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AN INTERTEMPORAL PRICE EQUILIBRIUM MODEL FOR KOREAN RICE

by

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This paper presents a model of price, storage and consumption behavior within the year. This model presented here is an extension of the model of storage and marketings that I developed elsewhere [7].

The underlying assumption in this model is that the market price is allowed to rise by the amount of the cost of storage. These storage costs are assumed to consist of the interest on the value of the inventory investment plus a monthly holding cost.

This paper is divided into sections which present the structure of the rice storage model, the data for and interpretation of the model, the solution of the model the validation of the model, the analysis of the price-import trade-offs, conclusions and suggested extensions.

Structure of the Rice Storage Model

Storage Level

$$S(t) = S(0) + \int_0^t (H(y) + G(y) - D(y))\, dy.$$

Inventory Cost

$$IC(t) = r\, P(t)\, S(t) + k\, S(t).$$

Demand Equation

$$P(t) = a - b\,(H(t) + G(t)).$$

Storage Profit Level

$$\int_0^t [P(y)(-S'(y)) - IC(y)]\, dy.$$

Farm Harvest Rate

$$H(t) = \frac{\alpha}{\beta} \rho \cdot e^{-\beta t}.$$

Government Sales Rate

$$G(t) = \gamma (P(t) - PT).$$

Gross Stock Level

$$TX(t) = TX(0) + \int_0^t H(y)\, dy.$$

Consumer Expenditure

$$X(t) = X(0) + \int_0^t P(y)\, D(y)\, dy.$$

Revenue from Government Sales

$$TX(t) = TX(0) + \int_0^t P(y)\, G(y)\, dy.$$

Operational Assumption

Storage levels and sales to consumers are such that the month-to-month rise in prices is just sufficient to equal the average cost of holding inventories.

Data for and Interpretation of the Model

The empirical numbers which are used in the application of this model are taken to broadly represent the marketing environment for domestic Korean rice. While careful thought preceded the choice of the parameter values, they are not the results of any exhaustive econometric study.

The storage equation reflects the identity which states that if additions to the private supply (harvest plus government sales) exceed the withdrawals for private consumption (or sales by the private sector to the public) the inventory of the commodity will increase.

The inventory cost equation states that there are two components of the (variable) costs of storage. The interest charge is based upon the instantaneous

Table 1: Variables and Parameters within the Model

Variables

P(t)	= Price	₩/MT*
D(t)	= Private sales rate to consumers	MT/Month
S(t)	= Private storage level	MT
IC(t)	= Inventory cost rate	₩/Month
Y(t)	= Accumulated profit level	₩
FY(t)	= Accumulated farm income	₩
X(t)	= Accumulated consumer expenditure on the commodity	₩
TX(t)	= Accumulated revenue from government sales, ignoring government storage costs	₩
H(t)	= Harvest rate	MT/Month
G(t)	= Government sales rate	MT/Month

Parameters

r	= Interest rate	%/Month
k	= Warehousing costs	(₩/MT)/Month
a	= Price intercept	₩
b	= Price response to total demand	₩/(MT/Month)
H	= Level of farm harvest	MT/Year
RP	= Government purchase response parameter	(MT/Month)/(₩/MT)
PT	= Government price target	₩/MT

* Won per metric ton. At the current time $1.00 U.S. = 400 Won Korean, approximately.

value of the inventory. By so doing the annual sum of these charges is equal to the annual interest rate multiplied by the average value of the inventory over the year. The second component of inventory cost indicates that there are storage costs that vary directly with the physical size of the inventory irrespective of its value. Such costs might include the costs of operating heating, cooling or drying equipment, the costs from quality deterioration and theft, and the losses due to rodents and bin leak-age. Costs which depend more upon the changes in the inventory, such as loading and unloading, and buying and selling costs, are not analyzed in this paper.

The assumed interest rate is 1.5 percent per month, which is the same rate charged by the Medium Industry Bank for operation loans.[1] Some interest rates on loans are higher and some lower. If anything, this rate may be lower than the opportunity cost of capital for many storage enterprises, since the so-called "curb-market" rates are much higher than the official bank rates.

The noninterest cost of storage is assumed to be 250 won per metric ton per month. The January 1971 MAF specification of storage charges for polished rice in Seoul was 7.70 won per metric ton per day, with an insurance fee of 1.09 won per metric ton per day, in addition to that.[2]

The demand equation, which determines the price in this model, states that price responds to the rates of private plus government demand in the same degree. If the government is purchasing (G(t) is negative), the price will be higher than it would be if the government is selling, for a given level of private consumption. This formulation assumes that any income effects which may alter the level or form of the demand relationship occur at the outset of the year, but at unchanging through the year. It further assumes that there is no seasonal price fluctuations which cannot be explained by quantity variations.

