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OPTIMAL FEED GRAIN PRODUCTION AND IMPORT POLICIES IN KOREA

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ABSTRACT

A dynamic programming model based on the Markov Decision Process was developed to optimize feed grain imports, stocks, and domestic prices in Korea. The results indicate that Korea should increase its carryover stocks and feed grain imports. This will reduce domestic prices and maximize net social benefits. The long-run equilibrium price of feed grain should be 165 won per metric ton which is equivalent to $6.55 per bushel at the exchange rate of 700 Won per one U.S. dollar. The optimal price is much higher than the world price, but substantially lower than the actual domestic price of feed grain in Korea ($9.52 per bushel).

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INTRODUCTION

The Korean economy has been growing sharply during the series of Five Year Economic Development Plans which were initiated in 1962. The most rapid economic growth occurred in the third and fourth Plan Periods during the 1970s. The Gross National Product increased 9,038 percent from 806 billion Won (Korean monetary unit) in 1965 to 73 trillion Won in 1985 while the population increased from 28 million in 1965 to 40 million in 1985. These increases in income and population triggered changes in the consumption patterns for livestock and poultry products. Substantial increases were made in meat, milk, and egg consumption while per capita consumption of cereals remained stable between 1965 and 1985. Per capita consumption of beef, pork, chickens, and eggs increased by 290 percent, 442 percent, 620 percent, and 423 percent, respectively, during the period. Further, milk consumption increased dramatically by 5,825 percent during the same period. This required an increase in utilization of both feed grains and feed grain supplements, causing feed grain imports to increase from 259 thousand metric tons in 1970 to 3,984 million metric tons (MMT) in 1985.

The utilization of concentrate feed increased 268 percent for cattle, 250 percent for hogs, and 124 percent for poultry during the 1980 to 1985 period. The utilization of concentrate feed is expected to increase continuously due to limited grassland available for forage. Consequently the supply of feed grains, which is a major ingredient of concentrate feed, has been one of the most sensitive issues in increasing meat production.

The Korean government has regulated feed grain imports to protect the domestic feed grain industry. However, Korea has been unable to achieve self-sufficiency in feed grains due to its limited cropland area. Arable land was only 2 million hectares or 22 percent of the total land area (9.9 million hectares) in 1986. Korea currently imports over 90 percent of its feed grain from other countries, mainly the United States. This import trend will continue in the near future.

The Korean government likes to maintain a two-price policy which separates the domestic price of feed grain from the world price. Under this policy the domestic price of feed grain will be controlled by the Korean government through buffer stock operation and be stabilized at a desired level. An important question in carrying out this policy is "what is the optimal amount of carryover stocks which will sufficiently stabilize the domestic price of feed grain and also maximize social benefits?" For example, price can be completely stabilized with an unlimited amount of carryover stocks, but such a program will not necessarily maximize social benefits because of high storage costs. On the other hand, a small amount of carryover stock will minimize storage costs, but may not be able to stabilize the price of feed grains.

The objective of this study is to determine the amount of feed grain imports and carryover stocks which maximize social benefits in Korea. The model used for this study is a stochastic dynamic programming model based on the Markov decision process. This model is similar to those developed by Gustafson (9) and Burt et al. (5), who focused on determination of optimal

carryover stocks and exports of feed grain and wheat, respectively, in the United States, while this study focuses on an importing country, Korea.

ESTIMATION OF ECONOMETRIC MODELS

The econometric models for the Korean feed grain industry include three behavioral equations: 1) demand, 2) supply, and 3) the price relationship. The demand model for feed grains is estimated by using time series data from 1965 to 1985 as follows:

$$(1) \quad QD_t = \underset{(-0.965)}{-556148.17} - \underset{(-1.365)}{3.065DP_t} + \underset{(2.496)}{1.07MP_t} + \underset{(11.519)}{0.938\ QD_{t-1}} + e_t$$

$$R^2 = 0.9410 \qquad S.E. = 377,232$$

where QD_t is demand for feed grain in time t, DP_t is the domestic price of feed grain, MP_t is the price of the final meat products and e_t is a disturbance term. This model was specified on the basis of the partial adjustment hypothesis.

