STABILIZATION POLICIES FOR UNITED STATES
FEED GRAIN AND LIVESTOCK MARKETS

Enrique R. ARZAC and Maurice WILKINSON*

Columbia University, New York, NY 10027, USA

This paper studies economic policy toward feed grain and livestock markets by applying optimal control theory to a quarterly microeconometric model. The results indicate that: (1) farm prices and the retail cost of meat can be stabilized by optimal control relative to unregulated markets, (2) the support price for corn and beef import controls are the most effective instruments while management of corn stocks is neither necessary nor a substitute for other instruments, (3) beef import controls are essential to stabilize producer prices for livestock commodities and (4) there is a definitive limit to the stabilization gain that can be achieved by a more intensive use of the instruments.

1. Introduction

The objectives of American agricultural economic policy are numerous and evolving. The programs for achieving these objectives are likewise complicated and subject to continuous modification. The stabilization of agricultural prices and the support of farm income are two of the principal objectives of economic policy toward agriculture. This paper presents some of the results obtained in utilizing a quarterly microeconometric model and optimal control theory to analyze economic policy for United States feed grain and livestock markets. This methodological framework can contribute to our understanding of how the agricultural economy works and may in the future contribute to the social welfare evaluation necessary for the formulation of agricultural policy.

The plan of the paper is as follows. The next section briefly discusses the relation between price stabilization and income support, the static welfare effects of price stabilization, and the macroeconomic (dynamic) arguments for agricultural price stability. Section 3 presents the optimal control problem and a short summary of the quarterly microeconometric model of United States feed grain and livestock markets. Section 4 analyzes the gains and costs of optimal price stabilization, the effectiveness of individual instruments,

and the effects of unanticipated changes in the export of feed grain. Finally, section 5 concludes with a discussion of some of the limitations of the present study and its applicability to the actual management of economic policy.

2. Agricultural policy objectives and programs

2.1. Policy objectives

The analysis presented in this paper cannot be expected to deal with all of the objectives and programs of current economic policy toward agriculture.[1] The support of farm income and the control of fluctuations in farm prices, however, are perhaps the most significant features of national agricultural policy. The argument for the need to support farm income is often based upon the following (highly simplified) view of the agricultural sector.[2] Change in agricultural technology is largely independent of farm prices and income. The source of these technological improvements is often public programs. Competition among individual farmers results in continuous adoption of improved technology with a consequent growth in output. Growth in consumer demand fails to keep pace with supply (largely due to low income elasticities of demand) and farmers experience declining prices relative to the non-agricultural sector. Thus the increase in output from technological change may benefit the non-agricultural sector but not the individual farmer who, in the absence of support, would suffer losses and have to move away from agriculture. Policies designed to support farm income have generally included some combination of the following programs: direct payments to farmers as determined by the relation between guaranteed and market prices; maintenance of public stocks of storable commodities; direct control of supply; and the disposal of output in foreign markets.

At the same time agricultural prices have been viewed as unstable due to the following features of the economy: (1) fluctuations in consumer demand associated with the business cycle combined with a (price) inelastic supply function, (2) fluctuating yields associated with weather combined with (price) inelastic demand, (3) production lags in livestock and feed grain markets resulting in cycles in livestock output and the demand for feed grain, and (4) with the growth in world demand for US agricultural commodities, export fluctuations derived from intervention in world markets by foreign governments which contribute to fluctuations in demand for domestic output. Recently an additional concern has been expressed about unstable agricultural prices. The latter result in fluctuations in food prices that through labor

[1]See Brandow (1977). and the references contained therein. for a recent review of agricultural policy issues and programs during 1945 71.

[2]One of the most influential expositions of this view is Schultze (1945).

markets may contribute to inflation and instability in the economy in general [Hathaway (1974), Houthakker (1974)].

Price stabilization has been pursued by means of many of the same programs utilized to support farm income (management of public stocks accompanied by commodity loans, guaranteed (forward) prices, and import quotas for livestock commodities). Indeed, it is not easy to separate either the objectives or the actual effects of past agricultural programs aimed at income support and price stabilization. The latter are often converted to income support programs by farm and political leaders who seek stabilized prices at a level above those that might result in unregulated markets.

2.2. Welfare implications

An evaluation of the welfare implications of farm income support and price stabilization policies would have to draw upon several areas of micro- and macroeconomic theory. The effects of perfect price stabilization on the distribution of consumer and producer surplus in a single market can be shown to be highly sensitive to the specification of the demand and supply functions and the source of the instability [Turnovsky (1976, 1978)]. A more general measure of consumer welfare can be derived from duality theory [Diewert (1978)]. Using this criterion Turnovsky, Shalit and Schmitz (1977) demonstrate that the effect of perfect price stabilization upon consumer welfare depends upon (own) price and income elasticities, the budget share and the coefficient of relative risk aversion. Conditions are derived under which consumers would lose from the stabilization of the price of a single and an arbitrary number of commodities. The effect upon producers (which could be analyzed with such a duality concept as the profit function) has not as yet been examined in this framework.