The demand equation is assumed to be linear, with no intra-year income effects, and in price-dependent form. This is assumed to have an own-price elasticity of -0.4 at the equilibrium price of 250 won per kilogram and the consumption rate of one-third of a million metric tons per month.[3/] Thus, price (in won per metric ton) is given by the relation:

$$P = 875000 - 1.875\ Q$$

The profit equation assumes that the same price is paid or received for the commodity whether it is being purchased or sold. Moreover, it assumes that the government pays the same prices for both buying and selling as consumers or private storage firms do. No buying or selling costs are assumed in this model. The profits in the model derive from buying the commodity when it is plentiful and the prices are low and selling it later when the prices are higher, taking account of the costs of holding the inventory. The time interval $[0, 12]$ is assumed to be such that it begins at the outset of harvest and ends just prior to the next harvest.

The interpretation of $H(t)$ as a harvest implies that the farmers participate in the storage activities. The sales from farmers to commercial warehouses at times other than harvest are ignored under this interpretation because the profit from the farmer's storage to that point would be a cost to the commercial warehouse and the storage profit equation represents the sum of the farm plus commercial storage profits. The model assumes that the farmer's production activity is reimbursed at the price which prevails at the moment of harvest and that farm consumption is included with urban consumption in $D(t)$. By default, the value of some marketing and transportation services are included in the "Farm Income" variable.

The particular form of the harvest equation assumes that both the amount and pattern of the harvest are known and deterministic. The 4 million ton annual harvest is assumed to be distributed within the year with a time pattern which is the same as a fourth order gamma density function with mean of one month and standard deviation of ½ month.[4] This annual harvest is virtually the same as the 1971 production of 3.998 million tons.[5] Table 2 shows that the assumed harvest is more than 95% completed by the end of the second month of the harvest season. In this model, the crop year and the time indexing begins at the time the harvest begins.

Table 2: Assumed Harvest Rate

Real Calendar Date	Months since the Start of Harvest	Percentage of Crop yet to be Harvested
September 1	.000	100.0%
September 28	.918	50.0%
October 20	1.670	10.0%
October 29	1.940	5.0%
November 15	2.511	1.0%
December 8	3.266	0.1%

The government purchase equation assumes that the government agency determines a target price for the rice year and buys grain while the price is below the target and sells when the price is higher. Domestic purchases need not necessarily equal sales and the accumulated difference would have to be either imported or exported. It is assumed that there is no binding constraint on government storage capacity.

Solution of the Models

The general solution to the storage model is

$$S(t) = S_0 + S_1 e^{rt} + \left(\frac{rak}{rb}\right) + 2RP\left(PT + \frac{k}{r}\right)t - He^{-4t}\left(1 + 4t + 8t^2 + \frac{32t^3}{3}\right)$$

with the price level determined to be $P(t) = br\, S_1 e^{rt}/(1 + 2b\, RP) - k/r$. The numerical constants S_0 and S_1 are determined by the boundary conditions imposed upon storage behavior in the particular situation. If we impose the conditions that there is no carry-in and no carry-out (i.e. $S(0) = S(12) = 0$) we can derive the values of the S_0 and S_1 parameters.[6]

$$S_0 = \left(H e^{12r} - 12\left(\left(\frac{rak}{rb}\right) + 2RP\left(PT + \frac{k}{r}\right)\right)\right)/(e^{12r} - 1)$$

$$S_1 = \left(12\left(\left(\frac{rak}{rb}\right) + 2RP\left(PT + \frac{k}{r}\right)\right) - H\right)/(e^{12r} - 1)$$

If there were no change in inventory and the carryover equaled a minimum level of working stocks, rather than zero, S_0 would be increased by the amount of these working stocks and S_1 would not be changed.

To determine S_0 and S_1 in the actual use of the model the conditions which state $S(0) = S(12)$ and that the storage levels are nonnegative. This involves a two stage process, the first step of which uses the above parameter definitions to calculate storage. The minimum value of the storage function, thus calculated, is subtracted from the storage function in the second stage of the process.

Relation to Gray Theories of Storage

The outstanding characteristic of this model for storage and intertemporal price behavior is that prices rise within each year just enough to compensate the speculators of storage for their costs. No abnormal profits from speculative behavior [illegible] but the full costs of storage are assumed to be [illegible].

Because of the periodicity of production, storage and consumption rates will also be periodic. Prices will also be periodic, except that this periodicity will, in general, take place around the trend which results from income growth and the income elasticity.

The basic idea of the supply of storage theory [1, 12, 13] is that the difference between the current price level and the expectation of some future price level is a positive function of the current level inventory. A large inventory and a large price difference (future price exceeding current price) are presumed to go together, as are a small inventory and a small, or even negative (current price exceeding future price), price difference. A problem with the supply of storage theory is that it explains relative price levels, but not absolute levels. Furthermore, without specifying a separate function for each point in time it is not possible to represent the effects of normal seasonal price patterns.

