CYCLICAL ASPECTS OF ADJUSTMENT TO CORN PRICE INSTABILITY

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The U.S. is the major supplier to the international corn market, which is characterized by price inelastic demand. On the average over the past decade, one-third of annual U.S. corn production has been exported, an amount which represents three-fourths of world corn trade. The import behavior of the Soviet Union has been a source of shocks to the corn market. Unstable domestic feedgrain production coupled with a commitment to stable livestock supply has resulted in sporadic, large purchases of corn on the world market. In 1975/76, unprecedented Soviet imports of 12 MMT represented 20 percent of world corn trade or eight percent of U.S. production. Corn price instability during the 1970s was marked. In the absence of significant price responsiveness elsewhere in the world market, adjustment to these disruptions has occurred in the domestic U.S. economy.

A structural econometric model of the U.S. domestic corn/livestock and exports markets is used to investigate the nature of adjustment to market shocks originating in USSR corn import behavior. The model is well suited to

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such an analysis due to the degree of disaggregation of the various market sources. In particular, the specification of derived corn demand by livestock category rather than in the aggregate allows the possibility of differential sectoral response to changes in corn price.

Sixty percent of annual U.S. corn production is fed to livestock. Cyclical movement in hog and beef cattle production (the main users of corn) has resulted in corresponding cyclical movement in derived corn feed demand. The significance of the cyclical movement is that price responsive corn demand in the hog and cattle sectors is most inelastic when animal numbers are highest. Consequently, market shocks during these periods cause large corn price gyrations which feed back into cycles through their effects on production and inventory decisions. While the phase of the cycles is not expected to change appreciably when shocks occur, the amplitude of the cycles may be affected as producers make short run adjustments in output and feed use. Therefore, market response to shocks will depend on their timing and sequence as well as their magnitude.

Previous empirical research into corn/livestock market interaction has not adequately captured differential short term sectoral response nor cyclical effects. For example, Arzac and Wilkinson specify total domestic corn demand as a function of grain-consuming animal units on feed, corn price, disposable income, and quarterly dummies (p. 301). This formulation constrains per animal feed use to be the same in every period; corn use thus cannot respond to changes in meat output levels per animal, a significant source of adjustment in the beef cattle sector. While cyclical variation in animal numbers is reflected in the animal units variable, this influence is ignored in their subsequent multiplier analysis of the market. By reason of their model's linearity, these multipliers are constant over time, implying that an exogenous shock to the system results in the same response from the endogenous variables regardless of the time period in which it occurs. In the present nonlinear model, the multipliers are nonconstant and depend on time, although they cannot be used to compare differential marginal response. However, by using the structural model in historical simulation and changing the values of Soviet imports, the effects of alternative timing can be evaluated. The salient features and results of the econometric model are presented first, followed by the results of the simulation.

The Structural Model

The full model contains 53 equations, of which 35 explain behavioral relationships (Offutt). Hog, fed and nonfed beef cattle, and broiler production are endogenous as are wholesale-level product prices. The demand for feed corn is derived from these livestock production levels. Stocks and other domestic disappearance, as well as corn production, are also determined within the model. The demand for corn on the world market is composed of a set of demand estimates for groups of importers, aggregated according to their similar importing characteristics. The U.S. is set as the residual supplier to the world market; corn exports by other countries are exogenous. Equilibrium corn price is determined endogenously when the world market clears.

Estimated over the corn crop years 1961/62 to 1978/79, the dynamic, nonlinear (in variables) model is annual in period, except for the hog production sector, which is semiannual. All equations in the model were estimated by ordinary or generalized least squares. Results were judged satisfactory based on standard errors of the coefficients, expected signs, goodness of fit, and turning point accuracy. Validation by historical simulation demonstrated the model's ability to track well; the average percentage root mean square error (MSE) (Theil, p. 27) for the 53 endogenous variables was 12 percent. Validation statistics for the endogenous variables are reported in Table 1.