Price variables (DP_t and MP_t) are deflated by using the Korean consumer price index. The t-values of the estimated parameters (numbers in parentheses) indicate that the price of meat and the lagged dependent variable are statistically significant at the 5 percent level while the price of feed grain is significant at the 10 percent level. Equation (1) has an R^2 of 0.941 indicating that 94.1 percent of the variation of feed grain demand is explained by the price of feed grain, the price of meat, and the lagged dependent variable. The estimated price elasticity is -0.41 at mean values of the dependent and independent variables and the cross price elasticity with respect to meat is 0.97. This implies that feed grain consumption is more sensitive to the meat price than to the prices of feed grain.

The supply model for feed grain is developed using the theory of a firm which maximizes profit subject to cost constraints. The partial adjustment hypothesis developed by Nerlove is also introduced to capture the farmers' dynamic behavior in making planting decisions.

The estimated model using time series data from 1965 to 1985 is shown as:

$$(2) \quad QS_t = 173.8 + \underset{(1.13)}{0.3257\ DP_{t-1}} - \underset{(-1.06)}{0.106\ RP_{t-1}} + \underset{(4.78)}{0.75\ QS_{t-1}} + V_t$$

$$R^2 = 0.975 \qquad S.E. = 36259.7$$

where QS_t is domestic supply of feed grain in time t, DP_{t-1} is the domestic price of feed grain in time t-1, RP_{t-1} is the price of rice in time t-1 and V_t is a disturbance term.

The price variables are deflated by the price index for Korean farm inputs. The t-values of the estimated parameters (numbers in parentheses) indicate that the lagged dependent variables are statistically significant at the 5 percent level, while the prices of feed grain and rice are not significant. This is primarily because feed grain production is limited to a certain area where soil types and weather conditions do not allow substitution

for the other crop production. The equation has an R^2 of 0.975, indicating that 97.5 percent of the variation of feed grain supply is explained by its price, the price of rice, and the lagged dependent variable. The estimated price elasticity is 0.36 and the cross price elasticity with respect to the price of rice is -0.27.

To identify the relationship between the domestic price of feed grain and import demand, a traditional price equation is specified as follows:

$$(3)\quad DP_t - DP_{t-1} = \theta(QS_t + M_t - QD_t)$$

where

M_t = the quantity of feed grain imported in time t

QS_t and QD_t are generally specified as:

$$(4)\quad QS_t = \beta_0 + \beta_1 DP_{t-1}$$

$$(5)\quad QD_t = \alpha_0 - \alpha_1 DP_t$$

Combining equations (3), (4), and (5) yields:

$$(6)\quad DP_t = \frac{\theta(\beta_0 - \alpha_0)}{1 - \theta\alpha_1} + \frac{(1 + \theta\beta_1)}{(1 - \theta\alpha_1)} DP_{t-1} + \frac{\theta}{(1 - \theta\alpha_1)} M_t$$

or $$(7)\quad DP_t = a_0 + a_1 DP_{t-1} + a_2 M_t$$

We can rewrite equation (7) as a function of DP_{t-1} and $(M_t - M)$ as follows:

$$(8)\quad DP_t = (a_0 + a_2 \bar{M}) + a_1 DP_{t-1} + a_2(M_t - \bar{M})$$

where $\bar{M}$ is the mean import of feed grain. The parameters of equation (8) can be estimated directly by regressing DP_t on DP_{t-1} and $(M_t - \bar{M})$. It was found from the preliminary estimation of the price model that the estimated coefficient for variable $(M_t - M)$ did not represent the true relationship between domestic price and imports because the prices of feed grain have been controlled by the Korean government. For this reason, the first order autoregressive price relationship was developed, and then imports of feed grain were indirectly introduced to the first order autoregressive price equation in such a way similar to Burt et al. (5). The estimated autoregressive price equation is as follows:

$$(9)\quad DP_t = 161298.32 + \underset{(2.81)}{0.2788}\ DPt\text{-}1$$

$R^2 = 0.78$
S.E. = 23702.35

To introduce a variable, $(M_t - \bar{M})$ into equation (9), a_2 in equation (8) was calculated as follows:

$$(10)\quad a_2 = \overline{DP} \div \bar{M} \cdot e_x$$

The import demand elasticity was estimated at -.552. The estimated domestic price equation by introducing a variable, $(M_t - \bar{M})$ into equation (9) is as follows:

$$(11) \quad DP_t = 161298.32 + 0.2788DP_{t-1} - 0.1334\ (M_t - \bar{M})$$

STOCHASTIC DYNAMIC PROGRAMMING MODEL

A stochastic dynamic programming model based on the Markov decision model was developed to determine the optimal import of feed grains, optimal stocks, and optimal feed grain price in Korea. The model includes feed grain stocks and the annual domestic feed grain prices as state variables, and the quantity of feed grains imported each year as the decision variable.

The total feed grain stock is defined as the sum of the quantity of feed grain production and the quantity of feed grains carried over from previous time period. The feed grain stock as a state variable is divided into ten different levels, starting at 0.5 million metric tons (MMT) with a constant interval of 0.15 MMT.

The annual domestic feed grain price, which is another state variable, is defined as the government purchase price for stabilization and has eight different levels, ranging from 150 thousand Won to 500 thousand Won in a constant interval of 50 thousand Won. Similarly, the decision variable has 30 different levels of imports, starting from 2 MMT of feed grain to 6.35 MMT with a constant interval of 150 thousand metric tons.

The joint transition probabilities associated with these state and decision variables are calculated using the econometric estimates of demand, supply, and the price relationship of feed grain. These estimates are then incorporated into the dynamic model.

The objective function of the model maximizes the present value of the expected net benefit obtained from demand and supply of feed grains in Korea. The expected benefit from feed grain consumption is represented by the consumers' surplus associated with the demand for feed grain. Similarly, the expected benefits for producers are represented by the producers' surplus associated with feed grain supply. There are three different costs associated with feed grain supply: 1) feed grain import costs, 2) storage costs for carrying feed grain over to the next time period, and 3) costs associated with feed grain production. Thus, the net expected benefit is calculated by subtracting import, storage, and production costs from the total expected benefit from feed grain consumption. This net expected benefit is equivalent to the sum of consumers' and producers' surplus minus storage costs. The criterion is to maximize present value of expected net benefit through the Markov decision process over time.

The dynamic programming model for the Korean feed grain is:

$$(12) \quad V_n(S,DP) = \underset{m}{\text{Max}}\ \{q_n(S,DP,M) + \beta \sum_{s} \sum_{dp} V_{n-1}(S,DP)\, Pr(S,DP|M)\}$$

where

$V_n(S,DP)$ = the present value of expected net benefits associated with stocks (S) and prices (DP) in the nth stage,

$q_n(S,DP,M)$ = expected annual net benefit or immediate expected return associated with stocks (S), prices (DP), and imports (M) in the nth stage,

$Pr(S,DP|M)$ = conditional joint transition probability for stocks (S) and prices (DP) when the mth level of imports is given,

β = discount factor.

Equation (12) determines the import level which maximizes the present value of immediate expected return as a function of two state variables (prices and stocks) through a recursive dynamic process.

Estimation of Expected Return and Transition Probabilities

The present value which maximizes the expected net benefit in equation (12) can be obtained from estimating the expected return and transition probabilities for price and stocks of feed grain.

Expected return, $q_n(S,DP,M)$, is defined as the net social benefit associated with stocks (S), price (DP), and imports (M), which is the sum of the consumers' surplus and the producers' surplus minus storage costs. The criterion function is mathematically expressed as:

$$(13) \quad q_n(S, DP, M) = CS(DP) + PS(DP) - SC$$

where $q_n(S, DP, M)$ = net social benefit, CS(DP) = consumers' surplus, PS(DP) = producers' surplus, and SC = storage costs. CS(DP) and PC(DP) are calculated from demand and supply equations, respectively.

