THE KOREAN ECONOMIC REVIEW
Volume 17, Number 2, Winter 2001

AN OPTIMAL STORAGE RULE WITH POLITICAL PREFERENCES TOWARD INTEREST GROUPS

JEONG-BIN IM*

This paper illustrates the public storage optimization process with special attention to the different welfare weights on interest groups. Public stock management is regarded as a major policy instrument which involves an intertemporal optimization under uncertainty. This study uses stochastic dynamic programming methods to examine the nature of dynamic equilibrium processes and to solve for the storage rules, with particular reference to the Korean rice market.

JEL Classification: D6, D7, Q1
Keywords: Optimal Storage, Interest Groups, Political Preferences, Dynamic Programming, Chebychev Approximation

I. INTRODUCTION

Markets for storable commodities are often subject to public stock interventions in the name of market stabilization. Governments in both developing and developed countries have sought to stabilize commodity prices by means of stockpiling schemes. Often, however, public storage is not undertaken merely for the purpose of stabilizing prices. In many countries, public storage schemes are tied to income redistribution programs. Governments intervene in food storage in order to affect the mean and variability of various interest groups' incomes and food consumption. Motives for doing so are a mix of economic and political objectives.

Several papers have analyzed commodity storage as an optimal inventory problem (Gustafson (1958), Gardner (1979), Burt, Koo and Dudly (1980)). According to Gardner (1979), optimal stockpiling requires holding back quantities from current consumption such that the expected social welfare, as measured by an objective function, is maximized given the current state of the world. An optimal stockpiling policy is a set of rules that specify optimal stocks for every

Received for publication: March 13, 2001. *Revision accepted:* June 30, 2001.

possible state of the world. To arrive at optimal stockpiling rules, a range of methods are available for identifying food-storage policies which are optimal given a defined set of policymaker's objectives. Most previous studies use a specific objective welfare function, such as the value of grain consumption. The planner's decision criterion is the maximization of the expected present value of the stream of consumers' and producers' surpluses less storage costs, i.e., conventional social welfare function. Whereas, according to several recent studies (Wright and Williams (1982,1984,1991), Miranda and Glauber (1993)), which have viewed competitive market for storable commodities, a competitive private storage industry could carry socially optimum stocks and thus, public stockpiling will be completely ineffective in the presence of competitive private storage. Based on the identity between the social planner's first order condition and the arbitrage equation for competitive storage without any distortion, Williams and Wright (1991) argue that undistorted competitive storage is socially optimal. In other words, a social planner, consciously selecting a level of storage to maximize social welfare, should behave like a competitive industry with rational expectations.[1]

However, the equivalence between the social optimal storage and competitive storage rule is based on the assumption that social welfare is the unweighted sum of producer, consumer and taxpayer's interests. Instead, if governments seek to maximize a political preference function that reflects relative welfare weights of various interest groups, the planner's decision rule for optimal storage is not the same as the equilibrium competitive storage. In other words, competitive private carry-over is not equal to the political-economic optimum if the policy-makers place different welfare weights on each interest group.

The primary purpose of the paper is to show the differences between optimal storage rules derived from conventional utilitarian policymakers' objective function (SWF) and a political preference function(PPF) weighted by political preferences toward various interest groups[2]. A simulation based on the Korean rice market parameters shows how optimal storage rules differ when welfare weight is considered in the model compared to when it is not included.

---

[1] According to these studies, the rationale for public storage can be made only in the case of the presence of a less than one to one trade-off between public and private storage. If the differences in terms of interest rate, marginal storage costs, risk aversion and information sets between private and public agency exist, then two agencies' storage rules would be different (Newbery and Stiglitz (1981), Sarris (1982)).

[2] Actually, both of these policy objective functions are called as one of social welfare functions, however SWE denotes the purely utilitarian social welfare function and PPF represents the weighted utilitarian social welfare function in this paper (Mas-Collel et al., ch.18).

Ⅱ. MODEL SPECIFICATION WITH IMPLICIT POLITICAL PREFERENCES[3]

Consider an annual model of a primary commodity market. It is assumed that stocks are included as the sole policy instrument and there is no private storage behavior while prices and quantities are determined by market forces.

Consumption Demand: Consumption is related to price via the consumption demand function, which is written in inverse form. Assume a linear demand curve that is deterministic and the market clearing price is a decreasing function of the quantity consumed:

$$P_t = P(C_t) = a - bC_t, \; a \text{ and } b > 0 \tag{1}$$

where C_t is quantity demanded, P_t is the price of grain in year t, and u_t a and b are parameters.

