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MULTIATTRIBUTE UTILITY ANALYSIS AND DECISION SUPPORT SYSTEMS: THE CASE OF FILIPINO RICE POLICY

Recent advances in dealing with conflicting objectives under uncertainty offer the possibility of actually making some difference in the selection and implementation of public policy. These advances involve multiattribute utility analysis and the construction of operational decision support systems. Such decision support systems integrate the decision-makers in the model construction process and its implementation. Throughout the model construction, the researcher must be continuously concerned with the implementation of the decision support system. He has to be willing to sacrifice the use of some sophisticated theories and techniques in order to achieve an operational model which can be implemented. Since the methodology described here depends very heavily on judgments and interviews, it is very important that the decision-maker not be confused with unnecessary terminology. Where sophisticated tools are unavoidable, the researcher should construct simple examples to enhance an intuitive appreciation of the approach.

The above approach to policy problems must be seriously entertained, especially since public agencies generally, and in many cases correctly, reject the conventional analysis provided by economists. The traditional "box of tools" often employed is not sufficient to address the important issues facing these agencies. The typical approach can be described as "solution rich" where the focus is on those perceived problems which are amenable to conventional economic analysis. In other words, the typical approach is not sufficiently "problem rich." The result of the solution rich approach is a "myopic blend of technical sophistication with an air of unreality that politicians often (rightly) reject" (Timmer).

Prior to the construction of a comprehensive decision support system for public agencies concerned with agricultural systems, a detailed qualitative analysis of the environment in which the agency operates must be conducted. Specifically, that qualitative analysis includes (1) the country—social structure, culture, education, economy, institutional setting, ethnic groups, etc.; (2) the agricultural sector—role in the economy, level of technology, producer characteristics, marketing channels, financial institutions, etc.; (3) the commodity—importance in diet, import-export, technology of production, biological growth characteristics, processing facilities, characteristics of the product, perishability, varieties, spatial and size distribution of farms and production, substitutable and complementary products, seasonality, etc.; and (4) the public agency—organization, facilities, budget, power, effective interest group coalitions, political constraints, activities, etc.

Given the above qualitative analysis, the model should be constructed so that its users are able to follow its design and provide feedback at each stage. Little claims that "the best approach is to lead the potential user through a sequence of models of increasing scope and complexity. . . . Often a user having a simple model, will start to ask for just the additional consideration found in the advanced models."

To correct many of the limitations of the traditional box of tools and satisfy Little's desired simplicity, two major issues facing public agencies must be explicitly recognized. These issues are uncertainty and multiple and conflicting objectives. Uncertainty is a principal feature of agricultural commodity systems. Weather conditions and pests and diseases cause high fluctuations in the quantities produced. As a result of low price elasticities of farm products, the price variabiltiy is also very high.

Public agencies such as Agricultural Marketing Boards (AMBs) and government agencies are generally charged with the responsibility of responding to the needs and desires of the different groups and participants within the commodity system. These groups are the producers, consumers, the government, suppliers of inputs, intermediaries (assemblers and distributors), and landowners. Therefore, these agencies have more than a single objective or performance measure by which to evaluate their effectiveness. The most common objectives are to increase and stabilize farm income, to reach self-sufficiency in food production, to increase consumer welfare, to decrease price variability, and to improve the balance of payments. Many of these objectives naturally conflict with one another so that explicit trade-offs must be recognized.

The purpose of this paper, then, is the construction of stochastic and multiattribute decision-making systems which will prove useful and operational for public agencies. These systems are viewed as a decision-making aid which will allow managers of public agricultural agencies to identify and structure objectives, to make value trade-offs, and to balance various risks. The first part of the paper describes the general model for optimization under uncertainty and multiple objectives. This model is then applied, determining the optimal price policy for rice in the Philippines.

Model and Methodology

The paradigm for operationally dealing with decision making under uncertainty and multiple objectives has been referred to as multiattribute decision analysis (Keeney and Raiffa). This approach consists of two major components: the decision tree and the objective function. As is well known, decision trees are flow diagrams which structure problems as a chronological arrangement of those choices that are controlled by the decision-maker and those choices that are determined by chance (Raiffa). The probability distributions assigned to the chance events can be based on historical data; regression analysis; econometric modeling; or, as it often happens in real cases, on subjective perceptions of the decision-maker.

The most difficult component of multiattribute decision analysis is to determine the appropriate objective function. The least restrictive objective function is the expectation of the multiattribute utility function:

$$E\, u\, (x_1, x_2, \ldots, x_n). \tag{1}$$

The construction of such a function involves the following steps: (1) list of objectives, (2) performance measure or attribute for each objective, (3) univariate utility functions for each attribute, (4) independence relationships among the attributes, (5) functional form of the multiattribute utility function, (6) scaling constants (weights) of the different attributes, and (7) expected value of the multiattribute utility for each alternative policy.

Objectives and Performance Measures

It is crucial to clearly identify the major objectives of the agency in question. Most often, objectives are only vaguely identified. The most common objectives of agricultural public agencies are (1) increased income of farmers, (2) increased consumers' welfare, (3) self-sufficiency, (4) price stability, (5) improvement of balance of payments, (6) decreased operational expenditures, and (7) stable flow of supply. Other "objectives"--like increased productivity, integration of the commodity system, improved quality, research and development, and the like--are means to achieve some of the objectives mentioned above and thus are only intermediate goals.

