corn, see equ. (32)	*PG*1	Corn price (¢/10 bu.)
ICC	Commercial corn inventory, end of per. (m. bu.)	*PRi*	Retail price of meat, $i = 1, \ldots, 4$ (¢/100 lb.)
IH	Number of pigs on feed, end of period (thou. hd.)	*SC*	Calves slaughtered (thou. hd.)
IP	Cattle and calves on feed, end of period (thou. hd.)	*SC*4	Prior calf slaughter, see equ. (28)
		XDC	Domestic corn demand (m. bu.)
*IP*4	Prior placement of cattle and calves on feed, see equ. (30)	*XDi*	Demand for meat, $i = 1, \ldots, 4$ (m. lb.)
		XSi	Meat production, $i = 1, \ldots, 4$ (m. lb.)
KB	Inventory of beef cows, begin. of period (thou. hd.)	*XSC*	Corn production (m. bu.)
		YZ	Real disposable personal income ($10 mill. 1967) See equ. (42).
KC	Net calf crop (thou. hd.)		
KH	Sows kept for breeding, begin. of period (thou. hd.)	*Zi*	Real retail price of meat, $i = 1, \ldots, 4$ (¢ of 1967/100 lb.). See equ. (38)–(41).
	Exogenous Variables		
*B*1	Choice beef by-product allowance (¢/10 cwt.)	*KD*	Inventory of dairy cows, begin. of period (thou. hd.)
*B*3	Pork by-product allowance (¢/10 cwt.)		
CPI	U.S. consumer price index (1967 = 10,000)	*LP*	Index of productivity in poultry production (1967 = 1000)
EC	Export of corn (m. bu.)		
EXi	Exports of meat, $i = 1, \ldots, 4$ (m. lb.)	*PF*	Support price for corn (¢/10 bu.)
H	Corn yield per harvested acre (bu./100 a.)	*PSB*	Price of soybean (¢/10 bu.)
ICG	Government corn inventory, end of period (m. bu.)	*Qi*	Dummy variable, $i = 2, 3, 4$. $Qi = 1000$ in *i*th quarter, $Qi = 0$ otherwise
ID	Dairy herd replacements, begin. of period (thou. hd.)	*W*	Wage rate in meat packing ($/100 w.)
		*W*2	Wage rate in poultry dressing ($/100 w.)
IMXi	Imports of meat, $i = 1, \ldots, 4$ (m. lb.)	*Y*	Current disposable personal income ($ 10 mill.)

Meat Commodity Index: $i = 1$ for fed beef, $i = 2$ for nonfed beef, $i = 3$ for pork, $i = 4$ for chicken.

Total consumer demand for the four meat commodities (*XDi*) is assumed to be a function of the real price of each commodity (*Zi*) and real disposable personal income (*YZ*). The consumer demand equations (1)–(4) exhibit theoretically plausible and statistically significant coefficients for own price and income.[3] Five of the twelve cross-price coefficients are negative, which would violate a priori belief that these four commodities are pairwise specific or net substitutes (Theil, p. 41). The econometric evidence, however, is not consistent (e.g., Christensen and Mancer, p. 47, and Freebairn and Rausser).

The second bloc of equations specifies the relationship between the consumer or retail prices of meat as a markup or margin model (George and King, Fox). Labor costs (*W*) and the by-product value of the respective commodity (*Bi*) explain a significant part of the difference between retail and producer prices (*Mi*).

Equations (9)–(19) explain livestock production, inventory, and supply. Equation (9) is a partially reduced form equation (Nerlove) in which the price of feeder steers (*PF*5), an important input in beef production, is determined by the producer prices of fed (*PF*1) and nonfed beef (*PF*2), feed grain (*PG*1), prior calf slaughter (*DSC*), and the available supply of calves, the net calf crop (*KC*) minus dairy herd replacements (*ID*). All estimated coefficients are significant and have the expected sign. *PF*5 is more responsive to *PF*2, which represents the current opportunity cost of feeding, than to *PF*1, which is only an indicator of the future price of fed beef. The supply side is modeled in terms of undeflated prices. Given the relatively modest inflation rate observed during most of the sample, deflating by any of the available general indexes would induce unacceptable errors in variables.

Equation (10) explains the inventory (herd) of (breeding) beef cows (*KB*) as a function of the prices of feeder calves and nonfed beef and the previous inventory. Although the price coefficients have the expected signs, the standard errors are relatively large and it is clear that the lagged dependent variable is the major explanatory variable. Equation (11) determines the net calf crop (*KC*) as proportional to the inventory of beef and dairy herds. Calf slaughter takes place from both beef and dairy herds. Equation (12) indicates that calf slaughter (*SC*) varies inversely with the price of feeder steers and directly with the inventory of dairy cows.