Corn importers in the world market are aggregated according to similarities in domestic livestock and feedgrain economies, income levels, and trade policies. The countries of the European Community comprise one group, nations which are mostly nonproducers (e.g., Japan) another, and other stable importers, such as Canada and Spain, a third. The bloc countries of Eastern Europe are a fourth group. Imports by the Soviet Union enter exogenously.

In the structural model, the various livestock sectors are disaggregated in order to portray accurately differential response in adjustment which arises due to differences among biological, technical, and economic aspects of the production processes. Hog and cattle production together account for two-thirds of all corn fed. The remainder is split evenly between the poultry and dairy industries. Because of the importance of short run adjustment possibilities and longer run cycles, the discussion of the model's specification concentrates on describing that of hog and cattle production and feed use.

In these two sectors, corn use is specified as a function of the level of animal output. In the model, animal numbers are largely fixed (within one year for cattle and six months for hogs). Slaughter of breeding herd members can increase short run production, but expansion takes three years in the cattle sector and two years in that of hogs. Consequently, it is mainly livestock prices rather than numbers which adjust in the short run to clear markets; livestock product demand equations are price dependent. Given animal numbers, short run sectoral response to changes in corn price depends on ration flexibility (the availability of substitutes for corn) and on production

TABLE 1. VALIDATION RESULTS, 1961/62-1978/79.

	Percentage Root MSE	MSE DECOMPOSITION[1/] Bias	Regression	Disturbance
PRICES				
Corn	23	0	48	52
Fed beef	12	4	46	50
Nonfed beef	12	18	14	68
Feeder cattle	20	2	36	62
Hog, Dec.-May	19	3	29	67
Hog, June-Nov.	31	3	47	49
Broiler	10	1	1	98
WORLD CORN IMPORTS[2/]				
European Community	7	10	6	84
Japan, et al.	18	2	48	50
Canada, et al.	22	0	8	91
Eastern Europe	45	4	53	42
US CORN PRODUCTION & STOCKS				
Area planted	5	1	33	66
Area harvested	5	1	30	69
Yield	4	0	4	96
Production	6	0	2	98
Total stocks	27	3	30	67
US DOMESTIC DISAPPEARANCE				
Exports	14	0	32	68
Food, seed industrial use	4	5	58	36
Fed to beef cattle	34	6	75	17
Fed to hogs, Dec.-May	8	1	40	58
Fed to hogs, June-Nov.	10	7	18	75
Fed to poultry	8	0	30	70
Fed to dairy cattle	7	19	81	78
Fed to all livestock	7	0	19	81

	Percentage Root MSE	MSE DECOMPOSITION[1/] Bias	Regression	Disturbance
BEEF PRODUCTION				
Beef cow inventory	2	42	6	52
Calf crop	2	65	3	32
Heifers added	7	37	0	63
Feeder cattle supply	7	30	25	45
Cow slaughter	14	12	7	81
Feeder cattle average lvwt.	3	1	48	50
Fed beef slaughter	12	0	70	30
Fed beef average lvwt.	3	1	48	51
Fed beef production	15	0	70	30
Fed beef cons. per cap.	14	0	70	30
Nonfed beef slaughter	35	0	37	63
Nonfed beef production	18	3	9	88
Nonfed beef cons. per cap.	18	3	9	88
PORK PRODUCTION				
Dec.-May:				
Sows farrowing	8	0	54	46
Pig crop	9	0	53	47
Pig slaughter	8	2	28	70
Sow slaughter	18	0	54	46
Gilts added	12	0	5	95
Pork cons. per cap.	8	1	36	63
June-Nov.:				
Breeding inventory	8	0	44	56
Sows farrowing	7	1	25	74
Pig crop	7	0	28	72
Pig slaughter	11	6	35	57
Sow slaughter	14	0	18	82
Gilts added	13	1	11	88
Yearly pork cons. per cap.	8	15	40	55
BROILER PRODUCTION				
Broiler production	6	0	50	50
Broiler cons. per cap.	0	0	50	50

1/ The MSE is decomposed into three parts which apportion the divergence between the simulated and actual values into that due to bias and the regression and that due to the disturbances. The modeler should be able to reduce the size of the systematic error (bias and regression) relative to that of the random error. The three components represent proportions and sum to one (see Maddala, p. 344, for formulae).

flexibility (ability to modify output with no change in animal numbers). Longer run response depends on how expected prices affect inventory adjustment decisions.