The performance measure or attribute associated with each relevant objective should be quantified. The measures should be simple and meaningful to the users of the decision support system. This is particularly important since the users must provide the utility functions for each of the attributes and the independence relationships and weights for the multiattribute utility function. This task by itself is sufficiently complicated with simple performance measures; thus, overly sophisticated or theoretical measures should be avoided.

After the objectives are known, the question to be asked is: What are the means to accomplish these objectives? The most common alternatives for achieving the objectives mentioned above are production and/or marketing quotas; floor price to the producers; ceiling price to the consumers; input subsidies to farmers; quality control; research and development; extension programs; reserve or buffer stocks; import or export taxes and premiums; and infrastructure facilities investments (transportation, irrigation, etc.).

The Objective Function

As mentioned above, the construction of the objective function is frequently the most difficult part of the analysis. It relies heavily on the preference structure of the decision-maker and, therefore, requires a thorough interviewing process. After the objectives are identified and the appropriate performance measures quantified, the following stages must be completed.

Univariate Utility Functions

In this stage the researcher evaluates the risk perception of the decision-maker with regard to each of the attributes. A five-point utility function is constructed by using 50-50 lotteries[1] and the general form of the function (risk neutral, constant risk averse, decreasing risk averse, etc.) is also determined. Using the general form of the utility function and the five-point utilities, a continuous utility function is approximated.

Independence Relationships

Three types of independence relationships will be examined. The set of attributes A is preferential independent of the set B if preferences over the set A do not depend on the amounts in B. Preferential independence is not reflexive. The set A is utility independent of the set B if preferences over lotteries on (a, b') do not depend on the fixed amount of b'. Utility independence is not reflexive. The set of attributes A and the set B are additive independent if preferences over lotteries (a, b) depend only on the marginal probability distributions of a and b and not on their joint distributions.

It has been shown by Fishburn and by Keeney that, if additive independence holds among all attributes, the multiattribute utility function is of the form

$$u(x) = \sum_i k_i \, u_i(x_i). \qquad \text{(additive)} \tag{2}$$

If, however, preferential independence and utility independence hold, but additive independence does not, the multiattribute utility function is of the form

(3) $$1 + ku(x) = \prod_i [1 + kk_i\ u_i(x_i)],$$ (multiplicative)

where k_i is the scaling constant for utility function u_i, and k is the aggregate scaling constant.

The Scaling Constants

After the independence relationships and the functional form of the multiattribute utility function are known, the researcher has to determine the scaling constants or weights of the different attributes in the functional form. These constants are represented by the k and k_i's in equations (2) and (3). They are determined by equating different combinations of the various attributes and then solving the resulting set of n + 1 equations with the n + 1 unknowns (the k_i's, i = 1, ..., n, and k).

The model and the computer program designed to solve the model should allow for flexibility in the implementation of the decision support system. Not only must sensitivity analysis be admitted in addition to the optimization but the model should enable the users to efficiently change the values of the variables, the probability distributions, and the utility functions in response to interactive feedbacks. This quality of the decision support system is extremely important since much of the input is based on judgments of some officials which may undergo revision.

One of the advantages of the multiattribute decision analysis approach is the requirement that decision-makers be faced with questions on the trade-off between attributes and the probabilities of uncertain events. This process "forces" the decision-maker to consistently evaluate the policy problem, an act which he/she does not typically perform.

In summary, multiattribute utility analysis begins a qualitative analysis of the environment in which the agency must operate followed by a specification of a quantitative model and a heavy dose of interaction with the actual decision-makers and users of the decision support system. The entire process is represented by information flows in figure 1.

The agency charged with the responsibility for formulating and implementing rice policy in the Philippines is the National Grains Authority (NGA). In general, the NGA attempts to promote the integrated growth and development of the Filipino rice industry. Specifically, Presidential Decree No. 4 states that:

> NGA shall devise a system by which it can insure the adequacy of supply and stability of consumer prices at levels within the reach of the low-income families while maintaining the announced floor price to assure farmers or producers with a fair return on their investment. The rationale behind this is the fact that grain is a major item in the food basket of Filipino families. Thus, it has a pervasive effect on Philippine society such that the slightest imbalance in its supply and price is felt nationwide.

Objectives and Performance Measures

Five objectives were chosen to represent the rice welfare of the Philippines for the NGA. These objectives were: (1) increase rice farmers' profits, (2) self-sufficiency in rice production, (3) increase consumers' welfare, (4) stabilize market price of rice, and (5) decrease government expenditures. The selection of these objectives was based on interviews with officials of