Since income support and price stabilization programs will result in a redistribution of income between producers and consumers a social welfare evaluation is needed. This would still be the case if one moved away from the current programs in agriculture toward some kind of unregulated market. The incorporation of the necessary information for interpersonal comparability into social welfare functionals is only beginning to be considered [Sen (1977)]. In the meantime we must be content with trying to better inform the political process.

Finally, all of the above results are based upon microeconomic welfare theory and do not consider the macroeconomic problems of employment and inflation. Many arguments for the agricultural programs discussed above, however, are based upon the possible welfare gains to producers and consumers of maintaining the economy upon the full employment growth path.

The optimal control experiments described in this paper do not attempt a

rigorous evaluation of the welfare implications of economic policy toward agriculture. Rather, they assume as given the goal of price stabilization and, within the context of the current practice of yearly revision of policies, study the effectiveness of alternative combinations of the currently available instruments. The purpose being to analyze if control over producer prices can be achieved and if such policies can stabilize farm income and the retail cost of the consumer's food basket. In addition we attempt to distinguish between substitute and essential instruments, to identify the most effective combinations of instruments, and to find out how much can be gained (in terms of price stabilization) and at what cost (in terms of the intensity of instrument utilization).

3. The stabilization problem

3.1. Optimal control formulation

The reduced form of the econometric model presented in section 3.2 below plus the equations describing the paths assumed for the uncontrolled exogenous variables (see section 3.3) can be compactly written in state-variable form as follows:

$$y_t = A_t y_{t-1} + C_t x_t + \varepsilon_t, \tag{1}$$

with given initial condition y_0. y_t is the vector of *all* endogenous and exogenous variables, x_t is the vector of control variables, and ε_t is a vector of uncorrelated disturbances with covariance matrix V. ε_t includes the reduced form equation errors as well as the disturbances of such exogenous variables as grain yield and grain exports. A_t and C_t are time-varying coefficient matrices.

Since the purpose of the present paper is to study the applicability of optimal control to agricultural policy in a realistic setting we do not allow for fine tuning during the year in response to quarterly developments. Rather, we assume that the government responds with a considerable lag and fixes the instrument values for four quarters ahead at the beginning of each year.

Stabilization policies are derived minimizing the expected loss function

$$E \sum_{t=1}^{T} (y_t - a_t)' K_t (y_t - a_t),$$

where E is the expectation operator, a_t is the target vector describing the desired paths for state and control variables and K_t is a positive definite matrix of assigned weights. Linear feedback controls are derived utilizing the

multiperiod certainty equivalence property of the above problem [see Chow (1975, pp. 156–180)]. These feedback rules do not take into account the uncertainty regarding estimated coefficients. Disaggregated evaluation of the stabilization gains and costs are based upon the root-mean-squared deviations (RMSD) of prices and instruments from target paths that are computed using the expected loss formula due to Chow (1975, pp. 166–167).

3.2. The econometric model

The optimal control experiments discussed below utilize a quarterly econometric model of United States livestock and feed grain markets. The model consists of forty-two equations of which five are market clearing and fourteen are identities.[3] These equations explain the demand and supply for five commodities (fed and non-fed beef, pork, chicken and the principal feed grain – corn) and the role of prices in clearing the market for each commodity.

Fig. 1 exhibits a flow diagram of the model while table 1 provides a dictionary of the endogenous and exogenous variables and table 2 presents the estimated structural equations. 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].

The forecasting accuracy (both static and dynamic) of the model has been compared with autoregressive models both within and beyond the sample period. In addition the policy implications of the dynamic multipliers have been analyzed. All of these experiments suggest that the model provides a reasonable representation of the working of the livestock and feed grain markets.[4]

While some DW statistics are rather low we are not using the coefficients resulting from estimation with the assumption of first-order serial correlation [see Pagan (1975)]. We view the model of table 2 as a linear approximation to a complex nonlinear structure and the choice between the coefficients of table 2 and those resulting from the *ad hoc* assumption of simple serial correlation as a rather arbitrary matter. Our choice is based upon the greater plausibility that we attach to the coefficients reported in table 2 in contrast to those derived by assuming first-order correlation. The results are not

[3]The state variable form of the model has 100 state variables and, depending on the number of active instruments, up to 13 control variables.

