FOOD POLICY IN BANGLADESH

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OPTIMAL STOCK FOR THE PUBLIC FOODGRAIN DISTRIBUTION SYSTEM IN BANGLADESH

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FOREWORD

In early 1989, the International Food Policy Research Institute entered into a contract with the U.S. Agency for International Development (USAID), Dhaka (under Contract No. 388-0027-C-00-9026-00), to conduct research on food policies and to extend technical assistance to the Ministry of Food, Government of Bangladesh. The Bangladesh Food Policy Project is the basis for a tripartite collaboration between IFPRI, the Government of Bangladesh, and USAID, Dhaka. This project consists of four subprojects and a large number of well-defined research topics. The subprojects together constitute a comprehensive approach for addressing the food policy problems of Bangladesh. The subprojects include the following studies: a price stabilization framework encompassing public and private marketing, evaluation of the effects of targeted distribution of foodgrains on consumption and nutrition, diversification of agriculture as a source of sustained growth of production, and capacity-building in food policy analysis.

This paper on determination of optimal public stocks of foodgrains for the purpose of price stabilization and targeted distribution is an important study under the first subproject. The level of stock is a significant determinant of the level of cost of the public distribution system. It is hoped that this study on optimal stock will enable a greater degree of efficiency in the use of stock in the public distribution system than has been possible in the past.

Raisuddin Ahmed

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1. SUMMARY

The search for an estimate of the optimal stock of public foodgrain has been a constant and intense demand from donors and policymakers in Bangladesh. The meaning of optimality has, however, remained different to different persons. A general perception in these debates is that there may be a precise figure that represents the optimal level of public stock. Optimality implies minimization of cost or maximization of net gains in achieving an objective. In the context of the present exercise (that is, estimation of an optimal foodgrain stock for the government), the optimal level of public foodgrain stock is defined as the level of stock that ensures a number of objectives such as a certain degree of price stabilization and a certain amount of foodgrain supply through the rationing system and for the food-for-work operations, vulnerable group development, and other relief programs at minimum cost. The definition of optimality is somewhat limited in the sense that the benefits from these public interventions are not questioned and incorporated into the analysis. However, sensitivity to changes in various types of interventions and their implications for the estimates of optimal stock are shown in this paper. As a result, it is possible to point out the optimal level of public stock for the present degree of public interventions and the stock levels for reduced degrees of public interventions or changes in policies. This procedure gives a range of estimates of optimal stocks and the corresponding types and degrees of public interventions, providing a space for gradual reform in policies and management of interventions.

The estimation of the optimal public stock obviously requires a comprehensive model that integrates a dynamic foodgrain sector with chosen policy regimes and well-defined objective and cost functions. Further, the mechanisms of simulation and sensitivity analysis are required for examination of results with varying assumptions. These analytical elements are developed in the paper. The dynamic foodgrain sector model captures the inherent seasonality of foodgrain prices, the effects of private storage decisions, and government activities involving procurement and offtakes from public godowns. In defining the objective function of the government the main concerns of price stability, minimal fiscal costs, and food security through targeted distribution (rations, food-for-work, vulnerable group development, and relief programs) were taken into consideration.

Because results of the analysis vary with the types of policies, it is necessary to understand the policies well before reading the estimates of stocks. Estimates of optimal stock relate to six types of policies specified in this paper. These are price band policy, optimal price stabilization policy, import policy approach to price

stabilization, cost minimization policy, price stabilization cum cost minimization (also called the benchmark policy in this paper), and approximation to optimal price stabilization. An estimate with a no-rationing policy is also added at the end. The specific contents of each of these policies can be gauged from the presentations in the main text. A baseline picture is developed in order to show how each policy simulation compares with the baseline.

The estimated stock requirements and costs for the specified policies are shown in the following table.

Policy	Average Total Foodgrain Stock	Total Cost
	(1,000 metric tons)	(Tk million)
Baseline	1,075	17,045
Price band	1,452	19,632
Optimal price stabilization	1,128	8,392
Import policy	847	14,716
Cost minimization	686	6,046
Benchmark: price stabilization cum cost minimization	724	5,137
Approximation to optimal price stabilization	876	8,473
No ration distribution	690	2,741

The baseline in the table is obtained by simulating the foodgrain model for the period July 1985-June 1988. The price band is defined by a plus or minus 4 percent margin around the target price. The optimal price stabilization policy uses open market operations to minimize the variance of rice prices around the target. The import policy uses imports to minimize variance of rice prices around the target. The cost minimization policy uses open market operations to minimize the total cost of food operations. The benchmark refers to cost minimization cum price stabilization, which uses open market operations and imports to minimize the total cost of food operations subject to price stabilization and foreign reserves constraints. The approximation to optimal price stabilization was computed through stochastic simulations of production shocks and ordinary least squares over rice production, wheat production, and a lagged term. No ration distribution refers to the benchmark when monetary offtakes are eliminated. Total cost equals procurement cost plus import cost minus ration sales minus open market sales.

The estimates in the table show that the optimal stock varies from the level of 686,000 metric tons for the cost minimization policy to 1,452,000 tons for the effective price band policy. Cost minimization implies allowing prices to go up in the peak price season in order to make a profit by public sale or to go down sharply in order to buy grains at cheap prices. Price stabilization is of no concern. Such a strategy forsakes the prime objective (that is, price stabilization) of the public system. Therefore, it may not be acceptable to policymakers. The policy of price stabilization cum cost minimization appears to be one of the best options and can be further improved by elimination of rationing if evaluation of the rationing scheme justifies such elimination.

One interesting piece of evidence that emerges from this exercise is that the cost and level of stock are higher for the price band policy than for other policies. This result originates from the maintained rigidity of a price band policy. When this assumption of a rigid price band is abandoned, the policy becomes similar to the approximation to optimal price stabilization, in which case both the stock level and cost are substantially reduced.

For the sake of simplicity, the policies are specified discretely and with somewhat narrower domain than would be dictated by the exigencies of actual application. In actual application, some of these policies would be combined to achieve multiple goals. But discrete analysis provides a sense of direction of change in levels of stock and costs due to these combinations. For example, some flexible price band, import, open market operations, and cost minimization goals would be implicit in an ideal price stabilization mechanism. In the present context it is important that these policies, if applied in a balanced and effective manner, would not require a stock level above about 750,000 tons and would also cost much less than historically experienced.

For low-cost operation of price stabilization, the analysis indicates that use of three policy instruments, that is, import policy, open market purchase, and open market sale (purchase and sale are defined as open market operations) have to be very judicious. In the past, import of foodgrain has not been based on rational analysis. Open market operations have also remained very timid. Moreover, management of these operations (not specifically analyzed here) is known to have caused inefficiency and high cost. The analysis here shows that private trade is very sensitive in price speculation and stocking behaviors to the public stock situation and operation. Therefore, erratic behavior in the public sector will compound the adverse effects throughout the foodgrain market.

This paper assumes that the public sector will continue in the Bangladesh foodgrain market and analyzes how the objectives of this sector can best be achieved with optimal stock and lower cost. There is of course a larger issue, which the paper does not address: Is the public sector necessary at all? Inefficiency in the public sector may generate the momentum for a comprehensive look at this larger issue.

2. INTRODUCTION

The foodgrain sector in Bangladesh is characterized by the active presence of the government sector, which is involved in various operations related to domestic procurement, public distribution, imports, and open market sales.

Central to this involvement is the management of public foodgrain stocks. The main issue related to public stocks is the need to understand the policy principles informing the stock policy. The broad concern of foodgrain stock policy is to guarantee food security at minimum cost. Ways of mitigating this concern are examined in this study.