In the beef sector, corn use is described as a stochastic function of the level of fed beef production. In the short run, corn price can affect fed beef production through the slaughter mix of fed versus nonfed beef and the average finished weight of fed cattle. Slaughter of nonfed beef (at weights less than those of feedlot animals) depends on the feeder cattle price, which is itself a positive function of the expected fed beef/corn price ratio. In the model, then, an increase in corn price (which decreases feeder cattle price) increases nonfed beef supply as cattle bypass feedlots and are fattened on forage. In the longer run, corn price affects breeding inventories through its effect on the number of cows slaughtered (another source of nonfed beef in the short run) and heifers added, where separate relationships are specified for each.

In the hog sector, corn use is determined by the number of animals slaughtered. The model reflects the fact that there are few substitutes for corn and no fed or nonfed marketing option in hog production. Moreover, once a hog is finished at a weight of about 240 pounds, it must be sent to slaughter. Thus, hog producers are, within a six month period, price takers. Price is dependent on current barrow and gilt supply, a quantity determined by the previous period's pig crop, itself a function of inventory decisions made at least one year earlier. The slaughter of breeding sows represents the only short run adjustment option.

Underlying these adjustment possibilities are production cycles, induced by a combination of economic and biological phenomena (Gustafson, p. 122). An average of ten years has elapsed between peaks in cattle numbers (Neumann,

p. 26); in the hog cycle, the interval has been about three years (Spreen and Shonkwiler, p. 6). In the previous decade, the cattle cycle peaked during the 1975/76 crop year and that of hogs in 1973/74 and again in 1976/77. These cycles are represented in the structure of the model through the use of dummy variables which reflect differential intracycle breeding, feeding, and slaughter decisions. The hog and cattle production processes are modeled in a series of recursive equations. Animal numbers are carried through each period until their dispatch at time of slaughter. Without such an intertemporal constraint on livestock numbers, the short run elasticity of livestock supply may be overestimated.

Adjustment to market disruptions is reflected in price responsive behavior; the empirical results suggest inelasticity in all but two sectors. In general, there is zero short run price elasticity of import demand, with the exception of the Eastern European countries (which had a low elasticity of -0.3 at sample means). In the U.S., neither food, seed and industrial use nor stocks have exhibited the capability to absorb or buffer shocks. The former has shown no responsiveness to changes in corn price, most likely because there are few substitutes for corn in these activities. Stocks have not overhung the corn market as in the wheat market; total corn carryover was an average of only 13 percent of production over the past decade, in contrast to 46 percent for wheat. Government-controlled stocks have been small, and were, in fact, zero from 1973/74 through 1976/77. Consequently, adequate stocks were not available for release at times of peak demand and/or reduced supply. As for production, the elasticity of area planted with respect to corn price is only 0.12 at sample means.

Within the livestock sector, the poultry and dairy industries have exhibited little corn price responsiveness. For poultry, the price elasticity of demand is -0.15 at sample means. For dairy, the elasticity is zero since the degree of government intervention in the sector distorts market price relationships. In contrast, the short run elasticity of corn fed to beef with respect to corn price is -1.6 at sample means. For pork production, the short run (six month) elasticity is approximately zero; but, one year later, after the size of the pig crop has been adjusted, the elasticity of corn use with respect to lagged corn price is -2.1 at sample means. Thus, as the most price responsive sectors, hogs and beef cattle have borne the brunt of adjustment to corn market shocks.