Samuelson's [7] theory of intertemporal price equilibrium assumed that the time pattern of production is known, and assumes that current consumption is a function of current prices, and then derives the schedules of equilibrium prices and consumption which maximize consumer utility subject to nonnegativity of inventory levels. He later [8] changed the production assumption to allow for stochastic production levels. In a recent refinement of this model, Pliska [5] modified Samuelson's objective function to subtract out the integral of the supply of storage function from the utility function. In the notation of this paper that integral would be the inventory cost function, however Pliska does not recognize it as such. In this way

Pliska brought together both the supply of storage theory and the intertemporal price equilibrium theory.

Thus the model in this paper is in the same tradition as the Samuelson model, as modified by Pliska, except that the driving force of this model is an assumption about overall market behavior (price rise to compensate storage costs) rather than about individual consumer behavior (utility maximization).

Validation of the Model

The purpose of the verification process is to determine the correspondence between the model and the observed data in the real world. The closer this correspondence is, the better the model is. This section presents an analysis of the intrayear dynamics of the model.

The annual aggregate statistics against which the corresponding model calculations are compared are imports, value of rice consumption, value of rice production, and, if the data is made available, foreign exchange costs and government grain management flows (the government storage profits).

The intrayear dynamics of the model are assessed by comparing the predicted time path of response with monthly observations of per capita consumption, prices, and per household grain storage holdings.

Methodology for Verification: This process compares the variance of the observed data around the predictions of the model with the variance around the mean of the observations. More specifically, the logarithms of the model predictions are compared with the logarithms of the observations, since the directly corresponding data are not available. The observations are for data which differ from the predictions of the model by multiplicative constants including population and the conversion of units of both weight and time.

The theory of the experiment can be most easily explained by reference to the underlying statistical models for both the observed data and the predictions of the model.

For the observed data, the following is the presumed statistical model: $\log(\text{Obs}) = a + b\,\text{Year} + v$, where v is normally distributed with mean zero and variance σ_v^2. For the data, conditioned on the model predictions, the statistical model is presumed to be $\log(\text{Prediction}) - \log(\text{Obs}) = a' + b'\,\text{Year} + u$, where u is distributed normally with mean zero and variance σ_u^2.

Taking the first model to represent the unconditional distribution of the observed data, and the second model to represent the conditional distribution of the observations given the model predictions, and referring to an expansion from elementary statistics, we are able to devise two tests of the model performance. Since the variance of $P - A$ is $\sigma_P^2 + \sigma_A^2 - 2\rho_{AP}\sigma_A\sigma_P$, the test of whether $\sigma_v^2 + \sigma_P^2$ is larger than σ_u^2 is equivalent to the test of whether there is a significant positive correlation between the predicted and observed data. Furthermore, the test to determine if σ_v^2 is larger than σ_u^2 is equivalent to the test of whether the correlation is greater than one-half the ratio of the standard deviation of the predictions divided by the standard deviation of the observations, i.e., for "well-behaved" data whether the correlation is greater than one-half. The first test will be called the Weak Test of model validity, and the second test will be called the Strong Test of model validity.

The test statistic for both these verification processes will be the variance ratio. This is distributed according to Snedecor's F under the respective null hypothesis — zero correlation, and correlation equal to $\frac{1}{2}\sigma P/\sigma u$. In each case the alternative hypothesis is one-side, i.e., the correlation is positive, or greater than $\frac{1}{2}\sigma P/\sigma u$. Both the numerator and denominator degrees of freedom will be equal to two less than the total number of observations in the test period. No special adjustment need be made for the weak test, since for each parameter set the variance of the model predictions is known with complete certainty.

Sample Period for Verification: The test period consists of monthly observations for the period September 1966 to September 1973. Under one series of tests the September observations for the mid-sample years were repeated since they represented both the last observation of one crop year and the first observation of the second crop year. In another series of tests, the sample period consisted of the eighty-four continuous months with no repetitions. This second test dropped out the model predictions at time zero within the year.

Results of the Verification: The results of the weak test of the model validity are presented in Tables 4 and 6. The results of the strong test of the model validity are presented in Tables 3 and 5. From this we can see that the model with the lower price targets and the lower levels of government market interference showed the greatest degree of correspondence with the actual recorded statistics.