[4]See Arzac and Wilkinson (1979) for a more complete discussion of the econometric model and some of its policy implications.
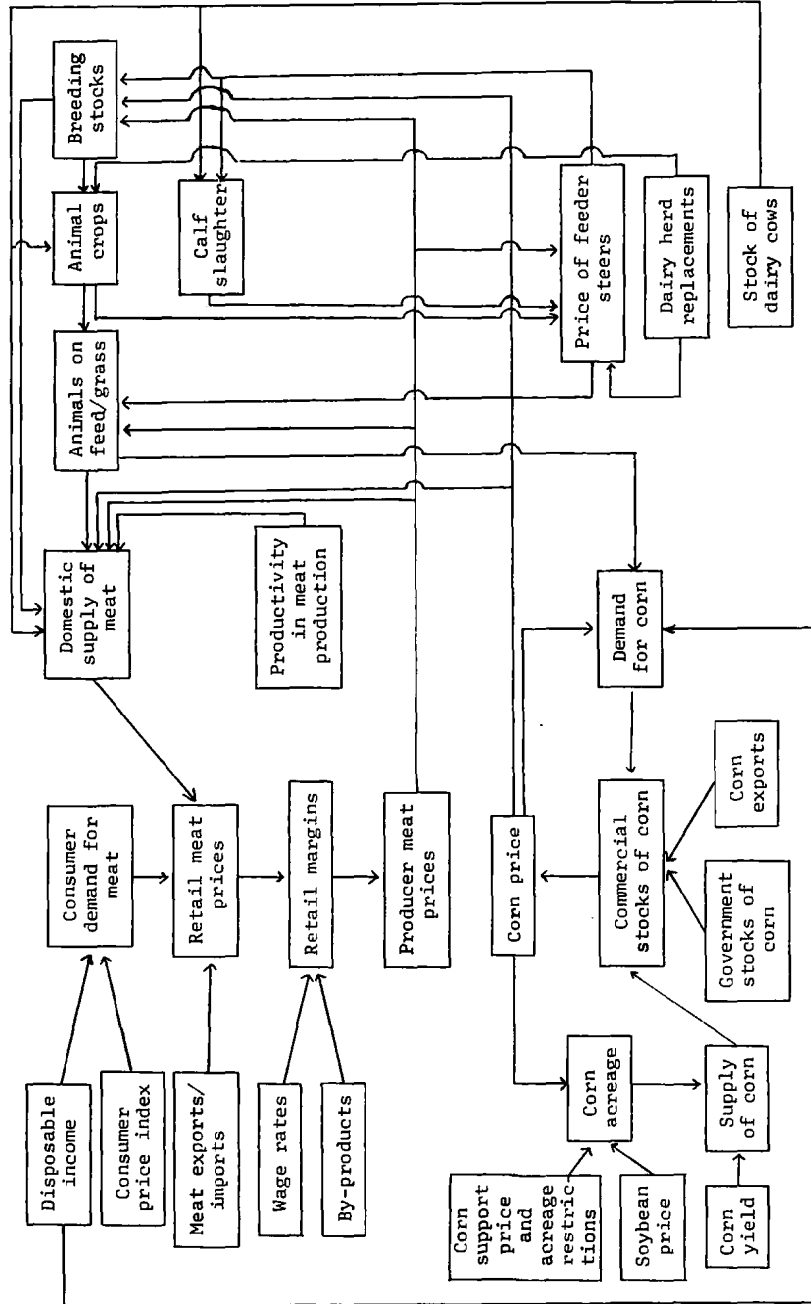
Fig. 1. Structure of the econometric model of the US livestock and feed grain markets.

likely to be significantly different in view of the very similar multiplier responses for both models reported in Arzac and Wilkinson (1979).

Finally, we should note that the mean-squared deviations that we report take into account any possible intrayear autocorrelation because the co-variance matrix of reduced form disturbances was estimated directly from the residuals of the solution given by the annual state variable form of the model.

3.3. The assumed paths for the uncontrolled exogenous variables

Table 3 presents the assumptions concerning the behavior of the exogenous variables during the 32 quarter horizon used to derive the optimal control policies.[5] The initial condition of the model is 1975 IV. In particular, the CPI was maintained constant to obtain a stationary structure and reduce the cost of computation. Additional computations allowing CPI to grow at 1.23 % per quarter did not change the nature of the results reported in this paper. The mean yield per acre is assumed not to increase during the 8 years of the experiment. On the other hand, corn exports are assumed to follow an autoregressive process plus trend with a seasonal pattern. Uncertainty about yield (which mainly represents uncertainty from weather) and corn exports are added to the covariance matrix of the reduced form of the model.

3.4. Controlled variables and instruments

Stabilization of prices, farm income and the retail cost of food is pursued by controlling producer prices. The targets for producer prices in conjunction with the level of output determine gross farm income. The controlled variables are the producer prices of beef, pork, chicken and the price of corn. The instruments are government stocks of corn, the corn support price (actually a guaranteed forward price), non-fed beef imports and corn exports.

Government policy toward grain stocks is allowed to be independent of the support price for corn. The government may implement the support price by deficiency payments without holding stocks of corn. At the same time our model allows for active management of government stocks by buying and selling at the market price. Beef imports are currently subject to an annual quota. In employing beef imports as an instrument we are assuming that foreign supply will be available when needed.

The targets for producer prices are set at their 1975 III levels which seem to have been politically acceptable at the beginning of our control period.[6]

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[5]After verifying that the results were not sensitive to extension of the horizon to 40 quarters, we opted for the shorter horizon in order to reduce computational costs.

[6]The producer price targets are $0.46/lb. for fed beef, $0.21/lb. for non-fed beef, $0.52/lb. for pork and $0.26/lb. for chicken. The price target for corn is $2.64/bu.

Table 1
Variable definitions.