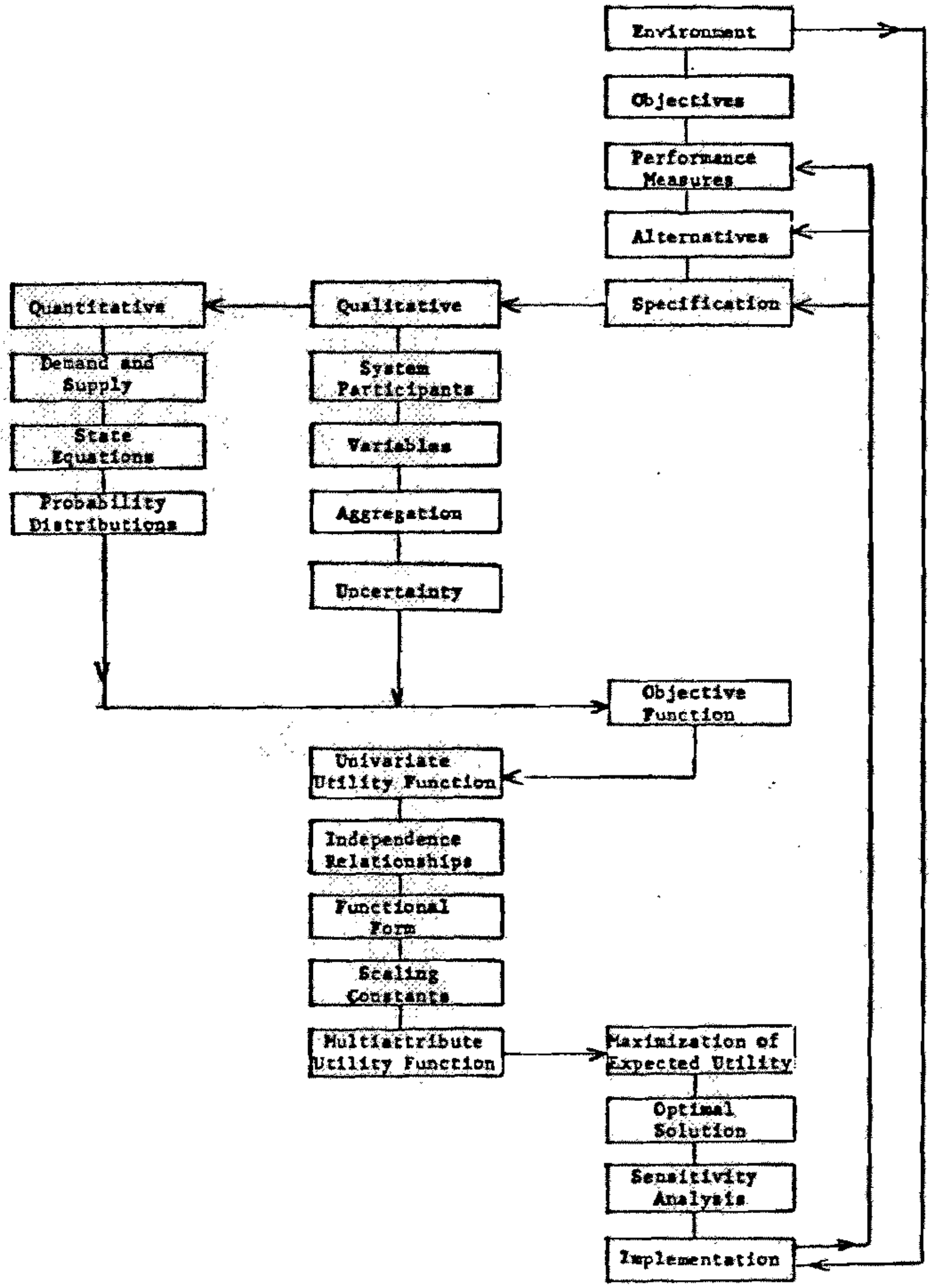

Figure 1. Decision support system construction process

the NGA. Similar objectives are reported in Barker, Apiraksirikul and Barker, Mangahas, Herdt and Lacsina, and Timmer.

Farmers' Net Income

The performance measure of this attribute is the average net income of a rice farm in one cycle (wet). The net income was defined as the gross income (sales) minus the variable cost (hired labor and inputs):

(4) $$x_1 = \frac{\sum_{j=1}^{2} M_j \left[(Y_j h - H_c - H_s)\, \tilde{P}_p - h\, (\tilde{C}L_j + \tilde{C}I_j) \right]}{\sum_{j=1}^{2} M_j},$$

where x_1 is average net income to farmer per cycle (pesos), M_j is number of farms in category j, j is 1 for irrigated farms and 2 for nonirrigated farms, Y_j is yield per hectare in farm of type j (kg. per hectare), h is average farm size (2.5 hectares), H_c is farm household consumption per cycle (535 kg. palay), H_s is farm household storage in wet cycle (135 kg. palay), $\tilde{P}_p$ is the price of palay to the farmer (pesos per kg.), $\tilde{C}L_j$ is cost of hired labor in farm type j (pesos per hectare), and $\tilde{C}I_j$ is cost of inputs in farm type j (pesos per hectare).

Self-Sufficiency in Rice Production

The performance measure for this objective is the percentage of the quantity supplied out of the quantity needed to meet the average consumption of the nonrice-farming population (100 kg. per capita per year),

(5) $$x_2 = \frac{q_s}{50} \cdot 100,$$

where x_2 is the measure for self-sufficiency, q_s is the quantity of rice supplied per capita (kg.), and 50 is the quantity consumed per semester per capita (kg.). Note that

(6) $$q_s = \frac{\left[\sum_{j=1}^{2} M_j \; (Y_j \cdot h - H_c - H_s)\right] \cdot .5}{T_n \cdot .625},$$

where all variables are as defined above and T_n is the total nonrice-farming population. Since about 5/8 of the total yearly production is produced in the wet season, 100 percent self-sufficiency is defined as the quantity necessary to meet the consumption at the wet season plus 1/8 of the yearly consumption to be consumed in the dry season but produced in the wet season. The total nonrice-farming population (T_n) is based on total population of 44 million and .96 million rice farms with average family size of 6.5.

Consumers' Welfare

The common measure for consumers' welfare is the area under the demand curve referred to as consumers' surplus. This measure has some difficulties, namely, the inability of government officials and economists to assign a utility function over this measure. For this reason, it is important from a preference assessment standpoint to select a measure which is meaningful to the decison-makers. Fortunately, in the case of rice in the Philippines, such a measure is readily available. In particular, for a perfectly inelastic demand, the change in consumer welfare, as implied by the consumers' surplus, is equivalent to the change in price. Hence, since the demand for rice in the Philippines is highly inelastic, a good performance measure is

(7) $$x_3 = P_m,$$

where x_3 is the measure of consumer welfare and P_m is the price of rice to the consumer.