Until as recently as 1988, the general guidelines of stock policy in Bangladesh followed the recommendations of the World Bank expressed in an influential report (World Bank 1979). That report suggested that the total foodgrain stock be 1.5 million metric tons as of July 1 of every year and 1.2 million tons as of November 1.[1] As pointed out by Chowdhury (1990), the World Bank's recommendation of a fixed stock on July 1 of every year misses the point that the multiple crop pattern of Bangladesh rice cultivation allows production downfalls that occur in one crop season to be compensated for within the same year. The recommendations of the World Bank in 1979 appear to be overly cautious, understandably so in light of the severe drought experienced in Bangladesh in that year. Nevertheless, in the years following 1981, government stocks have rarely exceeded the level of 1.2 million tons.

Taking into account the population growth, the per capita figures of stock levels have been much smaller than those the World Bank recommended in 1979. This situation has not prevented both nominal prices of rice and wheat and nominal prices deflated by the index of manufactured goods to become more stable from the 1970s to the 1980s. Tables 1 and 2 indicate both lower coefficients of variation of price and smaller yearly spreads between high and low prices for rice and wheat. The variability of total stocks decreased during 1972/73-1989/90 (Tables 3 and 4), even though Bangladesh experienced two of the worst production calamities of its history in 1987/88 and 1988/89.

The foregoing observations suggest that stock policy guidelines have to be revised substantially. During 1981-91 the foodgrain sector of Bangladesh has witnessed a few remarkable changes: a changed pattern of seasonality of production and prices (Ahmed and Bernard 1989; Chowdhury 1987); a reduced role for subsidized distribution (Chowdhury 1990); increasing experience with open market sales (Chowdhury 1990);

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[1] All tons referred to in this report are metric tons.

Table 1—Nominal rice and wheat prices, 1972/73-1989/90

Year[a]	Rice Price Average	Rice Price c.v.[b]	Rice Price Spread[c]	Wheat Price Average	Wheat Price c.v.[b]	Wheat Price Spread[c]
	(Tk/maund)	(percent)		(Tk/maund)	(percent)	
1972/73	75	14	50	n.a.	n.a.	n.a.
1973/74	100	21	64	62	35	143
1974/75	210	17	89	141	22	120
1975/76	124	24	94	77	34	157
1976/77	113	11	42	79	12	44
1977/78	138	6	20	91	9	40
1978/79	152	18	68	91	10	40
1979/80	201	8	31	124	15	64
1980/81	168	6	22	111	3	11
1981/82	220	17	69	135	15	48
1982/83	240	6	21	162	9	36
1983/84	262	7	23	167	9	25
1984/85	294	6	23	170	8	29
1985/86	280	7	22	181	7	26
1986/87	341	9	34	209	5	20
1987/88	352	5	17	215	6	22
1988/89	362	5	18	224	5	12
1989/90	355	5	20	233	3	13

Source: Based on data from Bangladesh Bureau of Statistics, Monthly Statistical Bulletin, various dates.

Note: n.a. means not available.

[a] The fiscal year starts in July.
[b] C.v. is the coefficient of variation, computed with monthly prices.
[c] Spread is the percentage difference between the highest and the lowest price of the year.

reduced gaps between market prices, ration prices, and procurement prices (Abdullah 1989b); and reduced subsidies on agricultural inputs such as fertilizers and irrigation equipment (Abdullah 1989a). At the same time, the need for a new framework to analyze the foodgrain stock problem has arisen. The initial attempts by Abbott (1988) for the FAO, Ahmed and Bernard (1989) at IFPRI, and Chowdhury (1987, 1988, 1990) and Shahabuddin (1990) for IFPRI form part of the growing literature. The general direction of these studies is away from a passive endorsement of quantity targets toward a more complete analysis of the food system of Bangladesh that tries to capture the complex interrelation between the free market and government operations. Moreover, a new concern related to the optimal stock problem has been emerging, where the word "optimal" refers to some prespecified policy or welfare concept. In particular, there is a growing awareness of the financial cost implications of different stock levels.

Table 2—Rice and wheat prices deflated by index of manufactured goods, 1972/73-1989/90

Year[a]	Rice Price Average	Rice Price c.v.[b]	Rice Price Spread[c]	Wheat Price Average	Wheat Price c.v.[b]	Wheat Price Spread[c]
	(Tk/maund)	(percent)		(Tk/maund)	(percent)	
1972/73	0.31	11	42	n.a.	n.a.	n.a.
1973/74	0.30	17	58	0.18	31	109
1974/75	0.41	16	73	0.28	22	124
1975/76	0.29	30	126	0.18	40	189
1976/77	0.26	9	37	0.18	9	38
1977/78	0.30	14	57	0.20	20	87
1978/79	0.33	12	48	0.20	10	33
1979/80	0.35	11	42	0.22	18	80
1980/81	0.26	4	16	0.17	5	15
1981/82	0.31	15	60	0.19	12	36
1982/83	0.31	6	22	0.21	9	40
1983/84	0.35	11	42	0.22	11	37
1984/85	0.37	7	30	0.21	10	35
1985/86	0.33	5	17	0.21	8	26
1986/87	0.38	9	34	0.23	6	25
1987/88	0.38	6	19	0.23	7	25
1988/89	0.37	4	16	0.23	6	20
1989/90	0.33	5	19	0.22	3	13

Source: Based on data from Bangladesh Bureau of Statistics, Monthly Statistical Bulletin, various dates.

Note: n.a. means not available.

[a] The fiscal year starts in July.
[b] C.v. is the coefficient of variation, computed with monthly prices.
[c] Spread is the percentage difference between the highest and the lowest price of the year.

To give a very rough dimension of this financial cost, one may think of the cost of 100,000 tons of foodgrains (35 percent of which consists of rice and the rest of wheat) evaluated at average 1988/89 world prices. This cost, equal to US$20.8 million, or 671.2 million taka (Tk), represents approximately 5.8 percent of the agricultural Annual Development Programme (ADP) budget and 1.4 percent of the total ADP budget.

The main purpose of this study is to present a general framework for designing a cost-effective stock policy that addresses the government's concerns related to ensuring price stability and the food security of the vulnerable groups. The design of an optimal foodgrain stock policy entails the construction of a dynamic model of the foodgrain sector of Bangladesh and the use of programming techniques to facilitate the analysis of different policy interventions (for a similar approach applied to foodgrains in India, see Krishna and Chhibber 1983; for other commodities, see Ghosh, Gilbert, and Hughes Hallett 1987).

Table 3—Total foodgrain stocks, 1972/73-1989/90

Year[a]	Average Total Stocks	C.V. of Total Stocks[b]	Spread of Total Stocks[c]	Average Total Stocks per Capita	Security Days[d]
	(1,000 metric tons)	(percent)		(kilograms/person)	
1972/73	326	39	268	4.44	9
1973/74	239	29	169	3.18	7
1974/75	262	41	351	3.39	7
1975/76	852	16	60	10.76	22
1976/77	583	29	142	7.20	15
1977/78	608	17	83	7.30	15
1978/79	637	26	180	7.48	15
1979/80	666	28	331	7.62	16
1980/81	1,230	15	80	13.79	28
1981/82	1,029	27	139	11.34	23
1982/83	687	17	70	7.39	15
1983/84	637	20	80	6.70	14
1984/85	817	21	105	8.38	17
1985/86	882	17	67	8.86	18
1986/87	736	36	206	7.23	15
1987/88	1,053	15	66	10.09	21
1988/89	1,208	18	73	11.33	23
1989/90	1,181	20	73	10.82	22

Source: Bangladesh Bureau of Statistics, Monthly Statistical Bulletin, various dates.