Table 3

Strong Test of Model Verification
Sample Years: September to September, 1966 to 1973

Gov't Procurement Percentage	Price Target W/Kkg	Prices (Won/80 kg) Consumer	Wholesale	Farm	Consumption (Liter/Capita/Day) Farm	Nonfarm	Average	Quantity (Liter/Household) Farm (Stat. Bureau Survey)	Urban Households	Farm (Food Balance Survey)
20	8800	1.2140	1.2935	1.6726	1.0290	1.0678	1.0467	.2026	[illegible]	[illegible]
	9200	1.2133	1.2881	1.6781	1.0307	1.0713	1.0494	.1183	[illegible]	[illegible]
	9600	1.2151	1.2896	1.6788	1.0315	1.0723	1.0506	.1019	[illegible]	[illegible]
	10000	1.2187	1.2917	1.6782	1.0328	1.0748	1.0526	.1816	[illegible]	[illegible]
	10400	1.2222	1.2943	1.6792	1.0344	1.0778	1.0551	.2246	[illegible]	[illegible]
	10800	1.2262	1.2955	1.6813	1.0361	1.0807	1.0578	.2438	[illegible]	[illegible]
15	8800	1.2113	1.2868	1.6766	1.0299	1.0682	1.0471	1.2705	[illegible]	[illegible]
	9200	1.2129	1.2880	1.6788	1.0306	1.0707	1.0492	1.1812	[illegible]	[illegible]
	9600	1.2153	1.2890	1.6780	1.0322	1.0741	1.0518	1.0773	[illegible]	[illegible]
	10000	1.2185	1.2922	1.6797	1.0327	1.0749	1.0526	.9601	[illegible]	[illegible]
	10400	1.2212	1.2933	1.6813	1.0315	1.0733	1.0506	.8344	[illegible]	[illegible]
	10800	1.2228	1.2948	1.6824	1.0360	1.0805	1.0577	.7011	[illegible]	[illegible]
No gov't involvement		1.2511	1.3147	1.6891	1.0726	1.1198	1.1140	.5722	[illegible]	[illegible]

5% One Tailed test, 89 degrees of freedom, critical value 1.32.

Table 4

Weak Test of Model Verification
Sample Years: September to September, 1966 to 1973

		Prices (Won/80 kg)			Consumption (Liter/Capita/Day)			Storage (Liter/Household)		
		Consumer	Wholesale	Farm	Farm	Nonfarm	Average	Farm (Stat. Bureau Survey)	Urban Household	[illegible]
[illegible]	[illegible]	1.9176	1.9111	2.4634	1.0303	1.0828	1.0500	1.7382	1.1362	[illegible]
	9200	1.9238	1.9177	2.4799	1.0321	1.0878	1.0530	1.4145	1.0657	[illegible]
	9600	1.9215	1.9153	2.4752	1.0331	1.0901	1.0545	1.3602	[illegible]	[illegible]
	10000	1.9189	1.9111	2.4649	1.0345	1.0943	1.0569	1.5650	[illegible]	[illegible]
	10400	1.9170	1.9083	2.4579	1.0362	1.0991	1.0598	1.6414	[illegible]	[illegible]
	10800	1.9152	1.9058	2.4555	1.0381	1.1039	1.0630	1.6485	[illegible]	[illegible]
15	[illegible]	1.9239	1.9183	2.4810	1.0306	1.0834	1.0505	4.9422	1.3177	[illegible]
	9200	1.9223	1.9168	2.4801	1.0321	1.0875	1.0529	4.6767	1.3076	6.3762
	9600	1.9213	1.9140	2.4734	1.0338	1.0924	1.0558	4.3694	1.2949	[illegible]
	10000	1.9197	1.9128	2.4096	1.0344	1.0945	1.0569	4.0270	1.2800	[illegible]
	10400	1.9162	1.9076	2.4621	1.0332	1.0934	1.0550	3.6604	[illegible]	[illegible]
	10800	1.9149	1.9065	2.4593	1.0380	1.1039	1.0628	3.2716	[illegible]	[illegible]
[illegible]		1.8901	1.8752	2.3930	1.0815	1.2215	1.1368	3.0959	1.2165	4.3920

*5% Durbin Failed Test, 89 degrees of freedom, critical value 1.32.

Table 5

Strong Test of Model Verification
Sample Years: October to September, 1966-1973

Quarter	Purchase Price Parameter Target Price	Prices (Won/80 kg) Consumer	Wholesale	Farm	Consumption (Liter/Capita/Day) Farm	Nonfarm	Average	Storage (Liter/Household) Farm (Stat. Bureau Survey)	Nonfarm Household	Total (Farm Nonfarm Average)
20	8800	1.1130	1.2663	1.9058	1.0560	1.1246	1.0873	.1544	.0200	[illegible]
	9200	1.1122	1.2599	1.9131	1.0591	1.1314	1.0924	.0901	.0133	[illegible]
	9600	1.1138	1.2611	1.9112	1.0611	1.1349	1.0954	.0784	[illegible]	[illegible]
	10000	1.1172	1.2631	1.9080	1.0638	1.1407	1.0997	.1413	[illegible]	[illegible]
	10400	1.1207	1.2657	1.9075	1.0668	1.1471	1.1045	.1768	[illegible]	[illegible]
	10800	1.1225	1.2667	1.9082	1.0700	1.1534	1.1096	.1941	[illegible]	[illegible]
15	8800	1.1105	1.2585	1.9118	1.0565	1.1254	1.0881	1.0190	.0700	[illegible]
	9200	1.1115	1.2592	1.9112	1.0594	1.1315	1.0927	.9312	.0666	[illegible]
	9600	1.1141	1.2606	1.9113	1.0621	1.1376	1.0972	.8373	.0628	[illegible]
	10000	1.1171	1.2636	1.9100	1.0640	1.1415	1.1001	.7378	.0583	[illegible]
	10600	1.1195	1.2643	1.9090	1.0634	1.1419	1.0991	.6360	[illegible]	[illegible]
	10800	1.1209	1.2656	1.9080	1.0702	1.1539	1.1099	.5318	[illegible]	[illegible]
Regression Equivalent		1.1479	1.2845	5.1669	1.1501	1.2941	1.2392	.7156	[illegible]	1.2726