Production: The current production is assumed to be the harvest amount which is randomly supplied with a known probability distribution. Variation in harvest is primarily caused by uncertain weather and other natural factors such as pests and diseases. The current harvest is assumed to be normally distributed with known mean and variance:

$$H_t = H + u_t \tag{2}$$

where H_t is the realized harvest, H is expected harvest and u_t is a random variable associated with production uncertainty.

Material Balance: The supply available (A_t) in year t is composed of current production (H_t) plus the preceding year's carryover (S_{t-1}). Available supply (A_t) in period t is either consumed (C_t) or stored (S_t) into the next year. Then, the resulting intertemporal connection and equilibrium are summarized in the following market-clearing condition:

$$H_t + S_{t-1} = A_t = C_t + S_t \tag{3}$$

In this formulation, H_t and S_{t-1} are the state variables while C_t and S_t are the decision variables. The state variable reflects the state of the economy, which together with the probability density function (PDF) of u_t summarizes all the relevant past and current information. This specification assumes no losses in storage and no qualitative difference between the stored commodity and the

[3] Political preferences have been interpreted in various ways: political bargaining power, political influencing power, political willingness to redistribute income, marginal value on the welfare measure and political attitudes toward interest groups(Swinnen and Van der Zee(1993), Baffes(1993)).

currently harvested commodity.

The problem considered in this section is to find the planner's optimal stock levels so as to maximize a policy criterion function subject to market equilibrium conditions. In this context, the optimal storage problem requires the specification of a formal objective function and the derivations of optimal policy rules over a specified time period subject to the constraints set in a model of the relevant market such as the supply and demand relationships representing each agent's behavior. In this study, we use a political preference function that reflects political weights for producers, consumers and taxpayers. Supply and demand can be viewed as constraints facing the central social planner. In such an environment, the planner's goal is to choose the optimal level of stocks that maximize the sum of consumer, producer and taxpayer's surplus weighted by political preferences, which is the discounted expected value of the future political preference function. That is, the planner's problem in the current period (t) is to select the current storage that will maximize the following policy objective function:

$$\underset{S_t}{Max} \sum_{t=0}^{\infty} \delta^t E[\lambda_C CS_t + \lambda_P PS_t + \lambda_G GS_t] \tag{4}$$

subject to $S_t \geq 0$

where δ is discount factor defined by $\frac{1}{1+r} < 1$, where r denotes the social discount rate, and t denotes the time. CS, PS and GS represent the consumer surplus, producer surplus and taxpayer net expenditure, respectively. $\lambda_i (i = P, C, G)$ is the political weight assigned to each interest group. Also, $E[.]$ denotes the expectation operator.

Consumer's surplus is defined by:

$$CS_t = \int_0^{A-S} P(C)dC - P(A_t - S_t)^*(A_t - S_t)$$

Producer's surplus is defined by:

$$PS_t = P(A_t - S_t)^* H_t - c^* H$$

where c is the unit cost of production and it is assumed to be known. In other words, producer surplus equals producer revenue minus the production cost.

Taxpayer's welfare is defined by the government's net expenditure resulting from the storage policy. Assuming a constant marginal cost of storage (k) and with net public stock purchases in period t being the change in the public stock holding $(S_t - S_{t-1})$, then the government's net expenditure generated by the public storage policy at time t is:

$$GS_t = -P(A_t - S_t)^*(S_t - S_{t-1}) - kS_t$$

where k represents the unit cost of storage.

Since the model is in a multi-period setting under conditions of uncertainty, market equilibrium in one period depends on a possible equilibrium outcome from the previous period. At the beginning of each time period t, there are given supplies that are composed of the current production and carryover stocks provided by the producers and the government, respectively. Any optimal decision concerning current storage (S_t) depends on the harvest (H_t) and stocks (S_{t-1}) carried forward from the previous period. However, the optimal storage rule is non-linear because stocks must be non-negative. The nonlinear dynamic market model cannot usually be solved with standard algebraic techniques.

Although the multi-period extension cannot express an optimal storage rule analytically, it is possible for us to derive it numerically. The task is now to derive the multi-period carryover rules and to compare storage rules. Equilibrium in the model requires that total available supply is equal to total demand. Then, the policymaker's objective is to allocate the available supply among current consumption and carryover to the following period. The resulting dynamic optimization problem, with two state variables (H_t, S_{t-1})[4] and action variable (S_t), yields the following Bellman equation:

$$V_t(H_t, S_{t-1}) = \underset{0 \le S_t \le A_t}{Max}\,[PPF_t(H_t, S_{t-1}, S_t) + \delta \underset{t}{E} V_{t+1}(A_{t+1})] \tag{5}$$

subject to $A_{t+1} = H_{t+1} + S_t$

where V_t is the net social value of the current state, which represents the sum of current and expected future social welfare provided the planner selects consumption and storage in period t through infinite horizon optimally. State transitions are governed by $A_{t+1} = H_{t+1} + S_t$ and $PPF_t(H_t, S_{t-1}, S_t)$ is the current social welfare that represents the weighted sum of three interest groups' surplus: $\lambda_C{}^*CS_t + \lambda_P{}^*PS_t + \lambda_G{}^*GS_t$. The current harvest (H_t) and carryover from the preceding year (S_{t-1}) is predetermined at the beginning of the period. The next period's availability (A_{t+1}) is partly a result of the optimal carryover, which is endogenous. Thus, the current storage decision influences subsequent state