[a] The fiscal year starts in July.
[b] C.v. is the coefficient of variation, computed with monthly stocks.
[c] Spread is the percentage difference between the highest and the lowest stock of the year.
[d] Security days express the number of days that public stocks would guarantee to the population of Bangladesh for that year a diet of 15.5 ounces of foodgrains.

In Chapter 3 the general approach to the design of stock policy is explained and formalized. In Chapter 4 the components of stock policy are put in their historical context. Chapter 5 presents a model of the foodgrain sector, incorporating decisions related to consumption and private storage. In Chapter 6 the policy constraints and policy objectives are spelled out. Various policy options are specified in Chapter 7, and the role of open market operations is discussed in Chapter 8. In Chapter 9 the evaluation of policy simulations is presented. Conclusions are given in Chapter 10. A series of appendixes deal with the technical aspects of the paper.

Table 4—Rice and wheat stocks, 1972/73-1989/90

Year[a]	Rice Stocks Average	Rice Stocks c.v.[b]	Rice Stocks Spread[c]	Wheat Stocks Average	Wheat Stocks c.v.[b]	Wheat Stocks Spread[c]
	(1,000 metric tons)	(percent)		(1,000 metric tons)	(percent)	
1972/73	44	44	271	282	45	433
1973/74	38	48	689	201	39	260
1974/75	63	102	4619	200	45	312
1975/76	382	43	182	470	17	80
1976/77	311	28	161	272	33	157
1977/78	234	64	530	373	35	200
1978/79	200	30	182	437	39	250
1979/80	294	35	533	372	34	312
1980/81	453	38	187	777	25	116
1981/82	481	26	158	548	32	148
1982/83	312	12	46	375	27	143
1983/84	213	30	239	424	29	172
1984/85	268	43	388	549	21	113
1985/86	400	14	57	482	26	163
1986/87	215	36	197	520	41	355
1987/88	350	21	89	703	14	68
1988/89	540	26	152	668	21	116
1989/90	619	25	154	562	44	368

Source: Based on data from Bangladesh Bureau of Statistics, Monthly Statistical Bulletin, various dates.

[a] The fiscal year starts in July.
[b] C.v. is the coefficient of variation, computed with monthly stocks.
[c] Spread is the percentage difference between the highest and the lowest stock of the year.

3. CHOICE OF APPROACH TO THE OPTIMAL STOCK PROBLEM

The search for an estimate of the optimal level of public foodgrain stock has been constantly demanded by donors and some policymakers in Bangladesh. Optimality has, however, been understood differently by different persons. In these debates the general perception is that there may be a precise figure that represents the optimal level. Optimality implies both minimization of cost and maximization of gains in achieving an objective. In the context of the present study, the optimal level of public foodgrain stock is defined as the level of stock that helps attain certain objectives such as price stabilization within given bands and a sufficient supply of foodgrains through the public distribution system at a minimum cost.

This definition is somewhat limited, since the benefits of these public interventions are not questioned and incorporated into the analysis.[2] However, various levels of these interventions and their implications for the estimates of optimal stocks are covered in this paper. This enables the study to recommend the optimal level of public stock under the present degree of public interventions and under reduced degrees of such interventions. This procedure gives a range of estimates of optimal stocks and the corresponding degrees of public interventions, providing room for gradual reform in public stock management and interventions.

The estimation of the optimal public stock obviously requires a comprehensive model that integrates a dynamic foodgrain sector with chosen policy regimes and well-defined objectives and cost functions. The techniques for simulation and sensitivity analysis are also required for examination of results with varying assumptions.

Three stages are involved in the design of the optimal stock policy problem. The first stage consists of the specification, identification, and estimation of a dynamic model of the foodgrain sector. The second stage comprises the specification and solution of an optimization exercise based on the dynamic model constructed in the first stage. The third stage is the evaluation of the optimal stock policy determined in the second stage.

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[2] The main reasons for not adopting a standard economic surplus approach are that, first, theoretical difficulties related to the use of consumers' surplus as an appropriate indicator of welfare still remain unanswered (Scandizzo and Bruce 1980; Scandizzo and Knudsen 1981; Cochrane 1980; Ladd 1987). Second, measures of consumers' surplus are of very limited value given the absence of reliable information about foodgrain consumption on a monthly or even a quarterly basis. Third, the objectives of food security and price stabilization are seen as the most relevant concerns for policy intervention, and their efficient implementation may be regarded as "optimal" policy.

The optimal stock problem may be formulated as the optimization of some objective function defining the priorities of the government, subject to the constraints imposed by the feasible performance of the market.

Formally, the optimization problem [P] can be expressed as follows:

$$[P]: \quad J_{t,T} = \min_{\{x_\tau\}} \; E_t \, (z_T P z_T + \sum_{\tau=t}^{\tau=T-1} W_\tau),$$

subject to

$$z_{\tau+1} = A_\tau \cdot z_\tau + B_\tau \cdot x_\tau \text{ and} \qquad (1)$$

$$l_\tau \;\leq\; z_\tau \;\leq\; u_\tau, \qquad (2)$$

where

$$W_\tau = z'_\tau \cdot \theta_\tau \cdot z_\tau + x'_\tau \cdot R_\tau \cdot x_\tau \qquad (3)$$

and the time index $\tau = t,...,T$.

In this notation z_τ is a vector of state variables, x_τ is the vector of control variables, with respect to which the government is optimizing. T is the time horizon of the optimization exercise, and the length of the optimization period is T - t + 1. P, A_τ, and θ_τ are matrices conformable with the vector z_τ; B_τ and R_τ are matrices conformable with x_τ.

The current period objective of the government is W_τ, which is assumed to be a quadratic form in the state and control variables; the final period objective is $z'_T P z_T$.

The state variables evolve according to the law of motion specified in equation (1) and are subject to inequality constraints as in equation (2). l_τ is the lower bound and u_τ is the upper bound for the state variable z_τ.

The optimal policy is a sequence of T-t+1 functions x^*_τ satisfying the problem [P].[3]

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[3] Because of the recursive structure of the problem, the optimal policy functions can be found by applying Bellman's equation recursively:

$$J_{t,T}(z_t) = \min_{x_t} E_t \, [W_t(x_t, z_t) + J_{t+1,T}(z_{t+1})],$$

subject to

$$z_{t+1} = A_t z_t + B_t x_t \quad \text{and}$$

$$l_t \;\leq\; z_{t+1} \leq u_t.$$

In the numerical solution of the optimal policy options considered in the text, the GAMS software has been used to find an open loop solution (Brooke, Kendrick, and Meeraus 1988).

Note that by specifying different government objectives and instruments, the general model can be used to deal with many different policy issues (see Chapter 7). The system in equation (1) represents the structural model of the foodgrain private sector, which the government is influencing by intervening through holding and distribution of stock. During the design of stock policy, the government takes into account the reaction of the private sector implied by a dynamic model of market behavior. At the same time, a set of other inequality constraints is imposed as specified in equation (2). Examples of these inequality constraints are capacity constraints, minimum stock requirements for food security, foreign reserves ceilings on food imports, and so on.

4. COMPONENTS OF FOOD STOCK POLICY

One way to gauge the extent of government operations in the foodgrain sector is to consider the ratio of total offtakes to total availability, the latter being defined as net domestic production (gross production less 10 percent for wastage and feed) plus imports plus opening stocks, for any particular year.