Endogenous Variables

$AP1$ — Acreage planted for corn (thou. a.)
AU — Animal units on feed (m. hd.)
DSC — Change in prior calf slaughter, see eq. (29)
$EC4$ — Prior exports of corn, see eq. (32)
ICC — Commercial corn inventory, end of per. (m. bu.)
IH — Number of pigs on feed, end of per. (thou. hd.)
IP — Cattle and calves on feed, end of per. (thou. hd.)
$IP4$ — Prior placement of cattle and calves on feed, see eq. (30)
KB — Inventory of beef cows, begin. of per. (thou. hd.)
KC — Net calf crop (thou. hd.)
KH — Sows kept for breeding, begin. of per. (thou. hd.)
Mi — Retail-producer price spread, $i=1,\ldots,4$ (¢/cwt.), see eq. (23)–(27)
PFi — Producer price of meat, $i=1,\ldots,4$ (¢/cwt.)

PFS — Price of feeder steers (¢/cwt.)
$PG1$ — Corn price (¢/10 bu.)
PRi — Retail price of meat, $i=1,\ldots,4$ (¢/100 lb.)
SC — Calves slaughtered (thou. hd.)
$SC4$ — Prior calf slaughter, see eq. (28)
XDC — Domestic corn demand (m. bu.)
XDi — Demand for meat, $i=1,\ldots,4$ (m. lb.)
XSi — Meat production, $i=1,\ldots,4$ (m. lb.)
XSC — Corn production (m. bu.)
YZ — Real disposable income (10m. 1967 dol.), see eq. (42)
Zi — Real retail price of meat, $i=1,\ldots,4$ (¢ of 1967/100 lb.), see eq. (38)–(41).

Exogenous Variables

$B1$ — Choice beef by-product allowance (¢/10 cwt.)
$B3$ — Pork by-product allowance (¢/10 cwt.)
CPI — US consumer price index (1967=10,000)
EC — Export of corn (m. bu.)
EXi — Exports of meat, $i=1,\ldots,4$ (m. lb.)
H — Corn yield per harvested acre (bu./100 a.)
ICG — Government corn inventory, end of per. (m. bu.)
ID — Dairy herd replacements, begin. of per. (thou. hd.)
$IMXi$ — Imports of meat, $i=1,\ldots,4$ (m. lb.)
KD — Inventory of dairy cows, begin. of per. (thou. hd.)

LP — Index of productivity in poultry production (1967=1000)
PF — Support price for corn (¢/10 bu.), weighted by acreage restrictions as in Ryan and Abel (1972)
PSB — Price of soybean (¢/10 bu.)
Qi — Dummy variable, $i=2,3,4$. $Qi=1000$ in ith quarter, $Qi=0$ otherwise
W — Wage rate in meat packing ($/100 w.)
$W2$ — Wage rate in poultry dressing ($/100 w.)
Y — Current disposable personal income (10m. dol.)

Meat commodity index: $i=1$ for fed beef, $i=2$ for non-fed beef, $i=3$ for pork, $i=4$ for chicken

Table 2
Econometric model of the US grain and livestock markets.[a]

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)

Table 2 (continued)

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. $XS2 = -2507.1 - 0.1625PF5 + 0.0670(KB + 0.56KD) + 0.0770(KC(-4) - ID) - 0.1570IP4 + 0.085Q2 + 0.302Q3 + 0.317Q4$
   (285.5) (0.038)   (0.011)   (0.018)   (0.016)   (0.051)   (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 – 1964I/75IV (semiannual)

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

18. $XS3 = -1271.7 + 0.1489PF3 + 0.090047IH(-1) + 0.333Q2 - 0.409Q3 + 0.051Q4$
   (655.7) (0.039)   (0.0129)   (0.110)   (0.087)   (0.087)
   $S/M = 0.07$, $DW = 0.48$,   2SLS – 1962II1/75IV (quarterly)

19. $XS4 = 77.5 + 0.09159PF4(-1) - 0.07762PG1(-1) + 0.3920LP + 0.06526XS4(-1) + 0.2247Q2 + 0.1102Q3 - 0.0622Q4$
   (67.5) (0.028)   (0.019)   (0.122)   (0.011)   (0.017)   (0.028)   (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)
$S/M = 0.10$, $DH = -0.76$. 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 (annual)[b]
(2899) (4.960)   (1.031)   (5.202)

23. $XSC = -4280 + 0.0604AP1 + 0.614H$, $S/M = 0.02$, $DW = 2.26$, OLS $-$ 1957/1975 (annual)
(274)   (0.003)   (0.013)

V. Market Clearing Equations and Identities

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

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

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

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

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

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

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

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

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

42. $YZ = Y/CPI$

[a]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 DH 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.
[b]Lags indicate the quarter previous to planting.
[c]Grain consuming animal units. See U.S.D.A. (1974, p. 94).