Price Variability

The performance measure for price variability will be the absolute deviation of the consumers' price from the price in the previous cycle,

(8) $$x_4 = \left| P_{m_t} - P_{m_{t-1}} \right|,$$

where x_4 is the price variability measure and P_{m_t} is the price to the consumer in period t. The common measure for price variability is the standard deviation of the prices. But, once again, a simple measure has been chosen which is clear to the users of the model when assigning the utility function. In addition, the proposed performance measure does not penalize for large deviations from the expected price. The performance measure should be used only for measuring the performance and not as a penalty function. The penalty for large deviation, if necessary, would be reflected in the utility function.

Government Expenditures

The performance measure for this attribute is the total expenditures per capita of NGA in executing its policies. These expenditures consist of the cost of purchasing palay from the farmers plus the cost of importing rice less the revenues from selling rice to consumers less the revenues from exporting rice.

The Alternatives of NGA

The price policy for rice consists of determining the floor price to the producers (pesos per kg. of palay), ceiling price to the consumers (pesos per kg. of rice), and reserve stock policy. Only the different alternatives of floor and ceiling price will be evaluated. It will be assumed that, if the market clearing price is above the ceiling price, the government would import the quantity necessary to drive the price down to the ceiling price. If the market clearing price is below the floor price, the government would export rice to drive the price up to the floor price. The current floor price to the producer (P_p) is 1.10 pesos per kg. of palay, and the ceiling price to the consumers (P_m) is 2.10 pesos per kg. of rice.

Three different levels of floor price to the farmers (1.00, 1.10, and 1.20 pesos per kg. of palay) and eight different levels of ceiling price to the consumers (1.70, 1.90, 2.10, 2.30, 2.50, 2.70, 2.90, and 3.10 pesos per kg. of rice) have been evaluated initially. In addition, the "free market" policy, namely, no floor or ceiling price, has been evaluated.

Uncertainties

Weather

A subjective probability distribution was assessed for the nature conditions variable, with three possible outcomes: "bad"--production is 10 percent below normal; "moderate"--production is normal; "good"--production is about 10 percent above normal. Based on the assessments of NGA officials, agricultural economists, and farmers, the probability distribution used in the analysis was:

Good nature conditions	p = .2
Moderate nature conditions	p = .5
Bad nature conditions	p = .3.

A more quantitative analysis of rice yields (Yassour) resulted in a very similar distribution.

Farmers' Response

Two types of farms are distinguished here: irrigated and nonirrigated. In the irrigated farms, the farmers usually grow more than one crop per year. They are less vulnerable to nature conditions and are more profitable. The nonirrigated farms, however, are less intensively cultivated. Most of them are in the areas far from the big marketing centers and are less flexible in their marketing options.

NGA officials and Filipino agricultural economists have been asked to assess the response of farmers who grow rice in irrigated and nonirrigated farms to different levels of floor price for palay. Their assessments are summarized in table 1.

Demand

Findings of Mears, Nasol, Apiraksirikul, and Te show that the price elasticity of demand for rice in the Philippines ranges between -.2 and -.5. By substituting the current quantity consumed per capita per year (100 kg.) and the current consumer price (2.10 pesos per kg.) in linear and Cobb-Douglas functions, the respective demand functions were obtained. A subjective probability distribution was then assigned over the elasticities. This was done

Table 1. Probability Distributions of Farmers' Response to Different Levels of Floor Price

	Probability					
	Irrigated			Nonirrigated		
Floor Price	.25	.5	.25	.25	.5	.25
	(percent of production[a])					
1.00 peso per kg.	92	97	102	95	98	101
1.10 pesos per kg.	100	100	100	100	100	100
1.20 pesos per kg.	102	104	106	100	101.5	103
Free market	99	100	101	97	99	101

[a]100 percent production is what the farmers intend to grow under the current floor price (1.10 pesos per kg.). This basic figure differs for irrigated and nonirrigated farms.

with the advice of the researchers of the Department of Agricultural Economics of the University of the Philippines, Los Baños, and of the International Rice Research Insititute. Higher probabilities were assigned to recent findings and to medial values. The elasticities to be analyzed in the model, their respective demand functions, and probabilities are shown in table 2.

In order to avoid skyrocketing prices for very small quantities as a result of an exponential demand function and negative prices for very large quantities as a result of a linear demand function, it has been assumed that the demand function is linear to the left of the current quantity consumed (100 kg. per capita per year) and exponential to its right.

World Market Price of Rice

The price NGA would pay (receive) for imported (exported) rice is also a random variable. Based on their knowledge about the situation of rice and grains in the international market, NGA officials provided the probability distribution shown in table 3 for the year 1978.

The prices in table 3 include the cost of the rice itself, sea transportation and insurance, and transportation from the port to the warehouse. The price that NGA would receive for 1 ton of exported rice (f.o.b.) is, of course, lower. NGA officials estimated that, for the same quality of rice, the export price per ton would be lower than the import price by about 20 percent.