[4] Note that if the welfare weights toward producers and taxpayers are the same, the state variable would just be the available supply as in the previous studies (Gustafson (1958), Williams and Wright (1991), Gardner and Lopez (1996), and Miranda (1998)). This is proved graphically in the section 4.

variables making the evolution of the system endogenous. The necessary condition for the planner's dynamic optimization problem is given by the following first-order equilibrium equation:

$$S_t \geq 0, \quad \frac{\partial PPF}{\partial S_t} + \delta E \frac{\partial V_{t+1}}{\partial S_t} = 0, \tag{6}$$

$$\delta E V_S(A_{t+1}) =$$

$$(\lambda_P - \lambda_C)^* P'(A_t - S_t)^* H_t + (\lambda_C - \lambda_G)^* P'(A_t - S_t)^*(S_t - S_{t-1}) + \lambda_G[P(A_t - S_t) + k]$$

where $A_{t+1} = H_{t+1} + S_t$

The above necessary condition implies that the planner's optimal choice of storage in the current period is determined where the marginal value of carryover from the current period equals the marginal value of carry-in stocks into the future period. The intertemporal arbitrage condition implicitly determines price, storage and consumption as a function of state variables. To solve the above arbitrage condition with the market constraints, one must determine how expected marginal value of storage can be derived. The rational expectation assumption in the present context is useful because the rationally expected marginal value might be determined by using all the current available information in the system. Then, mathematically, the expected marginal value could be expressed as the function of the current state variables, which include the current level of harvest and the carryover from the preceding year: $EV_S(t+1) = f(H_t, S_{t-1} | \lambda_P, \lambda_G, \lambda_C, \delta, k)$. Unfortunately, the expected marginal value function cannot generally be derived analytically and is usually not expressed with a closed form expression. However, an approximation to the expected marginal value function can be numerically computed through successive approximation and using an iterative nonlinear root-finding technique if we know the parameters of the model which include the welfare weights, storage cost, discount rates, and the distribution of harvest. With the expected marginal value function solved, other endogenous solutions to the dynamic market system are also resolved for price, storage and consumption.

Here, it might be interesting to point out that, when the welfare weights for the interest groups are equal to unity, the following relation holds in equilibrium under optimal carryover: $P(A_t - S_t) + k = \delta E[P(A_{t+1} - S_{t+1})]$ Thus, one may verify that the equilibrium conditions for this dynamic optimization problem are precisely the equilibrium conditions of the competitive rational expectations market storage model, provided that the shadow price of the optimization problem is identified with the rational expectations equilibrium market price (Miranda,1998, Williams and Wright, 1991).

Stochastic programming methods can be used to examine the nature of the dynamic equilibrium processes. This study uses polynomial approximation methods to solve the market equilibrium conditions presented in expression (6).[5] Polynomial approximation methods differ in how the polynomial nodes and basis functions are selected.[6] Chebychev approximation is known as a highly accurate and efficient technique for solving the functional equation problems that arise in dynamic economic analysis (Miranda, 1995, Judd, 1997).

Numerical analysis theory and empirical experience suggest that the Chebychev interpolation nodes and polynomials are nearly optimal choices for forming polynomial interpolants as compared to other interpolation methods. A well known result from numerical analysis theory is that the polynomial approximation error is minimized by selecting the Chebychev nodes (Atkinson,1989, Miranda 1994). Therefore, this study uses the Chebychev polynomial approximation to solve for the equilibrium levels of storage and price. For the purpose of this paper, Matlab 5.0 version is used as a vector processing language and useful Matlab subroutines were supplied by Miranda and Fackler (1997): Lecture Notes in Computational Economic Dynamics.

Ⅲ. SIMULATION RESULTS AND IMPLICATIONS

The model and solution method described above are used to solve for the optimal storage for a given set of parameters under different policy objective functions. For any given policy criterion, the model is simulated 20,000 times with different random harvests to generate the mean and variance during the simulation. The means and coefficients of variation are computed from the 20,000 observations on the endogenous variables. Finally, we examine the robustness of the model results through changes in the demand elasticity and welfare weights toward interest groups.