The joint transition probabilities of price and stocks with given imports $[P_r(DP, S|M)]$ are obtained by multiplying the transition probabilities for the feed grain stocks, given the domestic price and imports $[P_r(S|DP,M)]$ by the transition probabilities for price, given the feed grain imports $[P_r(DP|M)]$ as follows:

$$(14) \quad P_r(DP,S|M) = P_r(DP|M) \cdot P_r(S|DP,M)$$

$P_r(S|DP,M)$ is calculated from probability distribution of feed grain production. A similar procedure is used to calculate the transition probabilities for domestic prices, given feed grain imports. It is assumed that DP_t is normally distributed with a mean of $\hat{DP}_t$ from equation (11) and the standard error from equation (9).

Empirical Results

Variable costs of storage were taken as 3,000 Won per metric ton annually ($4.28 per metric ton or 12 cents per bushel at 700 Won = $1.00) and a discount rate (net of inflation) of 6 percent was used to calculate present values.

Long-Run Optimal Decision Rules for Korean Feed Grain Imports

Table 1 presents optimal decision rules as a function of state variables (domestic price and stocks). The optimal decision rule represents the quantity of feed grain which the Korean government should import to maximize the country's social benefits under the given domestic price of feed grain and stocks. For instance, when feed grain stock after harvest is 1.25 million metric tons and the price of feed grain is 250 thousand Won which is equivalent to $9.92 per bushel at $1.00 = 700 Won, the optimal decision rule indicates that Korea should import 4.85 MMT of feed grains to maximize the country's social benefits. Similarly, the country should import 5.45 MMT of feed grains with a stock of 1.7 MMT and a price of 500 thousand Won.

The optimal decision rules are not sensitive to the feed grain stock but are sensitive to domestic feed grain price. The decision rules remain constant over feed grain stock levels mainly because increases in storage costs as a result of increases in feed grain stocks are not large enough to change decision rule.

The optimal imports of feed grain have a direct functional relationship with the prices of feed grain as shown in Table 1. This is mainly because an increase in consumers' benefits by lowering the prices of feed grain through increases in feed grain imports is larger than the net increase in social costs associated with the additional imports and domestic production. This reflects the following characteristics of the Korean feed grain industry: 1) domestic production of feed grain has been a very small portion of the total feed grain consumed in Korea, and 2) the domestic prices of feed grain have been controlled by the Korean government to protect domestic producers and have been much higher than the world prices.

In 1985, the actual level of price and stocks were 238 thousand Won and 650 thousand metric tons, respectively. The actual quantity of feed grain imported was 3.984 MMT which is smaller than the optimal level under the given condition (4.850 MMT). This implies that Korea would maximize net social benefits by increasing imports by about 1 MMT. The import restrictions on feed grain resulted in the price of feed grain being much higher than the optimal price.

The optimal social benefits associated with domestic producers, domestic consumers and storage program are obtained by generating the present values of expected return associated with these components under the optimal decision rules over the planning horizon, while the actual social benefits are obtained by generating the present values for each component under the decision rule associated with the actual imports in 1985. The social benefits for domestic consumers, domestic producers, and storage program are shown in Table 2. The net social benefits associated with the optimal decision rules are 21 billion won, which is substantially larger than those associated with actual imports. This implies that Korea will be substantially better off if the country follows the optimal decision rule presented in Table 1. Consumer benefits under the optimal decision rule are much larger than those under the actual imports, while the social benefits given to producers under the optimal decision rule are substantially smaller than those under actual imports. This indicates that the current feed grain program in Korea is mainly designed to give more benefits to producers than to consumers, when compared to the benefit distribution under the optimal decision rule.

TABLE 1. OPTIMAL DECISION RULE IN TERMS OF THE QUANTITY OF FEED GRAIN IMPORTS IN MODEL 1 (Base Model).