In an actual policy setting these targets would have to be chosen by analyzing the implications of alternative targets for consumer and producer welfare (see section 2). The targets for the control variables are as follows: the average quarterly values during 1975 for non-fed beef imports and for corn exports (when the latter is used as an instrument),[7] 400 m.bu. for the government stocks of corn and $1.68 per bu. for the corn support price. The latter is equal to 90% of the support price included in the 1978 Feed Grain Program[8] expressed in 1975 IV dollars. The target level of government stocks of corn is below the goal of the reserve program for 1976 and 1977 grain[9] and according to the experiments described in this paper is large enough for the probability of stock-out to be small.[10] Since the mean path of stocks remains more than two standard deviations above zero (in all but one of the experiments reported in this paper) the probability of stock-out is negligible. Of course, the probability of stock-out can be further decreased by increasing the target level of stocks.[11]

4. Stabilization experiments

4.1. Alternative control policies

The main questions to be considered in this sub-section are the following:

(1) Can optimal control maintain prices close to the desired target paths without requiring excessive instrument utilization?

(2) Does limiting policy revision to once-a-year make stabilization policy ineffective?

(3) Are the available instruments complements or substitutes for attaining stabilization? In particular, what is the likely contribution of each of the individual instruments? Are there redundant and essential instruments?

(4) Is the price of corn a suitable intermediate target for achieving overall stabilization in the grain and livestock markets?

(5) Are farm prices a suitable intermediate target for stabilizing farm income and the retail cost of the consumer's food basket?

[7] The quarterly targets are 440 m.lb. for non-fed beef imports and 454 m.bu. for corn exports.

[8] As described in U.S.D.A. (1978, pp. 6, 11). The 10% reduction accounts for the set-aside requirements. See Ryan and Abel (1972).

[9] See U.S.D.A. (1978, pp. 11, 13). The goal is to store 670 m.bu. of corn equivalents of which approximately 522 m.bu. correspond to corn.

[10] Note that non-negativity constraints are ignored in the computation of the optimal policies.

[11] A detailed analysis of optimal inventory policy with particular reference to stock-out probability and carrying costs can be undertaken using the methodology of this paper. In fact, econometric estimation plus optimal control permits estimating the mean and variances of the paths followed by target and instrument variables and obviates the ad hoc assumptions about the nature of the uncertainty involved that are commonly made in grain reserve studies [see, for example, Eaton and Steele (1976)].

The results of this set of control experiments is reported in table 4.[12] The weights of targets and instruments in the loss function is given in table 4. The unregulated market is defined as zero government stocks of corn, beef imports and the support price of corn fixed at their target values, and corn exports following the path defined in table 3.

Examination of table 4 shows that effective control of prices can be attained with once-a-year policy revision without excessive utilization of the instruments. Control experiments 1 to 3 permit a rather similar degree of stabilization and are clearly more effective than experiments 4 to 7. An important implication of these results is that the combination of beef imports and the support price for corn does almost as well as policies including corn stocks and corn exports. In other words, the latter two instruments do not appear to be necessary to attain significant price stabilization.

Comparing the results of experiments 4 and 6 with that of 3 in table 4 we conclude that beef imports appears to be an essential instrument for stabilization of meat prices. In another paper [see Arzac and Wilkinson (1979)] we report that beef imports have relatively small multipliers. This explains its rather large RMSD. However, no combination of the other

Table 3

Paths assumed for uncontrolled exogenous variables.[a]

Variable	Path value
$B1, B3, EX1$	1971 I–75 IV average
CPI	1975 IV
ID, KD	Beginning 1976 level
PSB	1975 I–75 IV average
$LP, W, W2$	US productivity growth rate during 1955 I–75 IV from 1975 IV level
YZ	1955 I–75 IV growth rate from 1975 IV level
H	$8622 + u$, $S = 603.38$
	Value of quadratic trend for 1975 plus error with standard deviation about trend estimated with 1955 I–75 IV data
EC	$-15.86 + 0.644EC(-1) + 1.373(84 + t)$
	(13.6) (0.097) (0.396)
	$+0.037Q2 + 0.035Q3 + 0.285Q4 + u$
	(0.134) (0.134) (0.134)
	$S = 41.28$, $S/M = 0.27$, $DH = -0.99$
	$t = 1, 2, \ldots, 32.$
	Estimated with 1957I–75IV data

[a]u denotes a zero-mean disturbance with standard deviation S. See table 1 and footnote a to table 2 for variable definitions and other notation.

[12]The deviation weights in the reported experiments are chosen to obtain deviations of comparable order of magnitude for prices and quantities, respectively. Though a certain degree of trial and error was involved in arriving at the reported weights, the results of the paper are not sensitive to changes in the chosen weights.

Table 4

Price stabilization under alternative policies[a] (relative RMSD).[b]

	Producer prices				Corn market price	Retail cost of meat basket[c]	Government stock of corn	Beef imports	Corn support price	Corn exports
	Fed beef	Non-fed beef	Pork	Chicken						
Loss weights[d]	1	1	1	1	10	–	10	25	30	25
Unregulated market	0.314	0.465	0.312	0.461	0.176	0.252	0.000	0.000	0.000	0.215
			Price targets				Instruments			
Control experiment 1	0.186	0.309	0.224	0.325	0.098	0.153	0.068	0.385	0.027	0.301
2	0.204	0.316	0.245	0.353	0.108	0.167	0.349	0.406	0.173	0.215
3	0.209	0.317	0.253	0.362	0.117	0.171	0.000	0.406	0.208	0.215
4	0.269	0.432	0.252	0.385	0.106	0.212	0.375	0.000	0.179	0.215
5	0.226	0.320	0.275	0.391	0.134	0.184	0.548	0.456	0.000	0.215
6	0.272	0.434	0.260	0.393	0.115	0.216	0.000	0.000	0.217	0.215
7	0.291	0.454	0.270	0.412	0.116	0.229	0.257	0.088	0.110	0.215

[a]Expected results conditional on the 1975 IV values of the state variables.