The Domestic Price for Rice

The price of palay to the producers and the price of rice to the consumers are also random variables. However, a probability distribution does not have to

Table 2. Price Elasticities of Demand for Rice, Demand Functions, and Probabilities

Price Elasticity	Demand Function: Exponential	Demand Function: Linear[a]	Probability
-.2	$P = (116/q)^{5}$	$P = 12.60 - .105q$	.3
-.3	$P = (125/q)^{3.33}$	$P = 9.10 - .07q$	.3
-.4	$P = (135/q)^{2.5}$	$P = 7.10 - .05q$	.3
-.5	$P = (145/q)^{2}$	$P = 6.10 - .04q$	.1

[a]The linear demand functions are the linear approximations of the exponential functions at the region of the current price and quantity consumed per capita.

Table 3. Subjective Probability Distribution of World Market Price for Rice

Price of imported rice --(c.i.f., dollars per ton)--	Probability
250	.1
270	.2
300	.4
330	.2
350	.1

Source: Department of Corporate Planning, National Grains Authority, personal communication.

be assigned over these variables since they are determined by the intersection of the demand curve and the quantity supplied and by the margin of the intermediaries.

There is empirical evidence that the margin between the retail price and the farm price is more or less constant (Castillo; Mangahas, Recto, and Ruttan; Mears et al.; and Yassour). Based on these findings a fixed margin of .45 pesos per kg. was assumed.

Price Policies

Two possible policies of NGA are distinguishable: (a) the floor price to the producers plus the intermediaries' margin is greater or equal to the ceiling price to the consumers,

(9) $$P_p^* + P_i \geq P_m^*,$$

and (b) the the floor price plus the intermediaries' margin is lower than the ceiling price,

(10) $$P_p^* + P_i < P_m^*.$$

In case (a) NGA has to intervene regardless of the market behavior. It is assumed that, for those policies which imply relation (9), NGA will subsidize the rice by the amount $(P_p^* + P_i - P_m^*)$ for a kilogram consumed domestically. If the quantity locally supplied is greater (smaller) than needed to meet the ceiling price, NGA will export (import) the surplus (deficiency). Note that, for any level of P_m^* and a particular demand function, there is a corresponding level of q_m^* or quantity (per capita) marketed necessary to achieve the ceiling price. In this case,

$$P_m = P_m^*,$$

$$P_p = P_p^*,$$

and

$$x_5 = q_m^* (P_p^* + P_i - P_m^*) - (q_s - q_m^*) (\delta \cdot r \cdot P_x - P_p^* - P_i),$$

where P_p is the actual price of rice to the farmer (pesos per kg.), P_m is the actual price of rice to the consumer (pesos per kg.), x_5 is government expenditures per capita, q_s is the quantity locally supplied per capita (kg. per capita), P_x is the world market price for rice, c.i.f. Manila (dollars per kg.), r is the rate of currency exchange (pesos per dollar), and δ is 1 if $q_s \leq q_m^*$ (c.i.f.) and .8 if $q_s > q_m^*$ (f.o.b.). The first component of the left-hand side of the government expenditures equation is the subsidy paid by the government, and the second component is the revenues (costs) from exporting (importing).

It is assumed that, if NGA exports some of the rice, it would incur the same processing, transportation, and handling costs at the same level as those of the private sector. Therefore, NGA would pay for 1 kg. of exported rice the price $P_p^* + P_i$.

In case (b), where relation (10) applies, the market equilibrium is allowed to play a crucial role. In this setting, three possible market scenarios are distinguishable. Scenario 1 is when

$$P_e < P_m^* \text{ and } P_e - P_i < P_p^*$$

where P_e is the equilibrium price at the consumer level. For this scenario, the consumers' side is satisfied but not the producers'. It is assumed that, in order to meet the floor price to the producers, NGA would export the quantity $q_s - q_p^*$. The prices and expenditures would be:

$$P_p = P_p^*,$$

$$P_m = P_p^* + P_i \ (< P_m^*),$$

and

$$x_5 = (q_s - q_p^*) \cdot (P_p^* + P_i - .8 \cdot r \cdot P_x),$$

where q_p^* is the quantity marketed necessary to meet the floor price for the realized demand function.

Scenario 2 is when

$$P_e < P_m^* \text{ and } P_e - P_i > P_p^*.$$

In this scenario, since both sides are satisfied, NGA would not intervene in the market. The prices and expenditures would be:

$$P_m = P_e,$$

$$P_p = P_e - P_i,$$

and

$$x_5 = 0.$$

Scenario 3 is when

$$P_e > P_m^* \text{ and } P_e - P_i > P_p^*.$$

For this scenario, the producers' side is satisfied but not the consumers'. It is assumed that, in order to meet the ceiling price to the consumers, NGA would import the quantity $q_m^* - q_s$. The actual prices and expenditures would be:

$$P_m = P_m^*,$$

$$P_p = P_m^* - P_i \ (> P_p^*),$$

and

$$x_5 = (q_m^* - q_s) \cdot (r \cdot P_x - P_m^*).$$

Empirical Estimation of the Objective Function

Based on an interview with the former Administrator of the Rice and Corn Administration, it was found that the five attributes are pairwise preferential independent and that at least one attribute is utility independent of the other.

It was also found that additive independence did not exist among the attributes. Thus, the multiplicative utility function

$$(11) \qquad 1 + k\, u\,(x_1, x_2, x_3, x_4, x_5) = \prod_{i=1}^{5} [1 + kk_i\, u_i(x_i)]$$

was the appropriate objective function. Given equation (11), it is necessary to determine the k_i's and $u_i(x_i)$ for i = 1, 2, 3, 4, 5.