Model parameters are based on the recent five years of the Korean rice market. The price elasticity of demand is assumed to be - 0.20. The constant term and slope for demand is derived using 1991-95 average price and quantity market data. The random harvest is assumed to be independently and identically distributed following a normal distribution with an estimated mean of 5,325 thousand tons and standard deviation of 330 thousand tons, respectively. Choosing the appropriate interest rate and storage costs is essential because they represent the opportunity cost of holding stocks. Based on historical data during 1991-1995, we assume that the annual interest rate is 8 percent and the annual storage cost is 35 thousand won per ton (MAFF 1996). Also the implicit political(or welfare) weight for interest groups in the Korean rice sector is assumed as $\lambda_P = 1.33$, $\lambda_G = 0.91$, $\lambda_C = 0.76$. These weights are based on the previous studies, particularly, those in Im(1999). Although the estimated welfare weights on interest groups are not the same exactly in other previous studies,

[5] More detail computational procedures can be obtained by author if requested.

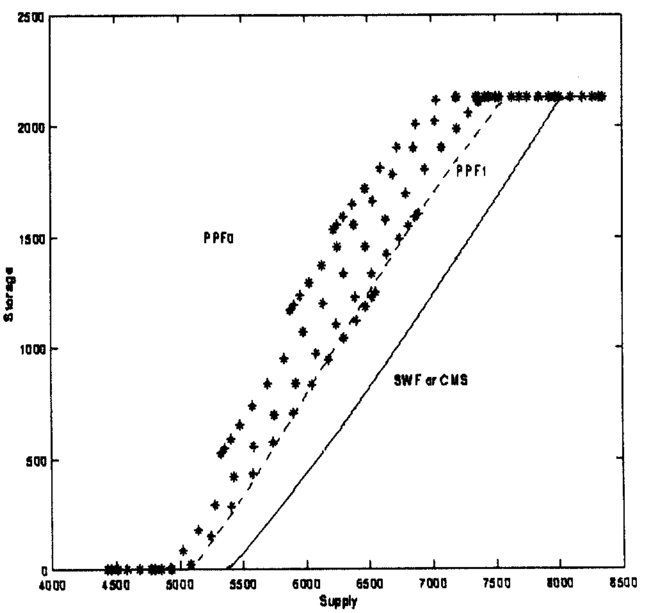
[6] Generally, four types of polynomial approximation schemes are often mentioned in numerical or computational analysis (Miranda 1998): Uniform, Chebychev, Linear spline, and Cubic spline approximations.

the political or welfare weights has also been estimated as the similar order of highest for producers, low for taxpayers and lowest for consumers(Kim(1998), Kwon and Yamauchi(1993)).

Now our interest is how different welfare weights will impact the optimal storage rule. For the purpose of comparison, the storage rule is expressed in terms of the current market availability which is composed of production plus carryover from the last period. Figure (1) illustrates the optimal rules in an attempt to compare the differences in storage between the PPF and SWF policy criterion. Optimal storage differs when welfare weight is considered in the model compared to when it is not included. This suggests that the optimal carryover levels for maximizing conventional social welfare function or private storage for maximizing profit is not the same as the optimal storage generated by maximizing political preference function. There is a kink point that storage occurs because of the non-negativity constraint on stocks. However, the optimal storage rule for maximizing PPF is not generally expressed as a function of the current supply available.

In the case of maximizing the PPF with different welfare weights, unlike the case of maximizing the SWF or competitive private storage, the optimal storage rule cannot be solely expressed as a function of the current supply available,

[Figure 1] Equilibrium Storage and Supply for Alternative Policy Functions

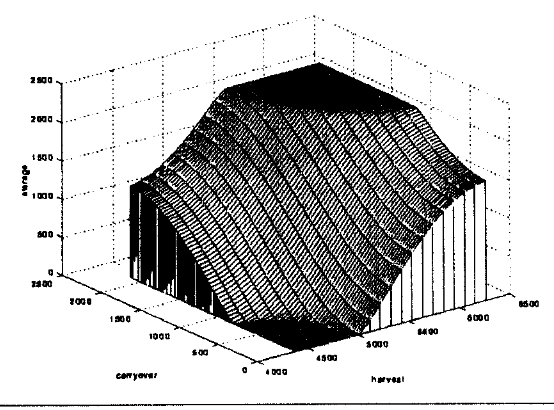


Note: PPF0: $\lambda_P = 1.33$, $\lambda_G = 0.91$, $\lambda_C = 0.76$, PPF1: $\lambda_P = \lambda_G = 1.12 > \lambda_C = 0.76$