The dimension of government intervention in foodgrain distribution has been substantial, ranging from 8 percent to 21 percent, with an average value of 13 percent for the ratio of total offtakes to total availability (Table 5).

Table 5—Components of public distribution of foodgrains, 1972/73-1989/90

Year[a]	Production	Net Production[b]	Offtake	Procurement	Initial Stocks	Imports	Avail- ability[c]	Offtake/ Availability
	(1,000 metric tons)							(percent)
1972/73	10,023	9,021	2,657	0	303	2,871	12,195	21.8
1973/74	11,832	10,649	1,756	72	269	1,719	12,709	13.8
1974/75	11,226	10,103	1,785	129	215	2,401	12,848	13.9
1975/76	12,780	11,502	1,679	503	761	1,488	14,254	11.8
1976/77	11,825	10,643	1,374	320	836	825	12,624	10.9
1977/78	13,120	11,808	1,863	559	422	1,665	14,453	12.9
1978/79	13,140	11,826	1,762	358	601	1,165	13,949	12.6
1979/80	13,362	12,026	2,203	354	210	2,809	15,399	14.3
1980/81	14,975	13,478	1,686	1,034	794	1,089	16,394	10.3
1981/82	14,598	13,138	1,840	303	1,208	1,234	15,883	11.6
1982/83	15,312	13,781	1,893	192	615	1,840	16,428	11.5
1983/84	15,719	14,147	1,896	272	611	2,069	17,099	11.1
1984/85	16,086	14,477	2,426	340	800	2,580	18,197	13.3
1985/86	16,083	14,475	1,419	361	1,008	1,198	17,042	8.3
1986/87	16,498	14,848	1,820	188	976	1,767	17,779	10.2
1987/88	16,462	14,816	2,016	374	751	2,911	18,852	10.7
1988/89	16,382	14,744	2,685	408	1,498	2,138	18,788	14.3
1989/90	18,656	16,790	1,981	962	905	1,534	20,191	9.8

Source: Based on data from Bangladesh Bureau of Statistics, Statistical Yearbook 1989, (Dhaka: BBS, 1990).

[a] The fiscal year starts in July.
[b] Net production is 90 percent of production.
[c] Availability = initial stock + net production + imports + procurement - offtakes.

There are three sources of public supply:[4] domestic procurement, imports, and government stocks. The relative importance of each of these factors is illustrated in Table 6, which shows that the role of domestic procurement was greater during the second half of the 1970s than in the 1980s. The role of imports has always been crucial in government, with an average ratio of total imports to offtakes of foodgrains equal to 90 percent over the period from 1972/73 to 1989/90.

Table 6—Sources of public distribution of foodgrains, 1972/73-1989/90

Year[a]	Procurement	Procurement Ratio[b]	Imports	Imports Ratio	Stocks Change	Stocks Change Ratio	Offtake
	(1,000 metric tons)	(percent)	(1,000 metric tons)	(percent)	(1,000 metric tons)	(percent)	(1,000 metric tons)
1972/73	0	0	2,871	108	0	1	2,657
1973/74	72	4	1,719	98	-34	3	1,756
1974/75	129	7	2,401	134	-54	-31	1,785
1975/76	503	30	1,488	89	546	-4	1,679
1976/77	320	23	825	60	75	30	1,374
1977/78	559	30	1,665	89	-415	-10	1,863
1978/79	358	20	1,165	66	179	22	1,762
1979/80	354	16	2,809	128	-390	-26	2,203
1980/81	1,034	61	1,089	65	583	-25	1,686
1981/82	303	16	1,234	67	415	32	1,840
1982/83	192	10	1,840	97	-593	0	1,893
1983/84	272	14	2,069	109	-4	-10	1,896
1984/85	340	14	2,580	106	189	-9	2,426
1985/86	361	25	1,198	84	208	2	1,419
1986/87	188	10	1,767	97	-32	12	1,820
1987/88	374	19	2,911	144	-225	-37	2,016
1988/89	408	15	2,138	80	747	22	2,685
1989/90	962	49	1,534	77	-593	0	1,981

Source: Based on data from Bangladesh Bureau of Statistics, Statistical Yearbook 1989, (Dhaka: BBS, 1990).

[a] The fiscal year starts in July.
[b] The ratios are taken with respect to offtakes.

[4] From the balance equation for stocks,

$$stock^i_\tau = \delta^i \cdot stock^i_{\tau-1} + m^i_\tau + qp^i_\tau - offtakes^i_\tau - oms^i_\tau,$$

it is possible to see that the sources of offtakes and open market sales are given by changes in stocks ($\delta^i \cdot stock^i_{\tau-1} - stock^i_\tau$), imports ($m^i_\tau$), and procurement ($qp^i_\tau$). Divergences from the share of the imputed sources and the actual figures come from unreported losses and from omissions.

THE CONTEXT OF PRODUCTION

Rice is produced seasonally in Bangladesh. Within a year, three main crops denoted aman (harvested from November to January), boro (harvested from April to June), and aus (harvested from July to September) are grown. Traditionally, aman has been the largest crop. In the last few years, however, boro production has been increasing rapidly, taking its share from 21 percent of total production in 1973 to 35 percent in 1989, largely due to the diffusion of high-yielding varieties (HYVs) and the extension of irrigation facilities. Aus and aman shares have declined commensurately (Table 7). Therefore, production is now more evenly distributed over the year. Consequently, arrivals in the market occur more smoothly, implying less need for storage than in the past to mitigate seasonal shortfalls.

The annual growth of total rice production between 1972/73 and 1989/90 was 2.62 percent, with 3.08 percent in the 1970s and 2.57 percent in the 1980s (Tables 8 and 9; Figures 1 and 2). Moreover, total production per capita does not exhibit any trend. It has oscillated around its mean of 148 kilograms in a random fashion (Figure 3).

Table 7—Total production of rice, 1972/73-1989/90

Year[a]	Aman	Boro	Aus	Share of Total Rice Production Aman	Boro	Aus
		(1,000 metric tons)			(percent)	
1972/73	5,587	2,071	2,274	56	21	23
1973/74	6,699	2,220	2,802	57	19	24
1974/75	6,000	2,250	2,859	54	20	26
1975/76	7,045	2,286	3,230	56	18	26
1976/77	6,906	1,650	3,010	60	14	26
1977/78	7,422	2,239	3,104	58	18	24
1978/79	7,429	1,929	3,288	59	15	26
1979/80	7,303	2,427	2,809	58	19	22
1980/81	7,964	2,630	3,289	57	19	24
1981/82	7,209	3,152	3,270	53	23	24
1982/83	7,604	3,546	3,067	53	25	22
1983/84	7,936	3,350	3,222	55	23	22
1984/85	7,930	3,909	2,783	54	27	19
1985/86	8,542	3,671	2,828	57	24	19
1986/87	8,267	4,010	3,130	54	26	20
1987/88	7,690	4,731	2,993	50	31	19
1988/89	6,857	5,831	2,856	44	38	18
1989/90	9,202	6,166	2,488	52	35	14

Source: Based on data from Bangladesh Bureau of Statistics, Statistical Yearbook 1989, (Dhaka: BBS, 1990).

[a] The fiscal year starts in July.

Table 8—Growth of foodgrain production per capita, 1972/73-1989/90

Period	Rice: Aman	Rice: Boro	Rice: Aus	Wheat	Total Rice
			(percent)		
1972/73-1989/90	1.72	6.83	0.09	15.68	2.62
1972/73-1980/81	3.66	1.50	2.91	37.97	3.08
1981/82-1989/90	1.08	8.49	-2.20	-3.51	2.57

Source: Based on data from Bangladesh Bureau of Statistics, Statistical Yearbook 1989, (Dhaka: BBS, 1990).