	Feed Grain Price							
	Thousand Won							
Stock	150	200	250	300	350	400	450	500
	million metric tons (MMT)							
0.50	4.70	4.85	4.85	5.00	5.15	5.15	5.30	5.45
0.65	4.70	4.85	4.85	5.00	5.15	5.15	5.30	5.45
0.80	4.70	4.85	4.85	5.00	5.15	5.15	5.30	5.45
0.95	4.70	4.85	4.85	5.00	5.15	5.15	5.30	5.45
1.10	4.70	4.85	4.85	5.00	5.15	5.15	5.30	5.45
1.25	4.70	4.85	4.85	5.00	5.15	5.15	5.30	5.45
1.40	4.70	4.85	4.85	5.00	5.15	5.15	5.30	5.45
1.55	4.70	4.85	4.85	5.00	5.15	5.15	5.30	5.45
1.70	4.70	4.85	4.85	5.00	5.15	5.15	5.30	5.45
1.85	4.70	4.85	4.85	5.00	5.15	5.15	5.30	5.45

Steady State Probability and Expected Values

The transition probabilities associated with the optimal decision rule are characterized as a first-order Markov process. This implies that the probability of having a particular price and a stock in stage n depends only upon those in stage n-1. When we operate the Markov process repeatedly, the initial condition can be washed out from the transition probabilities, which means that all elements of a row of the transition probability matrix becomes identical to those of all other rows. The row vector is known as a steady state probability.

The steady state probability vector for feed grain prices and stocks was calculated from the transition probabilities for the prices and stocks associated with the optimal decision rule. Then the steady state probabilites were used to calculate the expected values of feed grain prices and stocks as follows:

$$E(P) = \sum_{j=1}^{8} P(P_j)\, P_j \quad \text{and} \quad E(S) = \sum_{i=1}^{10} P(S_i)\, S_i.$$

TABLE 2. DISTRIBUTION OF NET SOCIAL BENEFITS UNDER ACTUAL AND OPTIMAL IMPORT DECISIONS

	Consumers Surplus	Producers Surplus	Storage Costs	Net Benefits
	----------million won----------			
Actual (1985)	9,893.0	11.6	1,428.0	8,471.6
Optimal	28,712.0	7.0	7,142.0	21,577

where E(P) is the expected value of feed grain prices, and E(S) is the expected value of feed grain stocks. The expected prices and stocks are interpreted as the long-run equilibrium prices and stocks.

The long-run equilibrium prices and stocks are 165 thousand Won and 1.72 MMT (Table 3), respectively. The equilibrium prices of feed grain are much lower than the actual prices in 1986 while the equilibrium stocks are much larger than the actual stock. Domestic demand for and supply of feed grain are expected to be 4.5 million and 114 thousand metric tons, respectively, under the expected equilibrium price. Accordingly, the total import should be about 4.7 MMT, which is larger than the actual imports of feed grains. This analysis indicates that the country should lower the prices of feed grain, and increase imports of feed grains and carryover stocks.

Concluding Remarks

A recursive dynamic programming model based on the Markov decision process was used to determine optimal imports of feed grain under given prices of feed grain and stocks. An econometric study of the Korean feed grain industry was made to provide empirical measures to use in the dynamic programming model for feed grain imports. The empirical results suggest that Korea should import much more than the actual imports to maximize the social benefits. This study also reveals that the country should maintain more carryover stocks than the actual level.

TABLE 3. ACTUAL AND LONG-RUN OPTIMAL STOCKS AND PRICES

	Actual (1986)	Long-Run Optimal
Stocks (thousand metric ton)	869	1,720
Prices (thousand Won)	300	165

This study also shows that the long-run optimal price of feed grain should be 165 thousand Won, which is about $6.55 per bushel at an exchange rate of 700 Won per the U.S. dollar. The optimal price is much lower than the actual price of 245 thousand Won ($9.52 per bushel), but much higher than the world price in 1986. Domestic feed grain production and consumption should be 114 thousand metric ton and 4.5 MMT, respectively, at the optimal price of 165 thousand Won per metric ton. This study also found that optimal stock should be about 1.72 MMT, which is substantially larger than the actual stocks.

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