The placement of cattle on feed (*IP*) is assumed in equation (13) to depend upon the prices of fed beef and feed grain and cattle available for placement [*SC*4 and *KC*(−4) − *ID*]. The inclusion of lagged placements as an explanatory variable reflects the partial adjustment of placements given the uncertainty of prices. All estimated coefficients are significant and have the expected signs. In equation (14) fed beef supply (*XS*1) is positively related to its own price, inversely related to the price of feed grain, and positively related to cattle placed on feed six months previously [*IP*(−2)]. The large standard error on *PF*1 indicates that in our quarterly model the own-commodity price has the principal impact upon decisions taken earlier in the production process—the supply and demand of feeder calves, equations (9)–(10) and (12), and the placement of cattle on feed, equation (13). Finally, the supply of nonfed beef (*XS*2) is explained in (15) as a function of *PF*5, culls from a weighted average of beef and dairy herds (*KB* + 0.56*KD*) (Freebairn and Rausser, p. 680), the supply of calves available for feeding on grass or feedlots [*KC*(−4) − *ID*] in conjunction with those placed on feed (*IP*4).

Equations (16)–(20) explain pork and chicken production. Equation (16) explains the partial adjustment of the inventory of breeding sows (*KH*) in response to the price of feed grain, producer price of pork (*PF*3), and the producer price of fed beef. The latter is often an alternative activity to pork production on

[3] Demand equations (1)–(4) imply the following elasticities at sample means:

	Own price	Income
Fed beef	−1.86	1.02
Nonfed beef	−2.97	.45
Pork	−.87	.65
Chicken	−.98	.52

Freebairn and Rausser report much smaller price elasticities for beef, higher income elasticity for fed beef, and negative income elasticity for nonfed beef. On the other hand, Christensen and Manser report price elasticities for aggregate beef of the same order of magnitude as our disaggregated elasticities and George and King found very small income elasticities for aggregate beef. Our estimates of the own-price elasticities are large because of the high degree of substitution existing between these commodities. Assuming that the ratio of fed to nonfed beef prices is constant and taking into account the cross-price coefficients of equations (1)–(2) we obtain:

	Own price	Income
Aggregate beef	−0.39	0.86
Fed beef	−0.49	1.02
Nonfed beef	−0.12	0.45

Table 2. Econometric Model of the U.S. Grain and Livestock Markets

I. Consumer Demand for Meat

1. $XD1 = 3421 - 0.6439Z1 + 0.7252Z2 - 0.0763Z3 - 0.3058Z4 + 0.2388YZ - 0.0564Q2 - 0.1089Q3 - 0.2550Q4$

   (605) (0.129) (0.123) (0.076) (0.140) (0.034) (0.063) (0.066) (0.069)

   $S/M = 0.06$, $DW = 0.49$, $2SLS$ – 1957I/75IV (quarterly)

2. $XD2 = -193 + 0.5497Z1 - 0.8768Z2 + 0.1838Z3 - 0.0109Z4 + 0.0588YZ + 0.0659Q2 + 0.3036Q3 + 0.2684Q4$

   (729) (0.156) (0.148) (0.092) (0.169) (0.041) (0.076) (0.079) (0.083)

   $S/M = 0.13$, $DW = 0.45$, $2SLS$ – 1957I/75IV (quarterly)

3. $XD3 = 2698 - 0.03311Z1 + 0.1451Z2 - 0.3676Z3 + 0.07382Z4 + 0.1486YZ - 0.1184Q2 - 0.0566Q3 + 0.1630Q4$

   (220) (0.048) (0.045) (0.027) (0.051) (0.0123) (0.023) (0.024) (0.025)

   $S/M = 0.02$, $DW = 1.50$, $2SLS$ – 1957I/75IV (quarterly)

4. $XD4 = 941 - 0.03316Z1 + 0.1432Z2 + 0.1104Z3 - 0.3882Z4 + 0.06106YZ + 0.1881Q2 + 0.1968Q3 - 0.02509Q4$

   (261) (0.046) (0.053) (0.033) (0.081) (0.017) (0.024) (0.025) (0.027)

   $S/M = 0.04$, $DW = 1.50$, $2SLS$ – 1960I/75IV (quarterly)

II. Retail and Producer Price Relations

5. $M1 = 66.7 + 0.5989PR1 + 0.0645W - 0.0297B1$, $S/M = 0.02$, $DW = 1.32$, OLS – 1957I/75IV (quarterly)

   (58.4) (0.028) (0.012) (0.017)

6. $M2 = -152.4 + 0.6999PR2 + 0.0351W - 0.0728B1$, $S/M = 0.05$, $DW = 0.33$, OLS – 1957I/75IV (quarterly)

   (100.2) (0.068) (0.019) (0.034)

7. $M3 = 540.9 + 0.5750PR3 + 0.0433W - 0.0911B3$, $S/M = 0.03$, $DW = 0.89$, OLS – 1957I/75IV (quarterly)

   (67.6) (0.032) (0.010) (0.026)