Note: Growth rates are derived from regression of logarithms of production on time and constant.

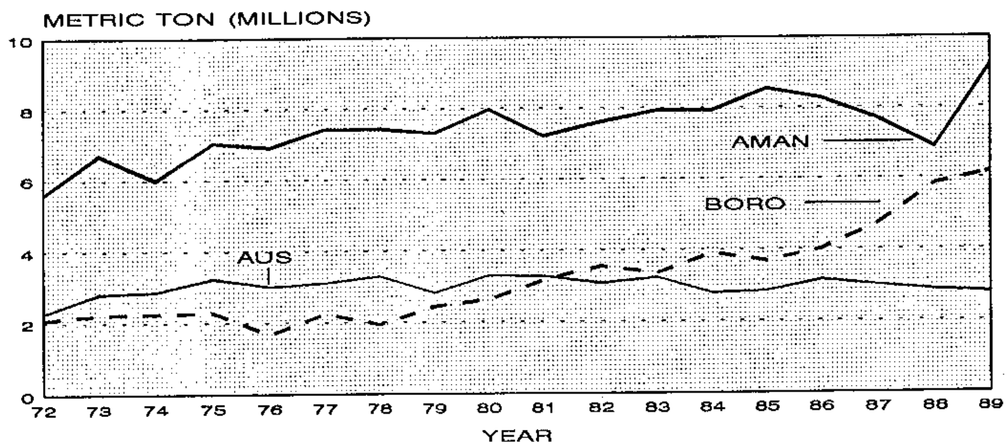
Table 9—Growth of foodgrain production, 1972/73-1989/90

Period	Rice: Aman	Rice: Boro	Rice: Aus	Wheat	Total Rice
			(percent)		
1972/73-1989/90	-0.58	4.41	-2.18	13.05	0.29
1972/73-1980/81	1.21	-0.90	0.48	34.71	0.64
1981/82-1989/90	-1.21	6.03	-4.42	-5.70	0.24

Source: Based on data from Bangladesh Bureau of Statistics, Statistical Yearbook 1989, (Dhaka: BBS, 1990).

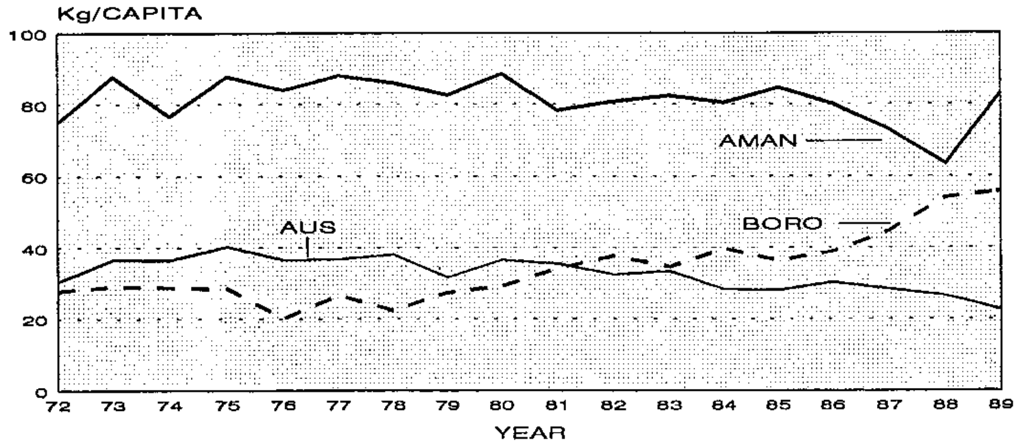
Note: Growth rates are derived from regression of logarithms of production on time and constant.

Figure 1—Total rice production, by harvest season, 1972-89



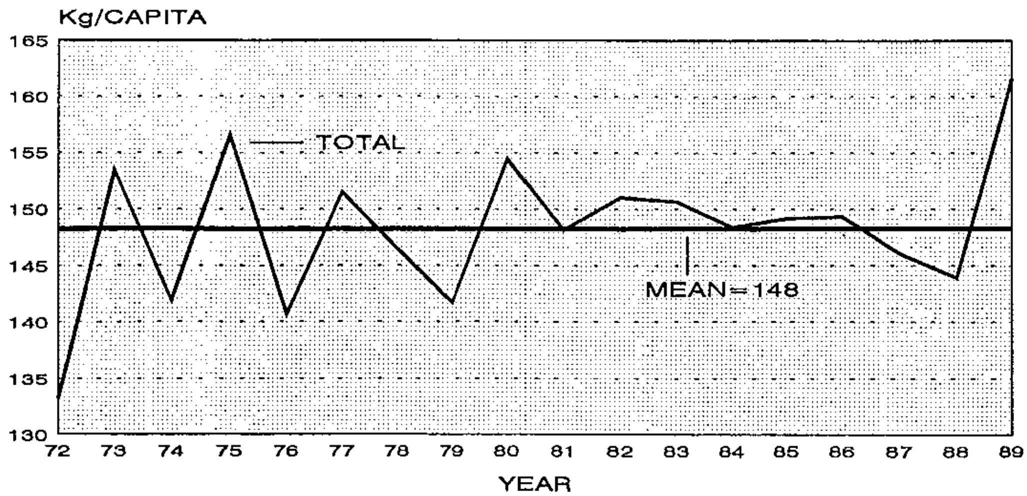
Source: Based on data from Bangladesh Bureau of Statistics, Statistical Yearbook (Dhaka: BBS, various years).

Figure 2—Rice production per capita, by harvest season, 1972-89



Source: Based on data from Bangladesh Bureau of Statistics, Statistical Yearbook (Dhaka: BBS, various years).

Figure 3—Total rice production per capita, 1972-89



Source: Based on data from Bangladesh Bureau of Statistics, Statistical Yearbook (Dhaka: BBS, various years).

These facts are also borne out by a trend analysis over the period 1972-90 (Table 10). Except for boro production, the growth rates are decelerating, as indicated by the negative sign of the quadratic trend terms.

In the past, public stocks have often shown a tendency to be overreplenished in expectation of a big shortfall in one crop. This tendency may be interpreted as a failure to understand the negative correlation among foodgrain crops. As the negative correlation between aman and boro and between aus and wheat shows (see Table 11), large shortfalls in one crop are associated with opposite movements in another crop, making the overall yearly production less variable than the seasonal production. These negative correlations are the reflections of adjustment mechanisms that are operative after a natural calamity. When a crop failure occurs due to drought or flood, farmers tend to make an above-normal effort to raise the subsequent crop in order to compensate for the loss. Moreover, a flood that causes loss to the aman or aus crop increases the supply of water for irrigation or in retained soil moisture that enhances the yields of boro and wheat crops in the subsequent dry season.

PROCUREMENT

Rice procurement was higher during the 1970s than during the 1980s (Table 12). However, procurement was abnormally high in 1980/81 and 1989/90 following major production shortfalls. Thus, procurement in these years may be seen as an excessive reaction of the government, more for the purpose of replenishing public stocks than to support a floor price.