[b]RMSD per unit of 1975 III prices, 1975 quarterly average beef imports and corn exports, 400 m.bu. corn stocks and $1.68 corn support price, respectively.

[c]RMSD of retail prices weighted by 1975 IV quantities.

[d]Loss weights per squared deviations: 1 unit per [¢/cwt]² for meat prices, 10 units per [¢/10 bu.]² for corn market price, 10 units per [m.bu.]² for corn stocks, 25 units per [m.lb.]² for beef imports, 30 units per [¢/10 bu.]² for corn support price and 25 units per [m.bu.]² for corn exports.

instruments is likely to substitute for beef imports as a stabilizer of meat prices. This is confirmed by the additional experiments reported in section 4.2. A comparison of experiments 4 and 6 indicates that, at least within the framework of annual policy revisions, inventory management does not contribute much to stabilization when the effective support price for corn is actively used to manage supply. Furthermore, experiment 5 shows that inventory management by itself is not very effective in the absence of supply management.

Finally, we note that experiment 7 which has the market price of corn as the single price target does poorly in terms of meat price stabilization. It seems that the internal dynamics of the livestock sector implies cyclical behavior that cannot be controlled by stabilizing the price of corn. In other words, the price of corn is not an adequate intermediate target for meat price stabilization. Moreover, because of the specific effectiveness of the available instruments the policy maker is not confronted with stabilization trade-off between the grain and livestock sectors.

What are the implications of the above results for stabilizing expected farm income? An approximation to the latter variable can be derived by multiplying the expected producer price times expected output.[13] On an annual basis the range of the sum of the market value of livestock and corn output for experiment 2 of table 4 is 34.6 to 38.6 (billions of 1975 dollars) and for the unregulated market 28.2 to 43.8 (billions of 1975 dollars). Thus farm prices are an effective intermediate target for stabilizing expected farm income from livestock and corn production.

4.2. Stabilization and instrument utilization

In this sub-section we consider additional stabilization attained by a more intensive use of the available instruments, and within this context reexamine some of the questions analyzed in section 4.1. Table 5 presents the results of increasing by multiples of 3, 5, 7 and 9 the weights assigned to the target prices in the control experiments 2 to 7 (except 5 which implies a high probability of stock-out and is thus omitted). These results show that, at least under annual policy revisions, there is a definite limit to the gain in stabilization that can be achieved by additional instrument utilization. Most of the gain is attained in the column corresponding to a multiple of 3. Further instrument utilization results in very small additional stabilization.

The experiments of table 5 permit the reexamination of the relative effectiveness of the instruments. A comparison of experiments 3, 4 and 6 shows that even a very intensive utilization of the alternative instruments cannot substitute for beef imports as a meat price stabilizer. However, the

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[13]Expected deficiency payments to corn producers are negligible.

support price of corn is an adequate substitute for corn stock management within the annual policy revision framework. Finally, experiment 7 shows that additional stabilization of the price of corn cannot significantly increase the stability of-the livestock sector.

Table 5
Price stabilization and instrument utilization[a] (relative RMSD).

Basic control experiment	Variable	Multiple of price target weights given in table 4				
		1	3	5	7	9
2	Cost of meat basket	0.167	0.136	0.125	0.120	0.117
	Corn market price	0.108	0.093	0.090	0.088	0.087
	Gov. stock of corn	0.349	0.552	0.674	0.768	0.845
	Beef imports	0.406	0.668	0.803	0.895	0.964
	Corn support price	0.173	0.232	0.253	0.263	0.270
3	Cost of meat basket	0.171	0.134	0.128	0.122	0.119
	Corn support price	0.117	0.109	0.100	0.099	0.099
	Beef imports	0.406	0.646	0.802	0.894	0.964
	Corn support price	0.208	0.292	0.324	0.342	0.355
4	Cost of meat basket	0.212	0.200	0.197	0.195	0.194
	Corn support price	0.106	0.094	0.091	0.090	0.090
	Gov. stock of corn	0.375	0.610	0.753	0.861	0.950
	Corn support price	0.179	0.241	0.260	0.270	0.275
6	Cost of meat basket	0.216	0.204	0.200	0.199	0.198
	Corn market price	0.115	0.103	0.101	0.101	0.103
	Corn support price	0.217	0.305	0.335	0.352	0.364
7	Cost of meat basket	0.229	0.221	0.219	0.218	0.217
	Corn market price	0.116	0.093	0.086	0.083	0.081
	Gov. stock of corn	0.257	0.451	0.570	0.662	0.737
	Beef imports	0.088	0.127	0.140	0.147	0.152
	Corn support price	0.110	0.154	0.169	0.177	0.182

[a]See notes to table 4.