8. $M4 = 474.6 + 0.4443PR4 + 0.0045W2$, $S/M = 0.02$, $DW = 1.54$, OLS – 1957I/75IV (quarterly)

   (45.5) (0.013) (0.0005)

III. Livestock Production, Inventory and Supply Relations

9. $PF5 = 365.7 + 0.2014PF1 + 1.4034PF2 - 0.1665PG1 + 0.2433DSC - 0.01371(KC(-4)-ID) - 0.1035Q2 - 0.1079Q3 + 0.0816Q4$

   (188.1) (0.072) (0.089) (0.044) (0.109) (0.0062) (0.035) (0.034) (0.035)

   $S/M = 0.04$, $DW = 0.92$, $2SLS$ – 1957I/75IV (quarterly)

10. $KB = -900.4 + 1.860PF5(-1) + 0.7133PF5(-2) - 2.285PF2(-1) + 0.9758KB(-1)$

    (905.6) (1.514) (0.3048) (2.396) (0.043)

    $S/M = 0.02$, $DH = 1.39$, OLS – 1956/75 (annual)

11. $KC = 0.8396(KB + KD)$, $S/M = 0.04$, $DW = 0.33$ (with intercept), OLS – 1956/75 (annual)

    (0.0073)

12. $SC = 519.3 - 0.2227PF5 + 0.1060KD(-4) - 0.186Q2 - 0.053Q3 + 0.059Q4$

    (260) (0.048) (0.009) (0.071) (0.071) (0.071)

    $S/M = 0.14$, $DW = 0.23$, $2SLS$ – 1957I/75IV (quarterly)

13. $IP = -1643.3 + 0.4702PF1 - 1.073PG1 - 0.1455SC4 + 0.1468(KC(-4)-ID) + 0.6793IP(-1) - 0.6041Q2 - 0.1858Q3 + 2.2053Q4$

    (956.5) (0.118) (0.146) (0.058) (0.032) (0.066) (0.118) (0.152) (0.174)

    $S/M = 0.04$, $DH = 0.50$, $2SLS$ – 1958I/1975IV (quarterly)

14. $XS1 = 918.2 + 0.0223PF1 - 0.1082PG1 + 0.3161IP(-2) - 0.6852Q2 - 0.6107Q3 - 0.2751Q3$

    (93.1) (0.055) (0.560) (0.010) (0.059) (0.057) (0.056)

    $S/M = 0.05$, $DW = 1.02$, $2SLS$ – 1957I/75IV (quarterly)

15. $XS2 = -2507.1 - 0.1625PF5 + 0.0670(KB + 0.56KD) + 0.0770(KC(-4) - ID) - 0.1570IP4 + 0.085Q2$
(285.5) (0.038) (0.011) (0.018) (0.016) (0.051)
$+ 0.302Q3 + 0.317Q4$
(0.051) (0.051)
$S/M = 0.11$, $DW = 0.97$, $2SLS$ – 1957I/75IV (quarterly)

16. $KH = 6089 - 0.9080PG1(-2) + 0.5862PF3(-2) - 0.2789PF1(-2) + 0.3891KH(-1) + 0.351Q3$
(1614) (0.297) (0.310) (0.331) (0.174) (0.213)
$S/M = 0.06$, $DH = 1.45$, OLS – 1964II/75IV (semiannual)

17. $IH = -4471 + 1.052PF3(-1) - 1.567PG1(-1) + 1.624KH + 0.6676IH(-1) + 8.519Q2 + 5.397Q3$
(3605) (0.356) (0.471) (0.484) (0.111) (0.772) (0.539)
$+ 3.285Q4$
(0.552)
$S/M = 0.03$, $DH = 1.63$, OLS – 1964I/75IV (quarterly)

18. $XS3 = -1271.7 + 0.1489PF3 + 0.09047IH(-1) + 0.333Q2 - 0.409Q3 + 0.051Q4$
(655.7) (0.039) (0.0129) (0.110) (0.087) (0.087)
$S/M = 0.07$, $DW = 0.48$, $2SLS$ – 1962III/75IV (quarterly)

19. $XS4 = 77.5 + 0.09159PF4(-1) - 0.07762PG1(-1) + 0.3920LP + 0.06526XS4(-1) + 0.2247Q2 + 0.1102Q3$
(67.5) (0.028) (0.019) (0.122) (0.011) (0.017) (0.028)
$- 0.0622Q4$
(0.031)
$S/M = 0.03$, $DH = 0.31$, OLS – 1960II/75IV (quarterly)

IV. Demand and Supply of Feed Grain

20. $XDC = 96.6 + 0.0261AU - 0.0160PG1 + 0.0174Y2 - 0.1090Q2 - 0.2413Q3 + 0.2259Q4$
(130.3) (0.0085) (0.0360) (0.0170) (0.043) (0.043) (0.046)
$S/M = 0.10$, $DW = 2.27$, $2SLS$ – 1962II/75IV (quarterly)