Table 10—Production trends of rice and wheat, 1972/73-1989/90

Variable	Rice			Wheat
	Aman	Boro	Aus	
Constant	5,698.12	2,343.41	2,412.92	-400.75
Trend	287.61	-147.34	161.39	217.15
$Trend^2$	-8.61	19.48	-8.41	-7.97
R^2	0.64	0.95	0.55	0.84
SER	549.90	310.70	199.58	189.51
Mean of dependent variable	7,421.78	3,226.00	2,961.22	728.72

Source: Based on data from Bangladesh Bureau of Statistics, Statistical Yearbook 1989, (Dhaka: BBS, 1990).

Notes: The coefficients of the regression are all significant at least at 5 percent, except the quadratic term for aman, whose t-statistic is -1.59. The regression was done taking production levels over a constant, a linear trend term, and a quadratic trend term. Production levels are measured in 1,000 metric tons. SER is standard error of regression.

Table 11—Correlation matrix of crop residuals from trend regression

Crop	Rice			Wheat
	Aman	Boro	Aus	
Rice				
Aman	1.00	-0.27	-0.02	-0.07
Boro	-0.02	-0.03	1.00	-0.42
Aus	-0.27	1.00	-0.03	0.14
Wheat	-0.07	0.14	-0.42	1.00

Source: Based on data from Bangladesh Bureau of Statistics, Statistical Yearbook 1989, (Dhaka: BBS, 1990).

Notes: The residuals are obtained from a quadratic trend regression as computed from the results in Table 10.

Table 12—Yearly procurement of rice and wheat, 1973/74-1989/90

Year[a]	Rice	Rice Procurement as Share of Production	Rice per capita	Wheat	Wheat Procurement as Share of Production	Wheat per capita
	(1,000 metric tons)	(percent)	(grams)	(1,000 metric tons)	(percent)	(grams)
1973/74	72	0.6	957	n.a.	n.a.	n.a.
1974/75	129	1.2	1,669	n.a.	n.a.	n.a.
1975/76	503	4.0	6,356	n.a.	n.a.	n.a.
1976/77	317	2.7	3,898	n.a.	1.2	37
1977/78	548	4.3	6,576	11	3.1	133
1978/79	306	2.4	3,596	52	10.5	604
1979/80	228	1.8	2,600	126	15.3	1,432
1980/81	855	6.2	9,596	179	16.4	1,998
1981/82	290	2.1	3,201	13	1.3	147
1982/83	168	1.2	1,800	24	2.2	256
1983/84	154	1.1	1,623	118	9.7	1,231
1984/85	130	0.9	1,328	210	14.3	2,143
1985/86	231	1.5	2,322	130	12.5	1,,297
1986/87	136	0.9	1,325	52	4.8	506
1987/88	288	1.9	2,747	86	8.2	819
1988/89	364	2.3	3,411	44	5.3	409
1989/90	919	5.1	8,403	43	5.4	391

Source: Based on data from Bangladesh Bureau of Statistics, Statistical Yearbook 1989, (Dhaka: BBS, 1990).

Note: n.a. means not available.

[a] The fiscal year starts in July.

Wheat is much more dominant in public procurement than rice. As a percentage of production, procurement of rice averaged 3 percent in the 1970s and 2 percent in the 1980s, whereas wheat averaged 5 percent in the 1970s and 7 percent in the 1980s. Moreover, in per capita terms, rice procurement has been declining, whereas wheat procurement has exhibited an upward trend. Wheat is procured only in the three to four months following the March-April harvest. Rice is procured throughout the year, reaching its peak in December-January, during the aman harvest, and in June-July, following the boro harvest. In the past few years, because of the growing importance of the boro season, rice procured during May-July has been greater than the procurement made during the aman season.

The following general observations in terms of procurement prices can be made. It seems that wheat procurement prices have been closer to market prices than rice procurement prices (Table 13; Figures 4 and 5). Moreover, both rice and wheat procurement prices followed a clear pattern during the second part of the 1980s, consisting of a smoothening of the deviations from market prices. In the case of wheat, the smoothening was associated with a general movement toward relatively higher procurement prices. Nevertheless, as shown in the analysis of procurement supply in Appendix 1, procurement prices have not been effective in stimulating procurement supply.

Table 13—Mean divergence with respect to market prices of rice and wheat, 1972-89

Fiscal Years	Procurement Price	Ration Price	World Price	Open Market Sales Price[a]
		(percent)		
Rice price divergences				
1972-89	-14.4	-27.7	10.2	1.9
1970s	-18.3	-45.1	17.2	-2.5
1980s	-11.3	-13.7	4.7	2.3
1980-84	-11.4	-18.2	17.5	4.4
1985-89	-11.3	-9.1	-8.2	0.3
Wheat price divergences[b]				
1972-89	-8.3	-16.0	-5.4	3.8
1970s	-5.2	-28.7	-9.5	0.3
1980s	-9.8	-7.0	-2.4	4.1
1980-84	-10.8	-9.7	0.0	4.3
1985-89	-8.8	-4.4	-4.9	4.0

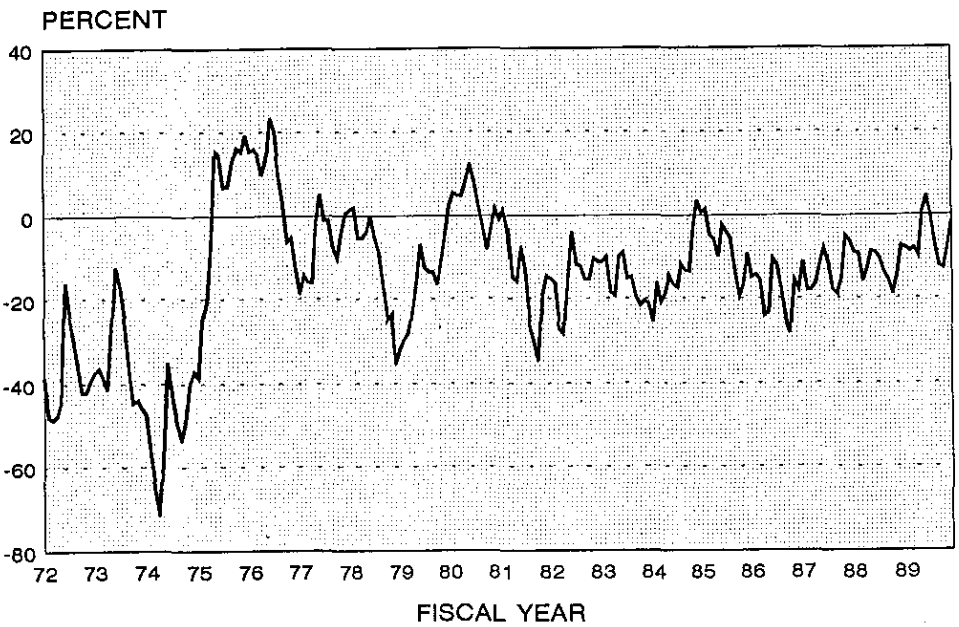
Source: Based on data from Bangladesh Bureau of Statistics, Monthly Statistical Bulletin, various dates.

Notes: The divergences are computed with respect to domestic market prices. The 1970s are from July 1972 to June 1980; the 1980s are from July 1980 to June 1990; 1980-84 is from July 1980 to June 1985; and 1985-89 is from July 1985 to June 1990.

[a] Data for open market sales mean divergences calculations are available from July 1979 onward for both rice and wheat.