Using 50-50 lotteries and fitting continuous utility functions, the univariate utility functions obtained were

$$(12) \qquad u_1(x_1) = 1.01 - 4.29 \exp(-.00125x_1),$$

(13) $$u_2(x_2) = -1.12 + 0.54 \ln (x_2 - 68),$$

(14) $$u_3(x_3) = 0.09 + 0.66 \ln (5 - x_3),$$

(15) $$u_4(x_4) = 0.72 \ln(4 - x_4),$$

and

(16) $$u_5(x_5) = -4.81 + 1.28 \ln (85 - x_5).$$

The estimated scaling constants (k_i's) were $k_1 = .8$, $k_2 = .58$, $k_3 = .65$, $k_4 = .52$, $k_5 = .33$, and k, which solves

(17) $$1 + k = \prod_{i=1}^{5} (1 + kk_i),$$

was calculated to be k = -1. Thus, the objective function used in the model was

(18) $$\begin{aligned} E\, u\,(x_1, x_2, x_3, x_4, x_5) = 1 - [1 - .8u_1(x_1)] \cdot [1 - .58u_2(x_2)] \\ \cdot [1 - .65u_3(x_3)] \cdot [1 - .52u_4(x_4)] \\ \cdot [1 - .33u_5(x_5)]. \end{aligned}$$

The Optimal Policy[2]

The expected utilities of the different policies are given in table 4. Note that a small difference in the expected multiattribute utility may imply a very large difference in the performance measures of the individual attributes. The reasons are: (1) at the higher levels of the utility (as those reported in the analysis above), the utility curve is very flat, and (2) if four of the five attributes are held constant, all the differences in the multiattribute utility are concentrated on the remaining attribute.

Table 4. The Expected Utilities of the Various Policies

Ceiling price	Floor price 1.00	1.10	1.20
1.70	.93569	.95244	.96190
1.90	.93977	.95566	.96470
2.10	.94362	.95809	.96678
2.30	.95274	.95851	.96581
2.50	.95752	.96222	.96577
2.70	.95946	.96351	.96666
2.90	.95983	.96375	.96675
3.10	.95940	.96345	.96646

No government intervention: .95569.

To find the difference between the alternative selected in the preliminary analysis [1.20, 2.10] and the current policy [1.10, 2.10], .84 is substituted for all $u_i(x_i)$, $i \neq j$ in (18), and the expected utility on the left-hand side of (18) is solved for the respective x_j, j = 1, 2, 3, 4, 5.[3]

For j = 5, x_5 = 39.5 pesos per capita was obtained for the current policy and x_5 = 11.5 pesos per capita for the selected policy. Thus, the total difference between the selected and current policies, in terms of government expenditures, is (39.5 − 11.5) · 44 million = 1,230 million pesos per semester. The results of similar comparisons for the other attributes are shown in table 5.

From table 4, it is observed that not only is [1.20, 2.10] superior to the current policy but, for any given ceiling price, the higher the floor price, the higher the expected utility. This implies that better performance may be achieved by a floor price higher than 1.20 pesos. NGA officials, however, provided for this study information only on the farmers' response to changes of .10 peso above and below the current floor price, which was 1.10 pesos. As will be shown in the sensitivity analysis section, even for a conservative assumption that farmers' response to higher floor prices is the same as for 1.20 pesos, the optimal policy was found to be [1.40, 2.10].

No Government Intervention

From table 4, it is obvious that government intervention in the form of fixed prices and subsidies or assured floor and ceiling prices is much preferred to no intervention. The policy of no government intervention is ranked nineteenth among the 25 alternatives. Moreover, policies with lower floor prices

Table 5. Comparisons Between the Optimal, Constrained Optimal, and Current Policies

	Policy				
	[1.40, 2.10]	[1.30, 2.90]	[1.20, 2.10]	[1.20, 2.90]	[1.10, 2.10]
Expected utility	.96984	.96696	.96678	.96675	.95809
Value of:[a]					
x_1 (pesos)	2,642	2,470	2,460	2,458	2,095
x_2 (percent)	107.6	102.0	101.7	101.6	89.3
x_3 (pesos per kg.)	1.78	2.08	2.10	2.11	2.84
x_4 (pesos per kg.)	.64	1.08	1.10	1.11	2.10
x_5 (pesos per capita)	-1.9	10.8	11.5	11.7	39.5

[a]These are values of x_i, the attribute being calculated, which result in the above expected utility when the values of the other attributes are fixed such that $u_j(x_j) = .84$, $j \neq i$ (x_1 = 2,583 pesos, x_2 = 105.7 percent, x_3 = 1.88 pesos per kg., x_4 = .79 pesos per kg., and x_5 = 2.40 pesos per capita).

and higher ceiling prices (which are steps in the direction of no intervention) were found to be less favorable than others with more involvement.

Optimal Constrained Policies

The policy selected on the basis of the preliminary analysis [1.20, 2.10] implies fixed farm and consumer prices and a subsidy program.[4] Using the .61 rate of recovery from palay to rice, the 1.20 pesos floor price for palay translates to 1.97 pesos per kg. of rice. Adding to that the intermediaries' margin of .45 peso, there is a minimum price to consumers of 2.42 pesos per kg. This figure is higher than the ceiling price of the optimal policy and thus implies a government subsidy of .32 peso per kg. for rice. (For the [1.40, 2.10] policy, the subisidy would be .64 peso per kg.).