The role of the U.S. as the residual supplier to a residual world market exacerbates the adjustment problems faced by the U.S. livestock sector, primarily in beef cattle and hogs. The price of corn will be determined and bid up at the margin by fluctuating foreign demand. The problem of sharp increases in corn price in response to destabilizing events is felt most acutely when livestock production in the main corn-consuming sectors is at its cyclical peak. At this point, derived demand for feed corn is most inelastic as animal numbers are at their highest. At the peak of the cattle cycle, the elasticity of corn use with respect to corn price is -0.95; at the cycle's trough, the same elasticity is -1.95, both compared to the mean value of -1.6 at the sample means. In the hog sector at the top of the cycle, the elasticity of corn use with respect to lagged corn price is -1.1, compared to -2.7 at the trough and -2.1 at sample means.

Effects of Market Shocks

To demonstrate the nature of differential cyclical and sectoral adjustment, alternative scenarios, using Soviet import behavior as the source of shocks, are simulated using the structural model. Two paths for Soviet imports (Table 2) are postulated. In Case I, the largest Soviet demands are assumed to have taken place in the early 1970s. The actual magnitudes over 1970/71 to 1978/79 are rearranged, leaving the series' variance unchanged but altering its sequence relative to U.S. production cycles. In Case II, an import ceiling of 5 MMT is imposed on the USSR to determine the relative effects of more moderately sized imports with smaller variance, such as might have existed under U.S. export controls. The historical sequence of imports is retained but values above 5 MMT are truncated.

Using the actually observed sequence of Soviet imports, the model is simulated over the period 1970/71 to 1978/79 as a base run for comparison with the two alternative scenarios. In the base and subsequent simulations, the disturbances in the stochastic behavioral relationships are suppressed, so the simulation results reflect only deterministic variation in the market. Comparison of results among scenarios thus allows an assessment of the relative effects of altered Soviet import behavior on deterministic movement.

For the base run, validation statistics are comparable to those reported in Table 1. In the base run, actual Soviet import demand increased as U.S. hog production approached its first peak; its maximum coincided with that of the cattle cycle. In Table 3, actual corn price is reported along with that of the base run and the other two cases. Total beef production and the percentage comprised of nonfed beef in each year of the three simulations is presented in Table 4.

TABLE 2. ALTERNATIVE SOVIET IMPORT PATHS (MMT)

	Actual (Base Run)	Case I	Case II
1970/71	0.27	12.30	0.27
1971/72	2.11	10.86	2.11
1972/73	4.10	9.60	4.10
1973/74	4.80	5.00	4.80
1974/75	2.20	4.80	2.20
1975/76	12.30	4.10	5.00
1976/77	5.00	2.20	5.00
1977/78	10.86	2.11	5.00
1978/79	9.60	0.27	5.00
Standard Deviation	4.24	4.24	1.76

TABLE 3. SIMULATED CORN PRICE ($/MT)

	Actual	Base Run	Case I	Case II
1970/71	52.36	56.56	80.56	56.56
1971/72	42.52	39.34	43.59	39.34
1972/73	61.81	61.90	69.72	61.89
1973/74	100.39	69.21	68.95	69.21
1974/75	118.90	119.47	88.14	82.13
1975/76	100.00	59.62	53.68	54.78
1976/77	84.65	75.48	65.33	70.50
1977/78	79.53	88.22	81.93	89.08
1978/79	88.58	100.42	96.06	109.34
Standard Deviation	24.79	24.62	16.63	20.85

Comparing corn price behavior across simulations, Table 3 shows that, as expected, the least instability occurs for the scenario (Case I) in which peak Soviet import demand does not coincide with the peaks in either U.S. cattle or hog production. The most unstable price sequence was that of the base run (reflecting actual Soviet imports), with the import ceiling scenario (Case II) the intermediate case. In Case I, corn prices are higher in the early part of the decade and lower in the later years than in the base run. In Case II, corn price during the cattle cycle peak was an average 15 percent lower than in the base run.