*5% One Tailed Test, 82 degrees of freedom, critical value 1.33.

Table 6

Weak Test of Model Verification
Sample Years: October to September, 1966-1973

[illegible]	Price Target W/80kg	Prices (Won/80kg) Consumer	Wholesale	Farm	Consumption (Liter/Capita/Day) Farm	Nonfarm	Average	Storage (Liter/Household) Farm (Stat. Bureau Survey	Urban Household	Farm (Food Bureau Survey)
90	8800	1.8365	1.9531	2.8162	1.0575	1.1425	1.0913	1.5807	1.0269	1.5461
	9200	1.8427	1.9504	2.8366	1.0609	1.1512	1.0967	1.2944	.9826	1.2647
	9600	1.8400	1.9472	2.8270	1.0629	1.1563	1.1000	1.2586	.9708	1.2357
	10000	1.8372	1.9423	2.8116	1.0658	1.1641	1.1048	1.4534	.9973	1.3935
	10400	1.8351	1.9391	2.8012	1.0690	1.1726	1.1101	1.5365	1.0051	1.4456
	10800	1.8330	1.9395	2.7959	1.0725	1.1813	1.1157	1.5553	1.0042	1.4410
15	8800	1.8429	1.9512	2.8384	1.0581	1.1434	1.0921	4.6086	1.4152	4.4860
	9200	1.8407	1.9486	2.8326	1.0611	1.1515	1.0971	4.2901	1.3771	4.1564
	9600	1.8401	1.9460	2.8264	1.0640	1.1595	1.1019	3.9556	1.3373	3.8169
	10000	1.8379	1.9442	2.8158	1.0661	1.1651	1.1052	3.6106	1.2966	3.4746
	10400	1.8277	1.9377	2.8045	1.0655	1.1660	1.1043	3.2619	1.2548	3.1344
	10800	1.8324	1.9360	2.7980	1.0726	1.1819	1.1160	2.9082	1.2111	2.7956
No gov't involvement		1.8055	1.8985	2.6894	1.1611	1.4267	1.2678	4.5619	1.8856	4.6928

5% One Tailed Test, 82 degrees of freedom, critical value 1.33.

The model does a good job in predicting the seasonal variation in farm prices and farm storage levels. The explanation of the seasonal variation of market prices is reasonably good, but not statistically significant. Because of the model generates a fairly flat pattern of consumption relative to the actual pattern, the explanation of that variable is not so good.

Analysis of the Price Target/Import Tradeoff

It is obvious that there is an inverse relation which exists between commodity import amounts and market prices. This is because the effect of commodity imports is to increase the supply in the face of an unaffected demand. By the same token, if a government agency wants to move the free market price toward some price target, other than the self-sufficiency price, net imports or exports will be required in order to accomplish this aim.

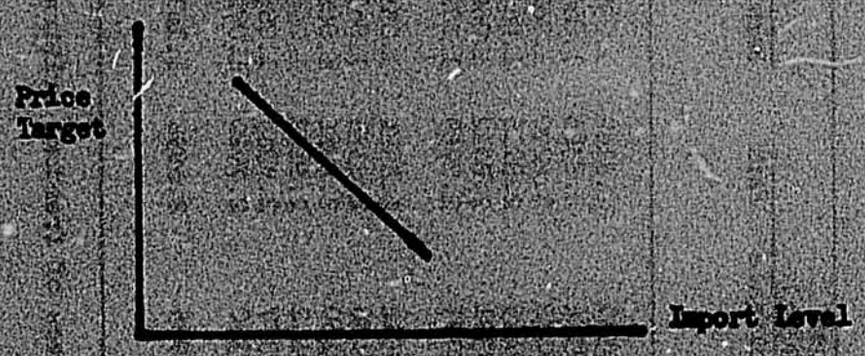

Figure 1: The Relation Between Import Levels and Target Prices

Thus some relation of the type illustrated in Figure 1 exists between price targets (or levels) and imports. The purpose of this section is to provide some numerical information about the slope of this relation, if not the scales on the axis of the diagram.