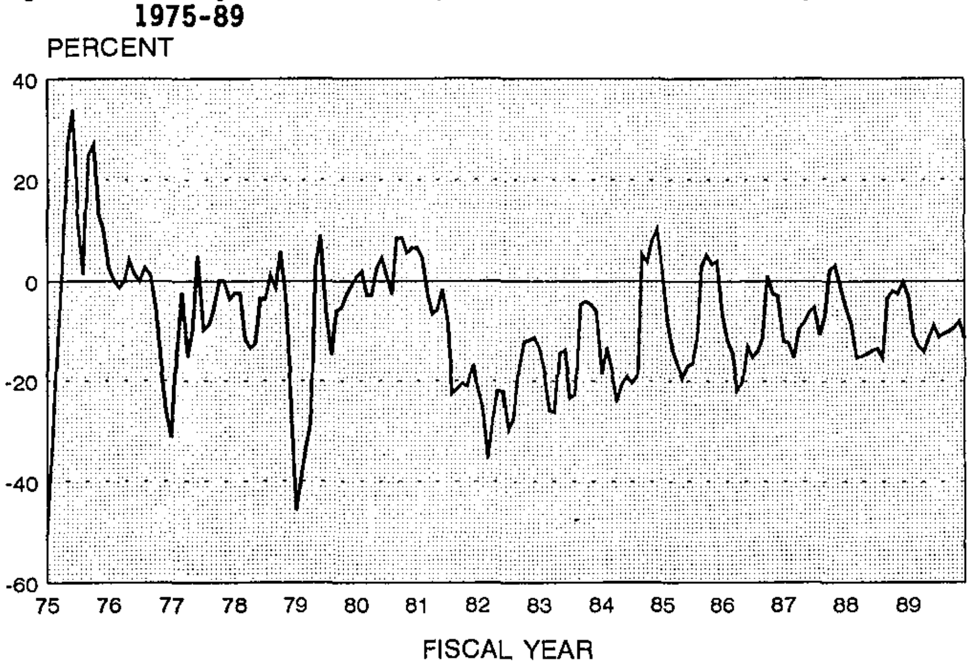
[b] For wheat, data for ration price and world price mean divergences calculations are available from July 1973 onward and for procurement from July 1975 onward.

Figure 4—Divergence between procurement and market prices of rice, 1972-89



Source: Based on data from Bangladesh Bureau of Statistics, Monthly Statistical Bulletin, various dates.

Figure 5—Divergence between procurement and market prices of wheat, 1975-89



Source: Based on data from Bangladesh Bureau of Statistics, Monthly Statistical Bulletin, various dates.

OFFTAKES

The purported objective of a dual market system is to make foodgrains available to those sections of the population that are most sensitive to food prices and who, even in normal circumstances, experience malnutrition and hunger. Unfortunately, in the past, most of the public supply in Bangladesh has been geared to the needs of the urban population and government employees, with a strong bias against rural areas, where the food problems are often more severe. This long-term bias has been partly corrected in recent years through changes in the rationing system (Chowdhury 1988; World Bank 1990; Goletti and Ahmed 1991).

Wheat offtakes have been growing both in absolute levels and in per capita terms. Rice has exhibited an opposite trend, to the extent that wheat offtakes in the most recent years have been about three times as much as rice offtakes (Table 14). The seasonal pattern of rice offtakes and wheat offtakes is quite similar, with a peak before the aman harvest (October-November) and before the boro season (March-May). In terms of ration prices, the subsidies on both rice and wheat have been gradually reduced (Table 13; Figures 6 and 7), and wheat ration prices are exhibiting less divergence from market prices than rice.

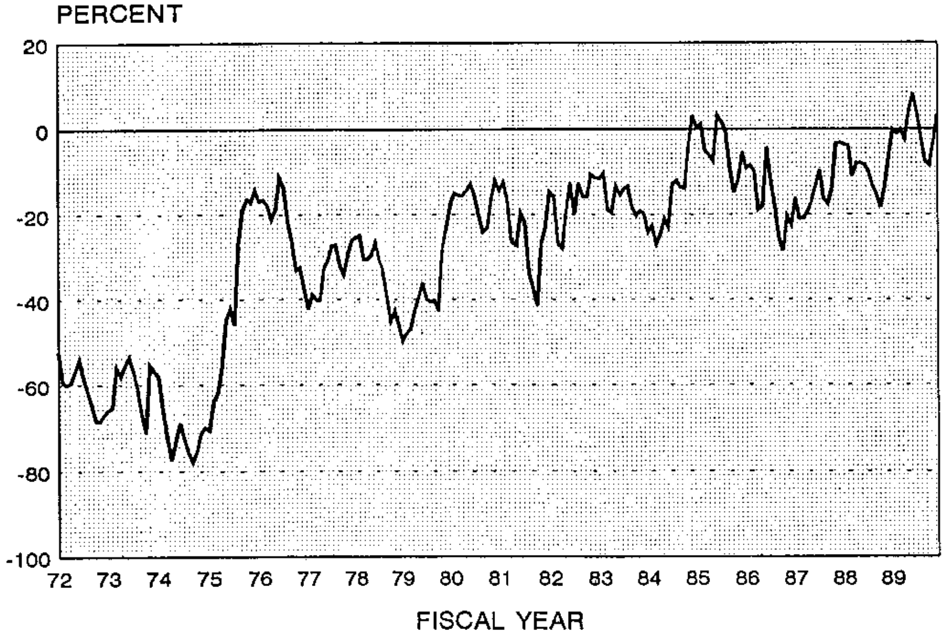
Table 14—Yearly offtakes of rice and wheat, 1972/73-1989/90

Year[a]	Rice	Rice per Capita	Wheat	Wheat per Capita
	(1,000 metric tons)	(grams)	(1,000 metric tons)	(grams)
1972/73	425	5,794	2,232	30,348
1973/74	125	1,660	1,630	21,639
1974/75	182	2,356	1,603	20,768
1975/76	502	6,339	1,177	14,902
1976/77	717	8,830	656	8,086
1977/78	600	7,218	1,263	15,195
1978/79	569	6,683	1,193	13,978
1979/80	695	7,962	1,508	17,290
1980/81	450	5,049	1,236	13,867
1981/82	589	6,479	1,251	13,752
1982/83	533	5,743	1,360	14,623
1983/84	426	4,478	1,470	15,431
1984/85	360	3,710	2,066	21,248
1985/86	309	3,106	1,110	11,139
1986/87	339	3,322	1,481	14,515
1987/88	340	3,271	1,676	16,088
1988/89	522	4,890	2,163	20,258
1989/90	655	5,990	1,326	12,149

Source: Based on data from Bangladesh Bureau of Statistics, Statistical Yearbook 1989, (Dhaka: BBS, 1990).

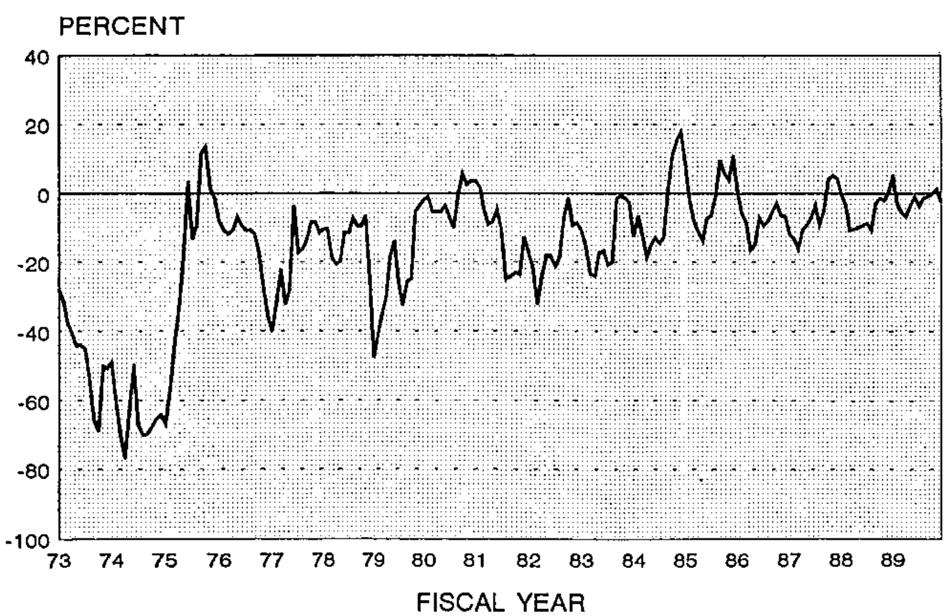
[a] The fiscal year starts in July.