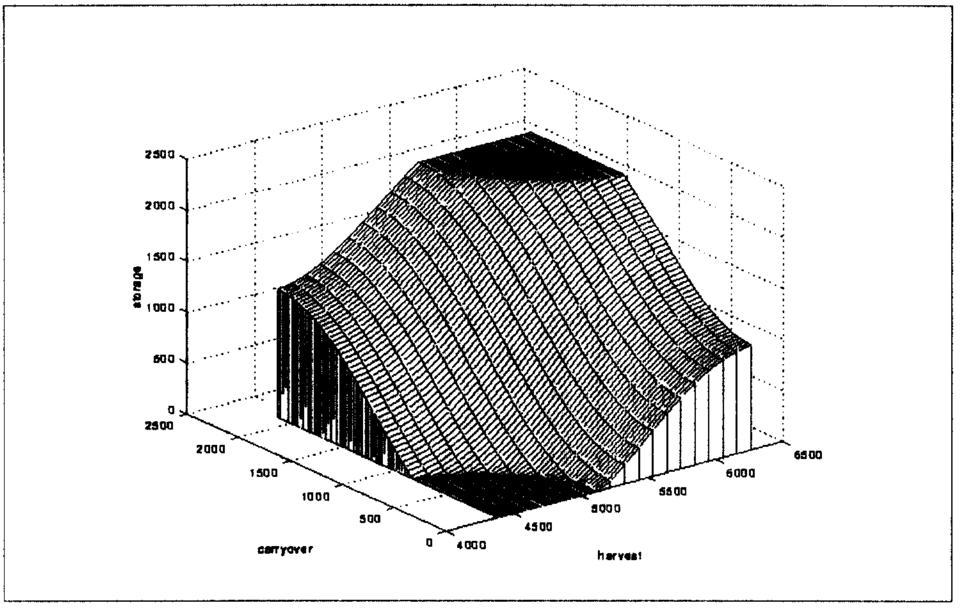
SWF: $\lambda_P = \lambda_G = \lambda_C = 1$, CMS: competitive private storage contrary to the results shown in previous studies. Stockholding under the political preference function has to consider the current amount of harvest and carryover from the last year independently if the welfare weights on producers and taxpayers are not the same. In particular, the optimal storage rule for maximizing PPF crucially depends on the relative magnitude of current harvest and carryover stocks from the last period. This indicates that the marginal effects of the current harvest and the carried stocks on the decision of current storage are different. The marginal propensity of the current harvest is larger than that of the carried stock from the last period.

This implication is explicitly shown in Figures (2), (3) and (4), which are three-dimensional graphs illustrating the differences in the marginal propensities of the current harvest and the carried stocks for alternative cases. Comparing with these figures, the marginal effects of current harvest and carried stock on storage decisions are different for alternative policy criteria. From these graphs, we also conclude that if governments seek to maximize a political preference function that has parameters that reflect relative welfare weights of various interest groups, optimal storage rules differ when welfare weight is considered compared to that of SWF. Specifically, the marginal propensity to store from the current harvest and carried stocks is not the same (see Figure (2)). Thus, the storage rule for the PPF approach cannot be expressed as a reduced form of the current market availability. However, if policymakers place the same welfare weight on producers and taxpayers, then the marginal propensity of both current harvest and carried stock on the current storage decision is the same as shown in Figures (3) and (4). Comparing to the case of SWF, the larger producer welfare weights induce a higher marginal propensity of the current harvest on storage and an earlier starting point for storage. Also, the optimal carryover will be greater if the welfare weight toward producers is larger than that of consumers and taxpayers. The upper shaded area in all the three-dimensional

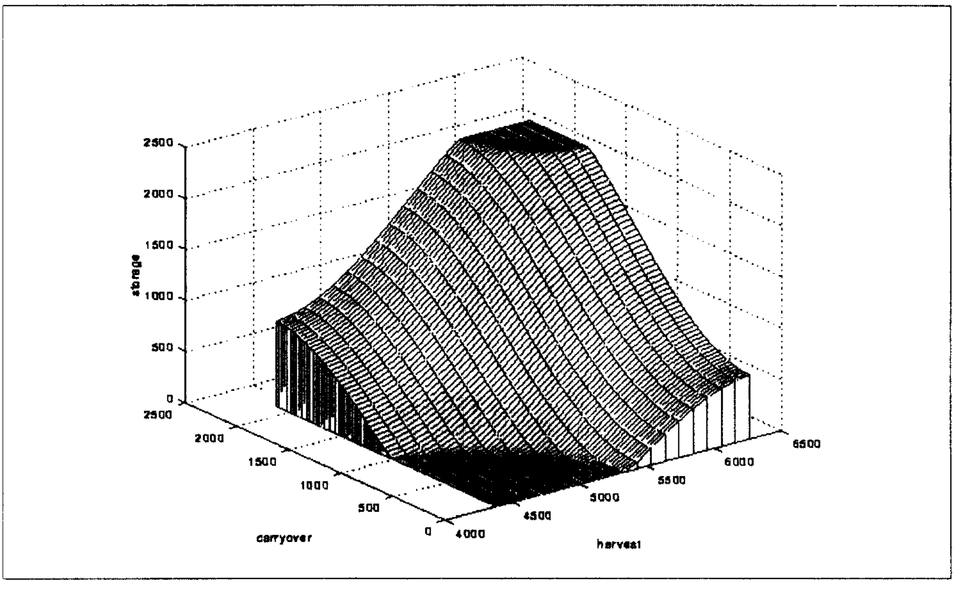
[Figure 2] Optimal Storage Rule in 3-D, $\lambda_P = 1.33 > \lambda_G = 0.91 > \lambda_C = 0.76$