NGA tends to limit its involvement in the rice industry in an attempt to maintain the objective of a capitalistic and free-enterprise economy in the Philippines. As a result, NGA may be reluctant to implement a policy which implies fixed prices to the farmer and the consumer and which requires an overall subsidy program for rice. If this attitude is to be kept by NGA despite the results of this analysis, it would imply implementing a suboptimal policy. Limited involvement in the rice industry was not considered as one of the objectives in the analysis; therefore, trade-offs between the rate of government involvement and the other attributes are not available. However, the cost (shadow price) of that constraint will be calculated; and it may be left to NGA and the government of the Philippines to decide whether the objective justifies its costs.[5]

The 20 best policies with floor prices ranging from 1.00 peso to 1.50 pesos, farmers' response to floor prices above 1.20 pesos equal to that of 1.20 pesos, and ceiling prices ranging from 1.70 pesos to 3.10 pesos are shown in table 6.

Policy 1 was found to be the optimal policy under no constraints, namely,

$$\max_{P_p^*, P_m^*} E\, u\, (x_1, x_2, x_3, x_4, x_5) = (1.40, 2.10), \tag{19}$$

where P_p and P_m are the floor price and ceiling price, respectively.

Policy 11 was found to be the optimal policy under the constraint of no subsidies. A subsidy program is necessary whenever the consumer price is lower than the farm price plus the intermediaries' margin. Thus,

$$\max_{P_p^*, P_m^*} E\, u\, (x_1, x_2, x_3, x_4, x_5) = (1.30, 2.90)$$

subject to

$$\frac{P_p^*}{.61} + P_i \leq P_m^* \tag{20}$$

where P_i is the intermediaries' margin.

Policy 16 was found to be the optimal policy when the floor price was restricted to its original range, namely, below or equal to 1.20 pesos per kg.

$$\max_{P_p^*, P_m^*} E\, u\, (x_1, x_2, x_3, x_4, x_5) = (1.20, 2.10),$$

subject to

$$P_p^* \leq 1.20. \tag{21}$$

Policy 18 was found to be the best under the two constraints, namely,

Table 6. Expected Utility of the 20 Best Policies

	Floor price	Ceiling price	Expected utility
1	1.40	2.10	.96984
2	1.50	2.10	.96960
3	1.40	2.30	.96923
4	1.50	2.30	.96918
5	1.30	2.10	.96902
6	1.50	2.50	.96827
7	1.30	2.30	.96824
8	1.40	2.50	.96818
9	1.40	1.90	.96754
10	1.30	2.50	.96705
11	1.30	2.90	.96696
12	1.50	2.70	.96696
13	1.50	2.90	.96695
14	1.30	1.90	.96690
15	1.30	2.70	.96687
16	1.20	2.10	.96678
17	1.40	2.70	.96677
18	1.20	2.90	.96675
19	1.30	3.10	.96667
20	1.20	2.70	.96666

$$\max_{P_p^*, P_m^*} E\, u\, (x_1, x_2, x_3, x_4, x_5) = (1.20, 2.90),$$

subject to

$$\frac{P_p^*}{.61} + P_i \leq P_m^* \tag{22}$$

and

$$P_p^* \leq 1.20.$$

A comparison between these four policies and the current policy [1.10, 2.10] is shown in table 5. From this table, it is observed that the difference between the three constrained policies [1.30, 2.90], [1.20, 2.10], and [1.20, 2.90] is insignificant. However, the differences between these three policies and the unconstrained policy [1.40, 2.10] and the current policy [1.10, 2.10] are very significant. For all other four attributes fixed at the level for which $u_j(x_j) = .84$, the total government expenditures are -84 million pesos for [1.40, 2.10], approximately 500 million pesos for the three constrained policies, and 1,740 million pesos for the current policy. The additional cost implied from imposing each of the constraints (shadow price) is 584 million pesos per semester. The cost of not changing the current policy would be 1,824 million pesos per semester.

Sensitivity Analysis

The optimal policy of floor price = 1.20 pesos per kg. and ceiling price of 2.10 pesos per kg. is a result of the data used and the assumptions of the model. In the following sections the sensitivity of the optimal solution to changes in some critical assumption and parameters of the model is tested.

This part of the analysis is more important in a decision-analysis model than in other models because it heavily relies on subjective evaluation which may not be shared by all participants in the decision-making process.

The Floor Price

In the interviewing process, it was quite difficult to get the evaluation of NGA officials on how farmers would respond to small changes in the floor price. Changes of more than .10 peso per kg. were not conceivable. Therefore, the analysis was limited to .10 peso of the current price, namely, over the range 1.00-1.20 pesos. As mentioned above, it was found that, over the initial range, the higher the floor price, the better the policy. It was suspected, therefore, that floor prices higher than 1.20 pesos per kg. might result in higher expected utility. Since farmers' response to a higher floor price was not available, a conservative assumption was taken in which the farmers' response to floor prices above 1.20 pesos per kg. would be the same as for 1.20 pesos per kg. The computer program was then run with the floor price ranging from 1.00 peso per kg. to 1.80 pesos per kg. and the ceiling price ranging as in the initial model, namely, from 1.70 pesos per kg. to 3.10 pesos per kg. The optimal policy under these ranges was found to be a floor price of 1.40 pesos per kg. for palay and a ceiling price of 2.10 pesos per kg. for rice [1.40, 2.10]. The second-best policy was [1.50, 2.10]. The expected utilities of these two policies were .96984 and .96960, respectively. It is certainly possible that, with more favorable farmers' response to a floor price of 1.50 pesos per kg. than to 1.40 pesos per kg., the optimal policy would have been [1.50, 2.10].

The Scaling Constants

The values of the scaling constants in the model were calculated on the basis of an interview with the former Administrator of the Rice and Corn Administration. His subjective preferences and risk perceptions do not necessarily coincide with those of NGA decision-makers. Thus, the model was run for different values of the scaling constants. Since the scaling constants are related to the importance of the different attributes, it was expected that the optimal policies would reflect the changes in these constants.