Table 7

Hypothetical Effects of Target Rice Prices
When Government Purchase Response Parameter is 15
Assuming an Equilibrium Price of 250 Won per Kilogram

Variable	Units	Price Traget (Won/80 kg) 8,800	9,200	9,600	10,000	10,400	10,800
Imports	1000 MT	440.2	424.5	408.7	393.0	377.3	361.6
Import Timing	Months	9.4	9.6	9.8	9.9	10.1	10.2
Foreign Exchange Cost	$ Million	224.73	215.59	205.26	201.83	189.44	184.68
Gov. Storage Used	1000 MT	322.6	348.0	373.4	398.8	424.2	449.6
Pvt. Storage Used	1000 MT	2688	2669	2651	2632	2613	2595
Carryover	1000 MT	98.1	100.7	103.3	105.8	108.4	110.0
Cons. Expenditure	Billion Won	548.5	568.7	588.7	608.3	627.7	646.7
Farm Income	Billion Won	411.8	430.1	448.3	466.5	484.7	502.9
Gov. Stor. Costs	Billion Won	3.887	4.441	5.033	5.666	6.338	7.050
Pvt. Stor. Costs	Billion Won	23.75	24.06	24.34	24.56	24.75	24.89
Gov. Stor. Profit 1/	Billion Won	-36.19	-32.14	-27.78	-26.36	-21.52	-19.91
Pvt. Stor. Profit	Billion Won	-2.298	-2.448	-2.602	-2.761	-2.925	-3.093
Gov. Stor. Credit 1/	Billion Won	35.58	40.12	44.92	49.97	55.27	60.82
Pvt. Stor. Credit	Billion Won	271.4	281.0	290.4	299.6	308.6	317.5
Total Stor. Credit 1/	Billion Won	293.3	305.3	317.2	329.0	340.7	352.4
Max. Cons. Rate	1000 MT/Mo	412.7	410.3	407.9	405.5	403.1	400.8
Min. Cons. Rate	1000 MT/Mo	400.3	397.4	394.6	391.7	388.9	386.0
Min. Cons. Price	Won/80 kg	8094	8453	8811	9170	9529	9887
Max. Cons. Price	Won/80 kg	9953	10380	10810	11240	11670	12100

1/ Excludes costs of storing imports.

Table 8

Hypothetical Effects of Target Rice Prices
When Government Purchase Response Parameter is 20
Assuming an Equilibrium Price of 250 Won per Kilogram

Variable	Units	Price Target (Won/80 kg) 8,800	9,200	9,600	10,000	10,400	10,800
Imports	1000 MT	442.1	426.3	410.5	394.5	379.0	363.2
Import Timing	Months	10.0	10.2	10.3	10.4	10.5	10.6
Foreign Exchange Cost	$ Million	228.58	214.39	209.28	203.44	196.83	189.43
Gov. Storage Used	1000 MT	485.5	517.4	549.3	581.2	613.1	645.0
Pvt. Storage Used	1000 MT	2543	2544	2546	2550	2555	2562
Carryover	1000 MT	132.1	160.8	191.3	223.4	256.9	291.7
Cons. Expenditure	Billion Won	546.0	566.4	586.4	606.2	625.7	644.8
Farm Income	Billion Won	409.6	427.9	446.2	464.5	482.8	501.0
Gov. Stor. Costs	Billion Won	6.243	7.018	7.842	8.712	9.630	10.600
Pvt. Stor. Costs	Billion Won	19.15	19.71	20.31	20.93	21.59	22.27
Gov. Stor. Profit 1/	Billion Won	-37.53	-31.45	-29.19	-26.79	-24.26	-21.59
Pvt. Stor. Profit	Billion Won	-3.074	-3.883	-4.786	-5.786	-6.880	-8.069
Gov. Stor. Credit 1/	Billion Won	53.53	59.63	66.04	72.77	79.81	87.17
Pvt. Stor. Credit	Billion Won	251.0	259.2	267.1	274.7	282.1	289.3
Total Stor. Credit 1/	Billion Won	281.9	293.2	304.4	315.5	326.5	337.4
Max. Cons. Rate	1000 MT/Mo	413.0	410.6	408.2	405.8	403.4	401.0
Min. Cons. Rate	1000 MT/Mo	400.7	397.8	394.9	392.0	389.2	386.3
Min. Cons. Price	Won/80 kg	8050	8410	8770	9131	9491	9851
Max. Cons. Price	Won/80 kg	9900	10330	10760	11190	11630	12060

1/ Excludes costs of storing imports.

The model is analyzed for two hypothetical levels of the government purchase response parameter. The actual value of this parameter can be adjusted by the government grain management bureau in such a way that it will produce a desirable set of results from the system. The values demonstrated here are 15 and 20, which mean that for every one won per kilogram the free market price is below the target price the government agency buys grain at the rate of 15000 or 20000 metric tons per month to add to its inventory. Similarly if the market price is above the target the government would sell at that rate.