[Figure 3] Optimal Storage Rule in 3-D, $\lambda_P = \lambda_G = 1.12 > \lambda_C = 0.76$

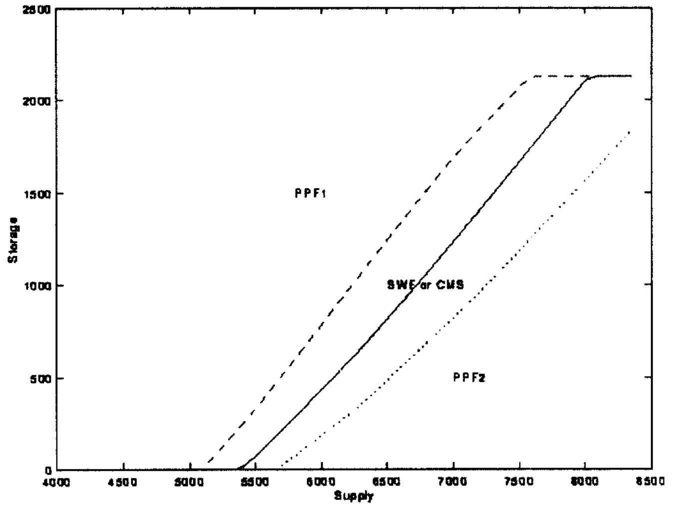


[Figure 4] Optimal Storage Rule in 3-D, $\lambda_P = \lambda_G = \lambda_C = 1$



graphs represents explicitly the maximum capacity which is assumed to be 40 percent of average harvest whereas the shaded bottom area shows the parts of no storage.

[Figure 5] Optimal Storage Rule where $\lambda_P = \lambda_G \neq \lambda_C$



Note: PPF1: $\lambda_P = \lambda_G = 1.12 > \lambda_C = 0.76$, PPF2: $\lambda_P = \lambda_G = 0.9 < \lambda_C = 1.2$,
SWF: $\lambda_P = \lambda_G = \lambda_C = 1$, and CMS: Competitive Market Storage

In addition, if the decision-maker has the same preferences on producers and taxpayers, then the optimal storage rule with maximizing PPF could also be expressed as a function of the current supply available. To see how optimal storage changes with different welfare weights, focus on the difference of welfare weights between producer and consumer for the sake of comparison. Figure (5) illustrates the similar shapes of optimal rules between PPF and SWF when the policymaker's preferences to both producer and taxpayer are equal to each other. Actually, it might be the same case where producers own all the stocks as well as current output.

As can be seen from the storage rules, the optimal storage levels increase monotonically as the available supply in the Korean rice market rises. Comparing with optimal storage rules for alternative policy objective functions, the optimal carryover will tend to be greater if the welfare weight toward producers is larger than that of consumers.

Ⅳ. SENSITIVITY ANALYSIS OF MARKET PARAMETERS

Sensitivity analysis is also essential to test the robustness of the model results according to the changes in selected market parameters. This section gives a special concern to demand elasticity and welfare weights toward interest groups because these are key parameters in the model to determine optimal storage levels. We examine the sensitivity of the results to changes in price elasticity of

[Table 1] Sensitivity Analysis to Demand elasticity and Welfare Weights: Storage (1000 ton)

	Welfare Weights			
Demand Elasticity	PPF 1	PPF 2	SWF	PPF 3
-0.1	1844	1591	218	33
-0.2	1727	1127	112	21
-0.3	1574	413	68	11
-0.4	1244	181	45	4

Note: PPF1: $\lambda_P=1.33$, $\lambda_C=0.76$, $\lambda_G=0.91$, PPF 2: $\lambda_P=1.12$, $\lambda_C=0.76$, $\lambda_G=1.12$
SWF: $\lambda_P=\lambda_C=\lambda_G=1$, PPF3: $\lambda_P=0.9$, $\lambda_C=1.2$, $\lambda_G=0.9$

demand and welfare weights.