21. $PG1 = 529.9 - 0.1730ICC + 0.7094PG1(-1) + 0.6167EC4 - 0.1491Q2 - 0.2739Q3 + 0.1037Q4$
(192.5) (0.073) (0.067) (0.137) (0.080) (0.139) (0.101)
$S/M = 0.10$, $DH = -.76$, $2SLS$ – 1957I/75IV (quarterly)

22. $AP1 = 51229 + 14.007PF + 5.042PG1(-1) - 0.6035PSB(-1)$, $S/M = 0.02$, $DW = 1.88$, OLS – 1961/75
(2899) (4.960) (1.031) (5.202) (annual)[a]

23. $XSC = -4280 + 0.060AP1 + 0.614H$, $S/M = 0.02$, $DW = 2.26$, OLS – 1957/1975
(274) (0.003) (0.013) (annual)

V. Market Clearing Equations and Identities

23+i. $Mi = PRi - PFi$, $i = 1, \ldots, 4$

28. $SC4 = \sum_{t=0}^{3} SC(-t)$

29. $DSC = SC4 - SC4(-1)$

30. $IP4 = \frac{1}{4} \sum_{t=0}^{3} IP(-t)$

31. $AU = 1.523IP(-1) + 0.2285IH(-1) + 0.0702XS4$[b]

32. $EC4 = \sum_{i=0}^{3} EC(-i)$

33. $XSC = XDC + ICC + ICG - ICC(-1) - ICG(-1) + EC$

33+i. $XDi + EXi = XSi + IMXi$, $i = 1, \ldots, 4$

37+i. $Zi = PRi/CPI$, $i = 1, \ldots, 4$

42. $YZ = Y/CPI$

Note: Standard errors are in parentheses. S/M is the ratio of the standard error of the equation to the mean of the dependent variable. DW is the Durbin-Watson statistic. DH is the simple Durbin H statistic [Durbin (1970)]. The basic set of instruments for $2SLS$ is YZ, CPI, W, $B1$, $B2$, $W2$, $KD(-4)$, LP, EC, PF, H, $Q2$, $Q3$, $Q4$. Lagged endogenous variables appearing in a particular equation are added to the basic set when estimating that equation.

[a] Lags indicate the quarter previous to planting.

[b] Grain-consuming animal units. See USDA (1974), p. 94.

small farms; however, the standard error is large on this variable. The partial adjustment of placement of pigs on feed (*IH*) is specified in equation (17) as a function of the prices of pork and feed grain and the inventory of breeding sows. Equation (18) indicates that the supply of pork is dependent upon its own price and prior placements of pigs on feed. Finally (19) specifies the supply of chicken as a function of its own price, the price of feed grain, an index of productivity in the poultry sector, and lagged supply of chicken. All variables are significant and exhibit the expected signs.

Equations (20)–(23) explain the demand for and supply of corn. Equation (20) explains the domestic demand for corn (*XDC*) for animal feeding and food processing as a function of the number of grain consuming animal units [see equation (32) and U.S. Department of Agriculture 1974, p. 91] on feed, real personal disposable income, and its own price. Omitting other feed grains seems an acceptable approximation. Corn accounts for more than 75% of the feed grain market. Moreover, the close substitutability between the different feed grains keeps the relative prices within close bounds. For example, during 1957–75, the coefficients of correlation of the price of corn with the price of sorghum, barley, and oats were 0.98, 0.97, and 0.81, respectively. Also the correlation between the prices of corn and soybeans was 0.89 in the same period. Corn exports are treated as exogenous. Its main determinants appear to be income, grain output, and government policy in the rest of the world—variables exogenous to our model. Our analysis of corn exports detected no negative price effect.

Equation (21) assumes the price of corn adjusts according to the size of commercial stocks, the recent evolution of exports, and the time of the year. Inventories are then almost exclusively determined as a residual by the rest of the model. (In a later section, we show that the model performs this task with high accuracy.) The rationale for this specification, rather than the more traditional normalization on stocks as a regressand, has been given by Heien. Essentially, as Working and Tomek and Gray already have pointed out, current stocks are the main determinant of both spot and futures prices of a commodity like corn with continuous storage. Incidentally, this argument also justifies our omission of futures prices.

Equation (22) describes acreage planted for corn production (*AP*1). The coefficients of the support price (*PF*) and the market price of corn are highly significant. The support price for corn is weighted by the restrictions imposed on program participants as in Ryan and Abel. The effect of the price of soybeans (*PSB*) is small and insignificant. This equation was estimated using 1961–75 data only. Pre-1961 data was excluded because in those years farmers could collect payments for corn acreage diversion and plant sorghum instead. This created an artificial sensitivity of corn acreage to diversion payments and sorghum price.[4] The effect of diversion payments on *AP*1 also was analyzed; however, this variable exhibited a positive and insignificant coefficient in the regression with 1961–75 data and is excluded.[5] The price of farm inputs was also tested and excluded because its coefficient was positive and insignificant, presumably because the available price series are too aggregated to be meaningful in the present context. Finally, the supply of corn (*XSC*) is specified in (23) as a function of yield per acre harvested in the fall (*H*) and acreage planted in the spring (*AP*1). Note this is not an identity because not all acreage planted is harvested for grain (part is used as forage or harvested for silage and part is lost due to bad weather). Although (22) and (23) constitute a relatively simple specification of the production of corn, both equations exhibit excellent fit and perform very well in the context of the complete model.