To evaluate the effects of alternative price targets on the rice import levels and other related variables, target prices from 110 to 135 won per kilogram were chosen in five won per kilogram increments. The model was then run and the criteria variables calculated. These are tabulated in Table 7 and Table 8.

An examination of these results reveals that for every five won per kilogram the target price is set below the self sufficiency price, about 15750 tons per rice must be imported.[7] (15700 tons are required, if the purchase response parameter is 15, while 15800 tons are required when the response parameter is 20).

In the tabulation, imports are calculated as the excess of government sales over government purchases. In this way, delivery timing for imports can also be inferred. In all of the cases analyzed in Tables 7 and 8 delivery was required in the ninth and tenth months of the crop year. This corresponds roughly to June or July of the calendar year.

The next two entries in the tables indicate the maximum levels of storage achieved by government and private storage facilities, respectively. Generally the maximum level is achieved in the second month of the crop year for the private inventories and about six months after the onset of harvest for government inventories.

The carryover is the minimum level of storage required at the beginning of the crop year to assure that private storage levels remain nonnegative throughout the year.

Consumer expenditure is the value of the demand for rice at the prevailing market prices. Since there is only a single set of market prices, the different valuations of production and consumption is due to the different time paths of harvest and demand. With exception of rounding errors the total consumer expenditure is the sum of farm income (value of production), private and government total inventory costs and government plus private storage profit.

Farm income is the value of the rice harvest at the market prices, so that this entry includes the value of the marketing and transportation services in it. These services may account for 20 percent or more of this "Farm Income" figure.

The costs per ton of holding inventory are assumed to be the same for both the private storage sector and the government sector. These represent the interest on the capital which is tied up in the form of the inventory plus a monthly storage charge per ton. The entries in the tables represent the year-end total of these charges.

The storage profit and storage credit calculations are closely related to each other. For both private and government storage operations, the profit is the difference between the year and gross margin on purchase and selling

activities and the year and accumulated storage costs. Storage credit is the amount of the largest deficit accumulated through the year in these "profit" accounts, i.e., the largest negative cash flow. The total storage credit requirement is the sum of the two cash flow deficits. It reaches its maximum a fraction of a month later than the private credit requirements.

Because the cost of purchasing and storing imports or the revenues and reduced costs from selling exports are not included in these calculations, both the government storage profit and the government storage credit estimates are biased. If rice is imported the government storage profit would be over-estimated and the credit requirements under-estimated, while if rice is exported the government storage profits would be under-estimated and the credit requirements over-estimated. The breakeven import cost is the combined cost of purchasing, handling and storing imports which would just exhaust the government storage profit costs higher than this would add to the deficits in the Grain Management Special Account. The impacts of the imports on the intra-year credit requirements were not estimated.

The consumption rate is the rate at which the rice in being sold to consumers through the year. The maximum rate of consumption occurs at the onset of harvest and the minimum rate occurs at the end of the crop year, just before the onset of the next year's harvest.

The consumer price is the market price calculated in this model. Its minimum value occurs at the onset of harvest and the maximum is achieved just before the onset of the next year's harvest.

In combination of the influence of increased target prices on the [illegible] criterion variable [illegible] the minimum consumer price rises by less than the target rise and the maximum consumer price rises by more than the target, so that the intra-year price range increases as the target price increases.

Because of the relatively heavier concentration of the rates of both harvest and demand in the earlier months of the crop year (during which prices have been increased less than proportionately), both the farm income and consumer expenditure totals increase by less than the amount of the increase in the target price times the annual harvest.

When we look at the effects of differing intensities of government market intervention, as indicated by comparing Table 7 with Table 8, we see that the more active the government purchase policy is (i.e. the larger the purchase response parameter), the larger the requirement for government storage. In addition to this, higher price targets call for more storage space.

The increased government activity reduces the amount of private storage used, which indicates that governmental storage activity and private storage are substitutes.

Even though the more intense government activity reduces the total amount of private storage, it increases the required level of carryovers. This is because the relatively heavier buying activity which occurs early in the year strains the supplies on the market.