Table 1 presents mean storage levels under varying parameters: 1) demand elasticity and 2) welfare weights on interest groups. The selected price elasticity of demand ranges from 0.1 to 0.4. The selected welfare weights include four cases where are possible to reflect the difference in welfare weights toward interest group. For the sake of comparison, note that PPF1 for welfare weights and price elasticity of demand, 0.2 has been assumed to reflect the current political- economic situation in the Korean rice sector.

The results indicate that a higher price elasticity of demand induces lower stocks. This is because more elastic demand reduces the incentive for holding stocks. With elastic demand, consumers absorb the variations in uncertain harvest by adjusting their consumption. For example, mean storage has decreased from 1.8 million ton to 1.2 million ton in response to an increase in price elasticity from -0.1 to -0.4 for the case 1 of the welfare weights considered. Also, the optimal carryover will be tend to be greater if the welfare weight toward producers is larger than that of taxpayers and consumers. At -0.2 of demand elasticity, mean storage has increased from 21 thousand ton to 1.7 million ton in the increasing trend of welfare weight for producers, i.e., from PPF3 to PPF1. Of course, there are lots of possible cases to be considered. In summary, for a given supply level, the optimal carryover will tend to be larger if demand is more inelastic or the producer's welfare weight is relatively greater than that of other interest groups.

V. SUMMARY AND CONCLUSION

Optimal storage differs when welfare weight is considered in the model compared to when it is not included. This suggests that the optimal carryover levels for maximizing conventional social welfare function or private storage for maximizing profit is not the same as the optimal storage generated by maximizing political preference function. There is a kink point that storage occurs because of the non-negativity constraint on stocks.

In the case of maximizing the PPF with different welfare weights, unlike the case of maximizing the SWF or competitive private storage, the optimal storage rule cannot be solely expressed as a function of the current supply available, contrary to the results shown in previous studies. Stockholding under the political preference function has to consider the current amount of harvest and carryover from the last year independently if the welfare weights on producers and taxpayers are not the same. In particular, the optimal storage rule for maximizing PPF crucially depends on the relative magnitude of current harvest and carryover stocks from the last period. This indicates that the marginal effects of the current harvest and the carried stocks on the decision of current storage are different. Comparing to the case of SWF, the larger producer welfare weights induces a higher marginal propensity of the current harvest on storage and an earlier starting point for storage. Also, the optimal carryover will be greater if the welfare weight toward producers is larger than that of consumers and taxpayers. However, if policymakers place the same welfare weight on producers and taxpayers, then the marginal propensity of both current harvest and carried stock on the current storage decision is the same. The decision-maker has the same preferences on producers and taxpayers, then the optimal storage rule with maximizing PPF could also be expressed as a function of the current supply available. Finally the optimal carryover will tend to be greater if the welfare weight toward producers is larger than that of consumers. Economically the above results can be interpreted as follows: If the decision-maker has the different preferences on producers and taxpayers, then policymakers would treat differently the current harvest which is closely related to the producers' welfare and the carried stock owned by government even though it is identical physically. In the case of the higher weight on producers' welfare rather than that of taxpayers, policymakers are more sensitive to the producers' welfare than that of taxpayer. In terms of enhancing the producers' welfare appropriately, the larger producer welfare weight induces a higher marginal propensity of the current harvest on storage and greater optimal carryover.

REFERENCES

Arzac, E. R. and M. Wilkinson, "Dynamic analysis and optimal control of agricultural commodity markets," In Bensoussan, A. et al (Eds), *Applied stochastic control in econometrics and management science*, North-Holland, ch2.,1980.

Atkinson, K. E., *An Introduction to Numerical Analysis*, Second Edition, John Wiley & Son, 1989.

Baffes, J., "Optimal tax/subsidy intervention in commodity markets when the groups of interest are weighted unequally," *European Review of Agricultural Economics*, 20, 365-378, 1993.

Becker, G. S., "A theory of competition among pressure groups for political influence," *Quarterly Journal of Economics*, 98, 371-400, 1983.

Bigman, D, *Food policies and food security under instability: Modeling and analysis*, Lexington Books, Lexington, 1985.

Buccola, S. T. and C. Sukume, "Regulated price and stock policies: Interaction effects and welfare preference," *Journal of Development Economics*, 35, 281-305, 1991.

Bullock, D. S. and K. S. Jeong, "Comment: a critical assessment to the political preference function approach in agricultural economic," *Agricultural Economics*, 10, 201-206, 1994.

Burt, O. J., W. Koo, and N. J. Dudley, "Optimal stochastic control of U.S. wheat stocks and exports," *American Journal of Agricultural Economics*, 62, 172-187, 1980.