The final bloc of equations in table 2 are the identities and market-clearing equations for the four meat commodities and corn (24)–(42). For fourteen of the twenty-three structural equations in table 2 (1–9, 11–12, 14–15, 18), the hypothesis of zero autocorrelated residuals is rejected at the 5% significance level on the basis of the Durbin-Watson (DW) or Durbin H (DH) statistic. These equations were reestimated with (truncated) two-stage least squares and the ad hoc assumption of first-

[4] We found no substitution in production between sorghum and corn. This is consistent with Houck and Ryan, who found no substitution since 1961. They also note that the substitution between soybeans and corn appears to be much less now than before 1961.

[5] Johnson (1973, pp. 34–35) has pointed out that "since the U.S. Department of Agriculture changes the features of the wheat and feed programs on the basis of anticipated supply and demand conditions, it is very difficult to know how much of the change in acreage seeded was due to diversion and how much was due to farmer response to the same set of supply and demand conditions." This might explain why diversion payments are a redundant regressor. Houck and Ryan report low *t*-values for *PF* and *DP* using 1960–69 data.

order serial correlation or generalized least squares and first-order serial correlation. With both estimators the optimal estimate of the first-order autocorrelation coefficient was obtained with scanning and local iteration (Fair, 1970). Few coefficients in these equations exhibited significant changes. Later in this paper we discuss the insensitivity of the policy implications of the model to autocorrelated residuals. While the low DW statistics probably indicate departures from linearity rather than simple serial correlation, the insensitivity of our results to the latter is reassuring.

Forecasting Accuracy of the Model

Table 3 compares the forecasting accuracy of the econometric model and a fourth-order autoregressive model. The root-mean-squared-error as a fraction of the mean is used as criterion of performance. The first two columns show the goodness of fit during 1965I–1975IV. The econometric model performs better than the autoregressive model for twenty-two out of thirty-two endogenous variables. The performance of the two models in predicting fed beef price is about the same. The autoregressive model does better for nonfed beef and feeder steer prices but worse for pork, chicken, and corn prices.

The last two columns measure the forecasting accuracy of the two models outside the sample. (For this purpose, both models were reestimated excluding 1975 data.) The econometric model performs much better than the autoregressive model. It exhibits smaller errors for twenty-four out of the thirty-two variables and the autoregressive model makes large errors in such key variables as the price of corn (75% versus 6.8%).

The results of dynamic simulation of the

Table 3. Forecasting Accuracy of Econometric Model

	Goodness-of-Fit 1965I–1975IV			*Ex-Post* Forecast 1975I–1975IV	
		Econometric Model			
Variable	Autoregressive Model	Static	Dynamic	Autoregressive Model	Econometric Model
	Root Mean Squared Errors as Proportion of Mean				
*PR*1	.048	.050	.104	.062	.071
*PR*2	.047	.088	.168	.086	.135
*PR*3	.070	.059	.109	.114	.053
*PR*4	.100	.054	.128	.143	.051
*PF*1	.094	.077	.133	.140	.099
*PF*2	.093	.132	.196	.377	.320
*PF*3	.156	.081	.152	.218	.053
*PF*4	.148	.091	.181	.230	.074
*PF*5	.079	.112	.205	.377	.164
*PG*1	.127	.096	.138	.746	.068
*Z*1	.043	.046	.118	.054	.069
*Z*2	.039	.073	.172	.112	.132
*Z*3	.061	.054	.105	.177	.057
*Z*4	.085	.049	.118	.058	.049
*XS*1	.053	.048	.056	.187	.056
*XS*2	.121	.087	.231	.356	.073
*XS*3	.081	.034	.078	.164	.024
*XS*4	.035	.033	.032	.047	.023
XSC	.096	.038	.033	.077	.006
*AP*1	.069	.029	.029	.041	.040
*XD*1	.054	.047	.054	.196	.055
*XD*2	.111	.137	.203	.293	.144
*XD*3	.006	.004	.080	.219	.032
*XD*4	.034	.036	.045	.044	.046
XDC	.114	.075	.093	.238	.106
SC	.078	.179	.240	.271	.330
IP	.098	.029	.071	.024	.043
IH	.067	.025	.052	.216	.050
ICC	.181	.050	.146	.242	.031
KH	.060	.030	.062	.186	.073
KB	.015	.020	.041	.012	.053
KC	.034	.046	.044	.050	.041

econometric model during the period 1965I–1975IV are presented in the third column of table 3 (forecasted rather than observed values of the lagged endogenous variables are used in dynamic simulation). As expected, the errors of prices and inventories are larger than in the static solution. This is because of random errors on the endogenous variables which, though not taken into account in dynamic simulation, affect the actual realization of the time series via the dynamic structure of livestock production.