The effect of heavier governmental activity is to even out the rate of private consumption. The more intense the government activity, the less steeply sloped is the time path of consumption. In the limiting case of no

Table 9

Hypothetical Effects of No Government Storage
Assuming an Equilibrium Price of 250 Won per Kilogram

Variable	Units	Value
Imports 1/	MT	0.0
Import Timing	Months	12.0
Gov. Storage Used	1000 MT	0.0
Pvt. Storage Used	1000 MT	3182
Carryover	1000 MT	32.79
Cons. Expenditure	Billion Won	998.8
Farm Income	Billion Won	921.7
Gov. Stor. Cost	Billion Won	0.0
Pvt. Stor. Cost	Billion Won	78.73
Gov. Stor. Profit 2/	Billion Won	0.0
Pvt. Stor. Profit	Billion Won	-1.605
Gov. Stor. Credit 2/	Billion Won	0.0
Pvt. Stor. Credit	Billion Won	739.4
Total Stor. Credit	Billion Won	739.4
Max. Cons. Rate	1000 MT/Mo	345.7
Min. Cons. Rate	1000 MT/Mo	320.1
Min. Cons. Price	Won/80 kg.	18136
Max. Cons. Price	Won/80 kg.	21976

1/ Negative value indicates exports.
2/ Excludes costs and revenues from imports and exports.

government sales (table 6), there is 7.7 percent variation around the normal average consumption rate, ranging from about 3 to 5 percent in the other cases.

The effect of the hypothetical government purchase strategy on prices is virtually unobservable in the comparisons which we can make from these tables. Thus there is no effect on the value of the farm rice harvest, and the effect on the amount of consumer rice expenditure occurs only as a result of the re-arrangement of consumption timing. This lumping of consumption toward the beginning of the year with its lower prices has the effect of reducing consumer expenditures.

Conclusions

These results suggest that a five won per kilogram increase in the target price for rice will reduce the rice import requirements by 17.75 thousand tons. If this relation holds more generally than just in this single analysis we will be able to estimate a self sufficiency price for Korean rice. Based upon the 1973 frozen price of 125 won per kilogram and the 1973 imports of 485000, our estimate of the 1973 self sufficiency rice price is 279 won per kilogram or 22317 won per 80 kilograms.

The second conclusion is that the more active a role the government plays in the rice market and the higher the target price set for rice, the more storage space the government will require for these activities.

The third conclusion is that since these government market interventions do not noticeably affect market prices, and hence farm income, the primary justification for them must be because of their effect in redistributing rice sales through the year and hence to reduce total consumer expenditure on rice.

Finally, the rice storage sector (both government and private) has need of between 282 and 352 billion won to cover the intra-year operating deficits. This is not simply the sum of the government deficit and the private deficit, since the larger private deficit reaches its peak about four months before the government deficit. In addition to this short-term financing, some arrangemen is necessary to cover the longer run cost (currently charged in the model against the private sector) of maintaining the year to year carryover stocks. These costs range from 1.6 billion won in the case with no government storage, to between 2.3 and 3.1 billion won when the government purchase parameter is 15, to between 3.1 and 8.1 when the government purchase parameter is 20.

Suggested Extensions

One of the primary accounting shortcomings of the current version of the model is that there is no provision to account for import storage costs These costs depend upon the import delivery schedule. Thus, an obvious improvement would be to incorporate an import delivery impulse and distribution. The peak level of imports would probably occur about six months out of phase with harvest and have a greater dispersion over time than the harvest has.[8/] Modelling this would also require information on either the time of maximum import deliveries or the time of the year in which they start.

A multiple year simulation would be a desirable extension of the model. In such a run as explicit account should be made of the effect of income growth on demand and the effects of changed supplies between the years. This would

The generalization of the model to describe the pattern of intertemporal price equilibrium for multiple commodities would be particularly desirable. Since any policy which affects rice storage and prices in Korea, also affects barley prices and storage, which in turn modifies the rice response. The same can be said for wheat as well. Conceptually, there is not much difference between the one commodity model which was analyzed here and the multiple commodity generalization, however the sequencing of the different production impulses and crop year accounting presents some difficulty in implementing the model.

Which the current version of the model seems to be representing the gross behavior in the rice production, marketing, and consumption sector fairly well, these refinements should greatly improve its analytical capability.

Footnotes

1/ [1, p. 337].

2/ [3, p. [illegible]]. In a September 12, 1973, interview the Planning Division of the MAF Food Bureau provided the current year specification of 9.55 won per metric ton per day storage charge for polished rice in Seoul, with an insurance fee of 1.32 won per metric ton per day in addition to this.

3/ The elasticity is the same as that used in the original KASS analysis [1]. The price level is the level at which wholesale rice price were frozen in 1973 by the Korean government. The consumption rate is 1/12 the annual harvest.

4/ Note that harvest is not assumed to be subject to any stochastic disturbance.

5/ [2, p. 136].

6/ The actual parameters, S_0 and S_1, differ from the values computed in the appraisal by a term of the order of magnitude approximately 10^{-10}. $19633\ He^{-48}/(e^{12r}-1)$ is subtracted from S_0 and added to S_1.

7/ This knowledge can be used to infer self-sufficiency prices from observed prices and import levels. Five times the actual import quantity divided by 15750 would be an estimate of the number of won per kilogram the actual price is below the self-sufficiency price.

8/ Perhaps a standard deviation of one month, rather than the one-half month in the harvest function would better describe the dispersion of imports.

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