Gardner, B. L., *Optimal stockpiling for grain*, Lexington books, 1979.

Gardner, B. L., *The economics of agricultural policies*, Macmillan Publicizing Company, 1987.

Gardner, B. L., "Economic theory and farm politics," *American Journal of Agricultural Economics*, 71, 1165-1171, 1989.

Glauber, J., P. Helmberger, and M., Miranda, "Four approaches to commodity market stabilization: A comparative analysis," *American Journal of Agricultural Economics*, 71, 326-337, 1989.

Gustafson, R. L., "Implications of recent research on optimal storage rules," *Journal of Farm Economics*, 40, 290-300, 1958.

Helmberger, P. and R. Weaver, "Welfare implications of commodity storage under uncertainty," *American Journal of Agricultural Economics*, 59, 639-651, 1977.

Helmberger, P. and V. Akinyosoye, "Competitive pricing and storage under uncertainty with an application to the U.S. soybean market," *American Journal of Agricultural Economics*, 66, 119-130, 1984.

Im, Jeongbin, "An Application of Political Prefernece Function Approach for the Korean Rice Sector," *Journal of Rural Development*, Vol., 22 No. Summer 1999.

Judd, K. L., *Numerical Methods in Economics*, Manuscript, Hoover Institution, Stanford University, 1997.

Kennedy, J. O. S., *Dynamic Programming: Applications to Agriculture and Natural Resources*, Elsevier Applied Science Publishers, 1986.

Kim, Y. T., "A political economics in the Korean rice procurement policy," *The Korean Journal of Agricultural Economics*, 39(2), 105-123, 1998(in Korean).

Kwon, Y. D. and H. Yamauchi, "Agricultural policy adjustments in the Korean rice economy," *Agricultural Economics*, 9, 335-346, 1993.

Mas-Colell, A., M. Whinston, and J. Green, *Microeconomic Theory*, Oxford University Press, 1995.

McNew, K. and B. Gardner, "Taxes, intertemporal equilibrium and price variability in storable commodity markets," *Working paper, Department of Agricultural and Resource Economics, University of Maryland*, 1997.

Miranda, M, J., "Numerical Strategies for Solving the Nonlinear Rational Expectations Commodity Market Model," *Computational Economics*, 11, 71-87, 1998.

Miranda, M. J. and J. W. Glauber, "Estimation of dynamic nonlinear rational expectations models of primary commodity markets with private and government stockholding," *Review of Economics and Statistics*, 75, 463-470, 1993.

Miranda, M. J. and P. L. Fackler, *Lecture Notes in Computational Economic Dynamics*, manuscript, Ohio State University, 1997.

Ministry of Agricultural, Forestry and Fisheries (MAFF), *Major Statistics*, Korea, Various Years.

Ministry of Agricultural, Forestry and Fisheries (MAFF), *Statistical Yearbook of Agricultural, Forestry and Fisheries*, Republic of Korea, Various Years.

Muth, J. F., Rational expectations and the theory of price movements, *Econometrica*, 29, 315-335, 1961.

Newbery, D. M., and J. E., Stiglitz, *The theory of commodity price stabilization*, Oxford University Press, 1981.

Oi, W. Y., "The desirability of price instability under perfect competition," *Econometrica*, 29, 58-64, 1961.

Sarris, A. H., "Commodity-Price Theory and Public Stabilization Stocks," In Chisholm A.H. and Tyers R.(ed), *Food Security: Theory, Policy, and Perspectives from Asia and the Pacific Rim*, ch5.,1982

Swinnen, J. and F. Van der Zee, "The political economy of agricultural policies: A Survey," *European Journal of Agricultural Economics*, 20, 261-290, 1993.

Taylor, C. R. and H. Talpaz, "Approximately optimal carryover levels for wheat in the United States," *American Journal of Agricultural Economics*, 61, 32-40, 1979.

Turnovsky, S. J., "Price expectations and welfare gains from price stabilization," *American Journal of Agricultural Economics*, 56, 706-716, 1974.

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

Turnovsky, S. J., "Stabilization rules and the benefit from price stabilization," *Journal of Public Economics*, 9, 37-57, 1978.

Waugh, F., "Does the consumer benefit from price instability," *Quarterly Journal of Economics*, 58, 602-614, 1944.

Williams, J. C. and B. D. Wright, "The economic role of commodity storage," *Economic Journal*, 92, 596-616, 1982.

Williams, J. C. and B. D. Wright, The welfare effects of the introduction of storage, *Quarterly Journal of Economics*, 99, 169-182, 1984.

Williams, J. C. and B.D. Wright, *Storage and commodity markets*, Cambridge University Press, 1991.