While the above evaluations are biased in favor of the econometric model because of the assumption that the values of the exogenous variables are known (Feldstein), the results suggest that the model provides a reasonable representation of the behavior of the grain-livestock sector which can be used for policy analysis.

Dynamic Multipliers

Expressing the model as a first-order, linear-difference equation system permits testing for stability and studying the dynamic behavior of the model with standard procedures of linear system analysis, Chow, for example.[6] Price responses are expressed in 1975 dollars.

[6] This is accomplished by embedding the structure of the model in an annual format which allows for intrayear nonstationarity due to different equations periodicities and quarterly dummies. The transformation is made writing four annual equations for each semiannual variable. Furthermore, the exogenous price level (*CPI*) which enters nonlinearly in equations (1)–(4) and (38)–(41) is fixed at its 1975IV level.

The model is stable. The characteristic roots of the reduced-form coefficient matrix of lagged endogenous variables all have moduli less than one and there is no borderline case. Moreover, the system exhibits damped cyclical behavior. Cyclical components in the time path of the endogenous variables are contributed by one negative real root and six pairs of complex roots.

Multipliers of Corn Exports

Quarterly exports of corn during 1973–75 were 97 million bushels above their 1972 level. Table 4 presents the effects of changes of this magnitude on market prices and corn acreage. All relative increases are expressed as a percentage of the level prevailing in the fourth quarter of 1975. When subject to a one-quarter 100 million bushel increase in corn exports (23%), the model exhibits a maximum response of 18.9¢ (7%) three quarters later and quickly returns to its preshock level. On the other hand, a permanent increase in exports of the same magnitude has a maximum multiplier of 95.0¢ (36%) after ten quarters, which then declines toward its long-run (steady state) value of 50.2¢ (19%). Most of the adjustment takes place during the first sixteen quarters.

Higher corn prices, in turn, induce upward adjustments in acreage planted and food prices. A one-quarter corn export increase produces transitory increases in meat and chicken prices of 3¢ to 5¢ at the retail level, and of 1¢ to 2¢ at the farm level. A permanent

Table 4. Multipliers of Corn Exports, Nonfed Beef Imports, and Government Inventory of Corn

Endogenous Variable	100 Million Bushel Increase in Corn Exports: Maximum Response to One-Quarter Increase	Permanent Increase: Maximum	Permanent Increase: Long-Term	100 Million Pound Decrease in Beef Imports: Maximum Response to One-Quarter Decrease	Permanent Decrease: Maximum	Permanent Decrease: Long-Term	Maximum Response to 100 Million Bushel Permanent Increase in Corn Stocks
Retail prices (¢/lb.)							
Fed beef	6.67(5)[a]	27.76(9)	7.62	7.39(0)	9.41(1)	.08	1.47(6)
Nonfed beef	4.81(5)	20.77(12)	2.54	8.30(0)	10.16(1)	1.14	1.03(6)
Pork	3.64(6)	25.04(13)	10.76	2.53(0)	2.95(1)	.93	1.19(10)
Chicken	2.72(5)	13.75(11)	5.02	3.15(0)	3.15(0)	.64	.63(7)
Producers prices (¢/lb.)							
Choice steers	2.68(5)	11.13(9)	3.08	2.96(0)	3.77(1)	.03	.59(6)
Utility cows	1.44(5)	6.23(11)	.76	2.49(0)	3.05(1)	.34	.31(6)
Hogs	1.55(6)	10.64(12)	4.60	1.07(0)	1.25(1)	.40	.50(10)
Chickens	1.51(5)	7.64(11)	2.80	1.75(0)	1.75(0)	.36	.35(7)
Feeder steers	2.26(5)	9.29(11)	.74	3.88(0)	4.78(1)	.36	.45(7)
Corn price (¢/bu.)	19.0(3)	95.0(10)	50.2	.7(6)	5.3(14)	3.8	4.5(5)
Acreage (m. acres)	.698(5)	4.702(9)	2.507	.032(5)	.256(17)	.191	.221(5)

[a] The number in parentheses is the delay of the maximum response in quarters.

increase in exports has a long-run effect of 7.62¢ (5.0%) on fed beef, 2.54¢ (2.2%) on nonfed beef, 10.76¢ (7.0%) on pork, and 5.02¢ (7.9%) on chicken prices.

Multipliers of Beef Imports

Table 4 shows that changes in nonfed beef imports have very small, long-run effects on the retail price of nonfed beef (*PR*2) and other meats. This is due to the long-run response of domestic beef supply to price.