4.3. Response to export fluctuations

The computations presented in the previous section take into account the disturbances affecting the econometric model by applying the autoregressive transformation represented by the model plus the control equations to the covariance matrix of residuals. The latter includes the residuals of corn exports. However, given the large impact of fluctuations in corn exports on the livestock and grain markets,[14] it is of interest to analyze the response of

[14]Fluctuations in corn exports have a larger effect on prices than fluctuations in corn output. Exports not only affect the price of corn through the market clearing equation but also directly in equation 21 in table 2 [see Arzac and Wilkinson (1979), where detailed multiplier computations are provided]. The larger effect of grain exports might be due to the variable's apparent autoregressive structure which is likely to be taken into account by market participants.

the model to a significant departure of corn exports from its expected path. For this purpose unanticipated changes in exports are introduced in both the unregulated market and control experiment 2, column 3 of table 5, which requires only a modest utilization of the instruments. The purpose of this experiment is to analyze how a policy of relatively mild optimal government intervention deals with significant unanticipated export fluctuations (i.e., large fluctuations not taken into account in deriving the control rules). The behavior of the unregulated model is used as standard of performance. A smoother optimal response of prices could obviously be attained by additional instrument activity as prescribed by other policies of table 5. However, the results in fig. 2 are perhaps more realistic in the sense of requiring only small adjustments in the instruments.

To generate a rather extreme pattern of export fluctuations the disturbances of the 5th to 8th quarters are fixed at −50 m.bu. and the disturbances of the 25th to 28th quarters are fixed at +50 m.bu. The other quarter disturbances are zero (their mean value). Exports departs from its expected path as depicted in the lower panel of fig. 2. Since a 50 m.bu. change is equal to 1.21 times the standard deviation of the export disturbances (which were

Market Value of Corn Harvest (billion $)

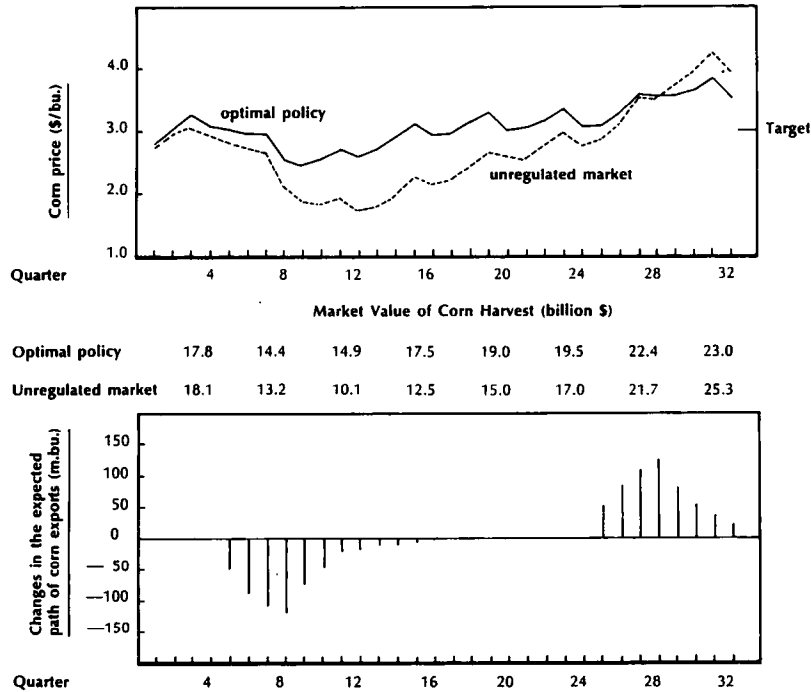|								
Optimal policy	17.8	14.4	14.9	17.5	19.0	19.5	22.4	23.0
Unregulated market	18.1	13.2	10.1	12.5	15.0	17.0	21.7	25.3

Fig. 2. Expected response of the price of corn to export fluctuations.

not autocorrelated during the sample period), a change of that magnitude with the same sign during four successive quarters is rather unlikely (the probability of such an occurrence if the disturbances are normally distributed is about 0.0002). The total effect amounts to a change beyond the expected level of exports of 360 m.bu. during the first year and 170 m.bu. during the second year.

The top panel of fig. 2 presents the response of the price of corn in the unregulated and the optimally controlled market. The price of corn is the most sensitive price to corn export fluctuations. The figure clearly shows that the optimal control rule succeeds in smoothing the price path and maintains it within a band of $1.35 while the unregulated market allows the price of corn to vary within a band of $2.50. The stabilizing effect on the value of the corn harvest is also shown in fig. 2.

A crucial question is whether the government should be prepared to handle a fluctuation of such low probability. However, the welfare aspects of preparation for extreme or catastrophic events is even less understood than the relatively simple question of variance reduction.