The scaling constants computed in the initial analysis were $k_1 = .8$, $k_2 = .58$, $k_3 = .65$, $k_4 = .52$, $k_5 = .33$. In the sensitivity analysis, we ran the computer program for all 243 possible combinations of $k_1 = .9$, .8, and .7; $k_2 = .7$, .6, and .5; $k_3 = .75$, .65, and .55; $k_4 = .6$, .5, and .4; and $k_5 = .45$, .35, and .25. Of the 243 combinations examined, 75 resulted in [1.50, 2.10] as the best policy; 47 in [1.40, 2.10]; 26 in [1.30, 2.10]; and 21 in [1.20, 2.70]; the remaining 74 combinations resulted in seven other policies.

The optimal policy was sensitive mainly to the values of k_1 and k_5. Table 7 summarizes the results of the sensitivity analysis on the scaling constants. From table 7 it is observed that the higher the k_1 (scaling constant for farmers' income), the higher the floor price. There is no change, however, in the ceiling price. It is also observed that the higher the k_5 scaling constant for government expenditures), the higher the ceiling price and the lower the floor price. Obviously, these results were expected. Where two or three policies were found optimal for the same combinations of k_1 and k_5 [see results for combinations (.8, .35), (.9, .35), (.7, .45), (.8, .45),

Table 7. Optimal Policies for Different Levels of k_1 and k_5

k_5 \ k_1	.7	.8	.9
.25	1.40, 2.10 (27)[a]	1.50, 2.10 (27)	1.50, 2.10 (27)
.35	1.30, 2.10 (21)	1.40, 2.10 (18) 1.40, 2.30 (6)	1.50, 2.10 (18) 1.50, 2.30 (6)
.45	1.20, 2.70 (18) 1.20, 2.10 (9)	1.30, 2.90 (15) 1.30, 2.10 (5) 1.40, 2.30 (5)	1.50, 2.30 (9) 1.50, 3.10 (9) 1.50, 2.50 (6)

[a]In parentheses, the frequencies out of 27 possible.

and (.9, .45)], the optimal policy was determined by the other three scaling constants. Thus, for example, for $k_1 = .8$ and $k_5 = .35$, the [1.40, 2.10] policy was found to be optimal for higher values of k_4 (scaling constant for price variability) and higher values of k_3 (scaling constant for consumers' welfare).

Sensitivity analysis was also conducted for some other important variables. As expected, it was found that higher expected utilities resulted for lower consumption, decreased population, higher yields, more rice farms in general, and more irrigated farms in particular. Generally speaking, the floor price of the optimal policy decreased as the total production increased.

Conclusions and Implementation

From table 6 it was observed that the optimal policy consists of a floor price of 1.40 pesos per kg. and a ceiling price of 2.10 pesos per kg. As mentioned above, this policy implies fixed farm and retail prices and a subsidy of .64 pesos per kg. Such a policy requires major changes in NGA operations and administration. In addition, this policy contradicts free-enterprise pursuits. It is suggested, therefore, that as a first stage, NGA take the policy in which the floor price is 1.30 pesos per kg. and the ceiling price is 2.70 pesos per kg. This policy does not imply fixed prices and subsidies ($1.30/.61 + .45 < 2.70$), and its expected utility is only slightly lower than that of [1.30, 2.90] which was shown to be optimal under the no-subsidy constraint. A ceiling price of 2.70 pesos per kg. may result in a sharp increase of the consumer price. The probability of such an increase, however, is lower under the suggested policy than under the current policy. This is because of the expected higher production in response to the higher floor price. In the rare case of a nationwide disaster, NGA may launch a temporary emergency program of subsidies. In addition, the government can compensate consumers for the increase in the price of rice by tax, welfare, and other programs.

In order to avoid what Raiffa calls the error of the fourth kind, namely, solving the right problem too late, it is suggested that other major improvements, such as incorporating other commodities into the model or constructing a dynamic model, be postponed until after the first stage of the implementation has taken place. This is consistent with the integrative and operational approach advanced in this paper.

Footnotes

*Giannini Foundation Paper No. .

[1]For a very good description of the 50-50 lotteries procedure, see Anderson, Dillon, and Hardaker (pp. 70-75).

[2]The following data were used in analyzing the model: average family size of rice-growing farm is 6.5 (Hayami et al.); current yearly consumption of rice is 100 kg. per capita (Aviguetero); rate of recovery from palay to rice is .61; wet season production is 62.5 percent of the total yearly production; yield of irrigated and nonirrigated farms is 2.25 and 1.5 tons per hectare, respectively (45 and 30 cavans per hectare); the number of irrigated and nonirrigated farms is 360,000 and 600,000, respectively, with an average farm size of 2.5 hectares; current price to consumers is 2.10 pesos per kg. (Alix, Kunkel, and Gonzales); cost of labor per irrigated and nonirrigated hectare is 400 pesos per hectare and 300 pesos per hectare, respectively; cost of inputs is 400 pesos per hectare and 250 pesos per hectare, respectively (NGA files); and exchange rate is 7.3 pesos per dollar.

[3]The value, .84, for $u_i(x_i)$, $i \neq j$, was chosen so that $0 \leq u_j(x_j) \leq 1$ for all j.

[4]This is certainly true for the [1.40, 2.10] policy which was found to be the optimal policy over a broader range of the floor price.

[5]For completeness of presentation, the analysis below also compares policies examined in the sensitivity analysis section which appears later in the paper.

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