Our long-run multipliers for beef imports (table 4, column 7) are of the same order of magnitude as those reported by the Council on Wage and Price Stability (pp. 7–10) and Freebairn and Rausser. Expressed in 1975 prices, the multipliers of a 100 million pound decrease in beef imports reported by the latter authors are .87¢ for fed beef, 1.52¢ for nonfed beef, .13¢ for pork, and .21¢ for chicken at the retail level and about half as large at the farm level. Both of their beef multipliers are slightly larger than ours. This seems to be due to the fact that their model implies a long-run decrease in the inventory of beef cows and in the production of nonfed beef following a permanent decrease in nonfed beef imports (Freebairn and Rausser, pp. 686–87). On the other hand, our model implies that, as one should expect, these two variables increase in the long run.[7]

Multipliers of Government Stocks of Grain

The multipliers of permanent changes in the government stocks of grain are presented in the last column of table 4. A permanent change in the stock of grain can offset in a bushel-for-bushel fashion a temporary change in domestic output. For example, a reduction of ten bushels per acre in corn yield reduces corn output by 614 million bushels [see table 2, equation (23)] and temporarily increases corn prices by 27¢. These changes can be offset by a concommitant decrease of the government stock of corn of the same magnitude. However, government stocks might not be so effective in offsetting price changes due to export fluctuations, because the latter seem to influence prices in two reinforcing ways: through total demand and through price expectations. For example, to offset the effect of a 100-million-bushel, one-quarter increase in corn exports, government stocks should decrease by 420 million bushels. This suggests that stabilization schemes based upon some form of inventory management might not be very effective in dealing with export fluctuations.

Other Multipliers

Table 5 presents the multipliers of corn yield, disposable income, and the support price of corn. A simple measure of their relative importance is presented in table 6, which shows the permanent change in each variable that has the same long-run effects on the retail cost of the 1975 meat basket. Grain exports and beef imports are also included in table 6. Column 2 shows the percentage change in each exogenous variable that results in a 3% change in the retail cost of meat (e.g., a 12.4% increase in corn exports above the 1975 level). Column 3 shows the absolute changes in the respective exogenous variables (e.g., a 55.7-million-bushel increase in corn exports). In order to give an idea of the possible variability of the exogenous variables, column 4 includes their standard deviations in the period 1958–75. The principal conclusion that emerges from this table is that changes in corn exports, corn yields, and consumer disposable income during 1958–75 were mainly responsible for the fluctuations in livestock and feed grain prices. The policy variables—corn price supports and nonfed beef imports—exhibit relatively small multipliers and variability during this period. In particular, table 6 shows that in order to offset the effect of 12.4% increase in corn exports, beef imports would have to increase by about 508.5 million pounds, 119% of their 1975 level. That is, the share of imports in the domestic nonfed beef market would have to increase from 8% to 18%.

Price Effects of the 1977 Farm Bill

Tables 4 and 5 allow us to estimate the likely effects of the 1978 Feed Grain Program and the Grain Reserve Program for 1976 and 1977 grain (USDA 1978, pp. 6, 11, 13). An approximation to the effective support price for corn for 1978, our *PF* variable, is obtained taking 90% of the target price ($2.10/bushel) in order

[7] The long-run multipliers given by our model for a 100 million pound permanent decrease in nonfed beef imports are 30.8, 51.9, −8.0, and 8.6 million pound for fed beef, nonfed beef, pork, and chicken production, respectively. The negative response of pork production is due to the strong effect of the price of corn on breeding and feeding decisions.

Table 5. Multipliers of Corn Yield, Disposable Personal Income, and Corn Support Price

Endogenous Variable	Decrease in Yield (1 bu./acre)			Increase in Income (1 bill. 1967$)			Decrease in Corn Support (10¢/bu.)		
	Maximum Response to One-Quarter Decrease	Permanent Decrease		Maximum Response to One-Quarter Increase	Permanent Increase		Maximum Response to One-Quarter Increase	Permanent Increase	
		Maximum	Long-Term		Maximum	Long-Term		Maximum	Long-Term
Retail prices (¢/lb.)									
Fed beef	.91(9)[a]	2.12(19)	1.15	2.15(0)	2.83(1)	.47	1.24(9)	2.90(19)	1.58
Nonfed beef	.64(9)	1.51(19)	.39	2.02(0)	2.63(1)	.23	.88(9)	2.07(19)	.53
Pork	.71(13)	1.97(19)	1.64	1.17(0)	1.30(1)	.80	.97(13)	2.70(23)	2.26
Chicken	.39(9)	1.07(19)	.76	1.15(0)	1.15(0)	.46	.53(9)	1.47(19)	1.03
Producers prices (¢/lb.)									
Choice steers	.36(9)	.85(19)	.46	.86(0)	1.13(1)	.19	.50(9)	1.16(19)	.63
Utility cows	.19(9)	.45(19)	.12	.61(0)	.79(1)	.07	.26(9)	.62(19)	.16
Hogs	.30(13)	.84(19)	.70	.50(0)	.55(1)	.34	.41(13)	1.15(23)	.96
Chickens	.22(9)	.60(19)	.42	.64(0)	.64(0)	.26	.30(9)	.82(19)	.58
Feeder steers	.28(10)	.67(19)	.12	.97(0)	1.26(1)	.08	.39(10)	.92(19)	.15
Corn price (¢/bu.)	2.7(8)	8.5(24)	7.6	.3(6)	2.7(18)	2.3	3.7(8)	11.6(24)	10.5
Acreage (m. acres)	.136(9)	.426(25)	.392	.014(5)	.133(17)	.116	−1.401(1)[b]	−1.401(1)[b]	−.864