5. Concluding remarks

The principal conclusions to be derived from the above results are the following:

(1) Farm prices and the retail cost of meat and chicken can be stabilized by optimal control relative to unregulated markets. Farm prices are a suitable intermediate target to stabilize both farm income and the retail cost of meat and chicken.

(2) The support price for corn and beef import controls are the most effective instruments while management of government corn stocks are neither necessary nor a substitute for an instrument such as beef import quotas.

(3) Beef import controls are essential to stabilize producer prices for livestock commodities. The price of corn is not an intermediate target that can be used to stabilize livestock prices.

(4) There is a definite limit to the stabilization gain that can be achieved by more intensive utilization of the policy instruments.

(5) Optimal control rules are also effective in achieving policy goals when significant unanticipated shocks occur. For example, a significant unanticipated fluctuation in exports extending over several quarters was handled quite well by optimal control relative to unregulated markets.

At the same time the analysis presented in this paper has a number of limitations. First, insofar as one justification for price stabilization is the reduction in risk born by producers, the failure to consider the role of futures

markets is a shortcoming of the analysis. Part of the risk from output and price variability may be eliminated by producer participation in futures markets thus reducing the need for public policies to stabilize prices.[15] Second, we have not taken into account the response of economic agents to the optimal control policies.[16] While one can dispute the degree to which the expectations of economic agents are rational, it is possible that the structure of commodity markets will be altered by the policies discussed above. If the estimation and control of the econometric model fails to consider this problem, the effectiveness of the economic policy instruments will exhibit more uncertainty than our analysis indicates [see Taylor (1978)]. Finally, for the purposes of actually implementing the optimal control rules it is desirable to analyze how much stabilization could be achieved by simple rules of thumb that approximate the optimal control rules. The derivation of such approximations and their evaluation – perhaps replicating the fluctuations in yields and exports experienced in 1971–73 – will be the subject of future research.

[15]See McKinnon (1967) for one analysis that supports this viewpoint, and Anderson and Danthine (1978) for a theory of future markets.

[16]The problem of the subject of the forecast being influenced by the forecast has long been recognized in the econometric literature. Recently Kydland and Prescott (1977) have provided a stronger result in the context of optimal control rules by making the assumption that economic agents possess the same information as policy makers and form rational expectations.

References

Anderson, R.W. and J.P. Danthine, 1978, Hedger diversity in futures markets: Backwardation and the coordination of plans, Research Paper no. 71A (Graduate School of Business, Columbia University, New York).

Arzac, E. and M. Wilkinson, 1979, A quarterly econometric model of United States livestock and feed grain markets and some of its policy implications. American Journal of Agricultural Economics, forthcoming.

Brandow, G.E., 1977, Policy for commercial agriculture, 1945–1971, in: L.R. Martin, ed., A survey of agricultural economics literature 1 (University of Minnesota Press, Minneapolis, MN).

Chow, G.C., 1975, Analysis and control of dynamic economic systems (Wiley, New York).

Diewart, W.E., 1978, Duality approaches to microeconomic theory, in: K.J. Arrow and M.D. Intriligator, eds., Handbook of mathematical economics (North-Holland, Amsterdam).

Eaton, D.J. and W.S. Steele, eds., 1976, Analyses of grain reserves (US Department of Agriculture, Washington, DC).

Hathaway, D.E., 1974, Food prices and inflation, Brookings Papers in Economic Activity 1, 63–109.

Houthakker, H.S., 1974, Comments on food prices and inflation, Brookings Papers in Economic Activity 1, 110–112.

Kydland, F.E. and E.C. Prescott, 1977, Rules rather than discretion: The inconsistency of optimal plans, Journal of Political Economy 85, 473–491.

McKinnon, R.I., 1967, Futures markets, buffer stocks, and income stability for primary producers, Journal of Political Economy 75, 844–861.

Pagan, A., 1975, Optimal control of econometric models with autocorrelated disturbance terms, International Economic Review 16, 258–263.

Ryan, M.E. and M.E. Abel, 1972, Corn acreage response in the set-aside program, Agricultural Economics Research 24, 102-112.

Schultze, T.W., 1945, Agriculture in an unstable economy (McGraw-Hill, New York).

Sen, A.K., 1977, On weights and measures: Informational constraints in social welfare analysis, Econometrica 45, 1539-1572.

Taylor, J.B., 1978, Estimation and control of a macroeconomic model with rational expectations, Discussion Paper no. 77-77821 (Department of Economics, Columbia University, New York).

Turnovsky, S.J., 1976, The distribution of welfare gains from price stabilization: The case of multiplicative disturbances, International Economic Review 17, 133-148.

Turnovsky, S.J., 1978, The distribution of welfare gains from price stabilization: A survey of some theoretical issues, in: F.G. Adams and S.A. Klein, eds., Stabilizing world commodity markets (Heath-Lexington, Boston, MA).

Turnovsky, S.J., H. Shalit and A. Schmitz, 1977, Consumers' surplus, price instability, and consumer welfare, Mimeo.

US Department of Agriculture, 1974, Livestock-feed relationships - National and state, Statistical Bulletin no. 530 (Washington, DC).

US Department of Agriculture, 1978, Feed situation, Feb.