This differential behavior in corn price among scenarios produces corresponding changes in the size of livestock production peaks, as shown for beef in Table 4. The higher corn price, the higher the percentage of nonfed beef in the slaughter mix and the lower fed beef finished weights, thus lowering fed beef and total beef production. Under Case I, beef output in the first four years, during a buildup period, is reduced by an average of four percent below that of the base run. At the 1975/76 peak, total production is three percent greater; high corn price in the early years moderates herd expansion. The proportion of nonfed beef in the total is higher than the base run in the early years but lower in the peak and subsequent liquidation years. In contrast, under Case II, which moderates corn price increases and instability in the mid-seventies, peak beef output was five percent higher than that in the base run, due to a larger proportion of fed beef in the slaughter mix (as well as heavier finished weights). In terms of revenue, in the peak year returns to fed beef producers were eight percent greater and fed beef price ten percent higher in the base run than in the other two cases. For nonfed beef, price was three percent lower in the base run than in the other two, but revenue was seven percent greater.

Because the hog cycle's peaks did not coincide with that of cattle in the 1970s, pork production was affected in different ways. The higher Soviet imports in the early 1970s resulted in production an average of six percent lower in the early seventies and at the first peak in 1973/74 than those observed in the base run. In the latter part of the decade, however, pork production was six percent above the base run 1976/77 maximum. In Case II, truncation of the 1975/76 import peak increased hog production at its peak the next year by about six percent.

TABLE 4. SIMULATED BEEF PRODUCTION (BIL. LBS.)

	BASE RUN		CASE I		CASE II	
	Production	% Nonfed	Production	% Nonfed	Production	% Nonfed
1970/71	20.5	24	18.7	31	20.5	24
1971/72	24.9	12	24.6	13	24.9	12
1972/73	20.2	24	19.4	26	20.2	24
1973/74	25.1	27	24.9	26	25.1	27
1974/75	26.6	41	27.1	37	27.9	36
1975/76	26.9	29	26.9	27	27.1	28
1976/77	24.7	31	25.3	28	25.4	29
1977/78	23.8	29	24.0	27	24.0	29
1978/79	23.9	26	24.0	25	23.7	28

Conclusions

The U.S. hog and beef cattle sectors have borne the brunt of adjustment to corn market shocks due to the absence of significant price responsiveness elsewhere in the domestic or world markets. The structural econometric model disaggregated livestock production and derived corn demand by category to allow explicit recognition of these differential sectoral and cyclical responses to changes in corn price. The simulation results demonstrate that market shocks during peak livestock production periods, when derived corn demand is most inelastic, both raise and destabilize corn price, resulting in a decrease in the amplitude of cyclical production at these peaks.

Cyclical movement in livestock production and feed use can be expected to recur in the future. In fact, in 1984/85 the hog and cattle cycles will likely peak simultaneously. In the coming years the world import market share of the Soviet Union can be expected to increase. Moreover, Soviet import behavior will continue to be erratic due to inherently unstable domestic grain production and an ongoing policy commitment to a stable livestock product supply that eschews internal adjustment when crop failure occurs. Consequently, the potential for considerable disruption to corn and livestock markets from Soviet corn import variability will grow over time.

The implication for U.S. agricultural trade policy points to the desirability of avoiding market shocks during years of peak domestic corn demand. The current US-USSR bilateral agreement sets a minimum 6 MMT annual grain purchase requirement; quantities above 8 MMT may be bought only after consultations. If necessary, a maximum can be set on American grain sales to the Soviets. Even once a ceiling is imposed, however, the USSR could, as it has in the past, turn to other exporters. As the residual world supplier, the

U.S. would then still be in the position of adjusting to Soviet import behavior. Export controls might therefore be indicated. While the Soviet Union has not been and will not be the sole source of instability in the corn market, it is a major one, so efforts to anticipate the occurrence of Soviet-sourced shocks and dampen their effects will help stabilize the U.S. corn and livestock sectors.

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