[a] The number in parentheses is the delay of the maximum response in quarters.
[b] Minimum.

to account for the 10% set-aside requirement on program participants (see Ryan and Abel). Thus, the new program reduces by 11¢ per bushel the effective support price with respect to 1977. By equations (22) and (23) of table 2, this change will produce a reduction in acreage planted for corn of 1.54 million acres, and a reduction of corn output of about 92 million bushels. The effect on prices will be modest. The market price of corn will increase by about 4.1¢ per bushel and the retail cost of meat consumption about 1.2% (table 6, column 2). On the other hand, the goal of the grain reserve program is to store 670 million bushels of corn equivalents, of which approximately 522 million bushels correspond to corn. By the end of 1979, this action can add up to 23.5¢ per bushel to the price of corn and 4.2% to the retail cost of meat (table 4, last column). The model also predicts decreases of the same magnitude if and when the grain is released to commercial channels.

Sensitivity of Multipliers to Alternative Model Specifications

Table 7 compares the long-run response of the retail cost of meat under three alternative specifications: the basic model (table 2), the basic model with the meat demand block reestimated after deleting those cross-prices with negative coefficients, and the basic model reestimated assuming first-order serial correlation for those equations not passing the DW or DH tests (see above). Table 7 shows that the response of the model varies little among the three specifications. Furthermore, a detailed comparison of specific multipliers (not reported here) confirmed the lack of sensitivity

Table 6. Permanent Changes in Exogenous Variables Resulting in a 3% Increase in the Retail Cost of Meat Consumption

Exogenous Variable	Change: Percent[a]	Change: Units	Standard Deviation (1958–75)
Corn exports	12.4	55.7 m. bu.	95 m. bu.
Nonfed beef imports	−119.0	−508.5 m. lb.	124 m. lb.
Corn yield	−4.2	−3.64 bu./a.	13.74 bu./a.
Disposable income	4.7	$7.5 billion	$26.8 billion
Corn support price	−23.9	−27 ¢/bu.	16 ¢/bu.

Note: Estimation based on the cost of the 1975 meat basket.
[a] Percentage of change with respect to 1975 level.

Table 7. Long-Run Response of the Retail Cost of Meat Consumption to Permanent Changes in Exogenous Variables under Alternative Model Specifications

Exogenous Variable	Change in Exogenous Variables (Percent)[a]	(Units)	Model Response[a] Basic Model (table 1)	Constrained Estimation of Demand for Meat	Basic Model with First-Order Serial Correlation
				(%)	
Corn exports	23	100 m. bu.	5.39	5.41	4.50
Nonfed beef imports	23	100 m. lb.	−0.59	−0.63	−0.85
Corn yield	1.2	1 bu. a.	−0.82	−0.82	−0.65
Disposable income	0.6	$1 billion	0.40	0.41	0.30
Corn support price	9	10¢/bu.	−1.12	−1.12	−0.91

Note: Percentage of change in the cost of the 1975 consumption basket.
[a] Percentage of 1975 level.

of the policy implications demonstrated in table 7.

Conclusions

Some of the findings derived from the analysis of the model are as follows: (*a*) While the slaughter of feeder calves and the placement of steers and hogs on feed are responsive to own price and the price of corn, the supply (slaughter) of beef, pork, and chicken are not responsive to the current (quarter) prices. These lags in the response of livestock supply to price are, of course, the basis for the observed cyclical behavior of the sector: (*b*) Acreage planted in corn is determined by the market and effective support price, with only small substitution between corn and soybeans and no discernible effect of payments for acreage diversion. (*c*) The forecasting performance of the model within and beyond sample is accurate relative to autoregressive forecasting. (*d*) The model is stable and can exhibit sustained cyclical behavior when disturbed by such factors as weather, exports, and government programs. (*e*) Analysis of the multipliers reveals that corn exports, yield, and consumer disposable income are more significant than nonfed beef imports and corn price supports as a source of fluctuation in retail and producer prices and acreage planted in corn. And (*f*) the multipliers for nonfed beef imports confirm the position taken recently by the Council on Wage and Price Stability concerning the impact of reduced quotas on retail prices. Unlike an earlier study by Freebairn and Rausser, however, we find that nonfed beef production varies inversely in the long-run with imports.

[*Received October 1977; revision accepted August 1978.*]

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