Figure 6—Divergence between ration and market prices of rice, 1972-89



Source: Based on data from Bangladesh Bureau of Statistics, Monthly Statistical Bulletin, various dates.

Figure 7—Divergence between ration and market prices of wheat, 1973-89



Source: Based on data from Bangladesh Bureau of Statistics, Monthly Statistical Bulletin, various dates.

The analysis of the demand for ration distribution in Appendix 2 shows that ration prices of rice have had a significant impact on ration distribution, whereas for wheat ration prices this is not the case.

IMPORTS AND WORLD PRICES

Traditionally, imports of foodgrains in Bangladesh have been the domain of public monopoly. Only recently, under pressure from donors, some private imports have been allowed, but their importance is still negligible (USAID 1988, 1989). The most powerful factor affecting imports has been food aid, which in turn has been responsive to both public stocks and expected production shortfalls. From the analysis of a simple model of import demand where imports are related to world prices, public stocks, domestic production, and lagged imports, it seems that imports have not been influenced by world prices, as indicated by the low significance of the coefficients of world prices (Table 15). The gap between world and domestic prices of rice has been fluctuating considerably, with domestic prices losing competitiveness with international prices in the last half of the 1980s (Tables 16-18; Figures 8 and 9). Per capita imports of both rice and wheat have not exhibited any definite trend. Most of the large arrivals occur in July-September (Table 19).

Table 15—Estimated equations for imports of rice and wheat, 1975/76-1989/90

Variable	Coefficient	t-statistic
Rice imports equation		
Constant	1.365	1.80
wop_t^R	1.369	0.62
$stock_{t-1}^R$	-0.297	-3.59
$stock_{t-1}^W$	-0.017	-0.23
q_t^R	-0.002	-0.31
m_{t-1}^R	0.237	1.92
N	59	
R^2	0.27	
SEE	0.96	
Wheat imports equation		
Constant	5.207	2.10
wop_t^W	11.381	0.90
$stock_{t-1}^R$	-0.497	-2.07
$stock_{t-1}^W$	-0.534	-2.19
q_t^R	0.030	2.15
m_{t-1}^W	0.005	0.03
N	59	
R^2	0.28	
SEE	2.67	

Source: Estimated by the authors, based on data from Bangladesh Bureau of Statistics, Monthly Statistical Bulletin, various dates.

Definitions of terms:

wop_t^R, wop_t^W = world prices of rice and wheat in period t;

$stock_{t-1}^R$, $stock_{t-1}^W$ = opening public stocks of rice and wheat;

q_t^R = domestic rice production in period t;

m_{t-1}^R, m_{t-1}^W = lagged imports of rice and wheat;

SEE = standard error of estimation.

Table 16—Coefficients of variation of world and domestic prices of rice and wheat, 1973/74-1989/90

Year[a]	World Rice Price c.v.	World Wheat Price c.v.	Domestic Rice Price c.v.	Domestic Wheat Price c.v.	Average Difference of World/ Domestic Rice Prices	Average Difference of World/ Domestic Wheat Prices	Domestic c.v./ World c.v. of Rice	Domestic c.v./ World c.v. of Wheat
				(percent)				
1973/74	20.44	13.33	20.66	35.28	-32.70	5.64	1.01	2.65
1974/75	16.64	13.62	17.02	21.88	50.75	124.56	1.02	1.61
1975/76	13.51	5.42	24.17	33.84	-23.64	-19.01	1.79	6.25
1976/77	6.12	10.70	11.49	12.01	-24.09	9.49	1.88	1.12
1977/78	17.80	9.47	5.74	9.47	-24.71	36.08	0.32	1.00
1978/79	7.49	9.80	17.65	10.03	-17.79	10.12	2.36	1.02
1979/80	8.94	7.90	8.34	15.02	-8.38	17.87	0.93	1.90
1980/81	12.66	8.47	6.16	3.24	-42.21	-12.18	0.49	0.38
1981/82	15.44	3.19	17.15	14.66	-20.63	1.13	1.11	4.59
1982/83	4.84	5.61	5.86	8.51	-0.62	10.28	1.21	1.52
1983/84	6.06	2.25	7.45	8.87	5.94	4.78	1.23	3.94
1984/85	5.95	7.74	5.55	8.48	26.96	5.88	0.93	1.09
1985/86	5.60	7.43	6.68	7.43	16.74	-11.37	1.19	1.00
1986/87	3.12	5.56	9.06	5.09	43.72	34.25	2.90	0.92
1987/88	12.07	14.00	5.25	5.85	11.25	30.67	0.43	0.42
1988/89	6.01	2.40	5.05	4.76	0.79	-9.29	0.84	1.99
1989/90	6.71	3.49	5.36	3.02	-9.64	2.45	0.80	0.86
				Means				
1973-89	9.96	7.67	10.51	12.20	-2.84	14.20	1.20	1.90
1973-76	14.18	10.76	18.34	25.76	-7.42	30.17	1.43	2.91
1977-80	11.72	8.91	9.47	9.44	-23.27	12.98	1.02	1.08
1981-85	7.58	5.24	8.54	9.59	5.68	2.14	1.14	2.43
1986-89	6.98	6.38	6.18	4.68	11.53	14.52	1.24	1.05

Source: Based on data from Bangladesh Bureau of Statistics, Monthly Statistical Bulletin, various dates; and World Bank, Commodity Trade and Price Trends (Washington, D.C.: World Bank, various years).

Notes: World price of rice: 5 percent broken, white, milled, government standard, f.o.b. Bangkok export price. World price of wheat: from July 1973 to September 1973, no.1 Canadian Western Red Spring; from October 1973 to March 1985, no.1 Canadian Western Red Spring, 13.5 percent protein; from April 1985 to June 1990, St. Lawrence export. C.v. is the coefficient of variation of monthly prices.

[a] The fiscal year starts in July.

Table 17—Correlation matrix of world and domestic price levels for rice and wheat

Item	World Price of Rice	World Price of Wheat	Domestic Price of Rice	Domestic Price of Wheat
World price of rice	1.00	0.85	0.75	0.78
World price of wheat		1.00	0.87	0.86
Domestic price of rice			1.00	0.96
Domestic price of wheat				1.00

Source: Based on data from Bangladesh Bureau of Statistics, Monthly Statistical Bulletin, various dates; and World Bank, Commodity Trade and Price Trends (Washington, D.C.: World Bank, various years).

Notes: World price of rice: 5 percent broken, white, milled, government standard, f.o.b. Bangkok export price. World price of wheat: from July 1973 to September 1973, no.1 Canadian Western Red Spring; from October 1973 to March 1985, no.1 Canadian Western Red Spring, 13.5 percent protein; from April 1985 to June 1990, St. Lawrence export. C.v. is the coefficient of variation of monthly prices.

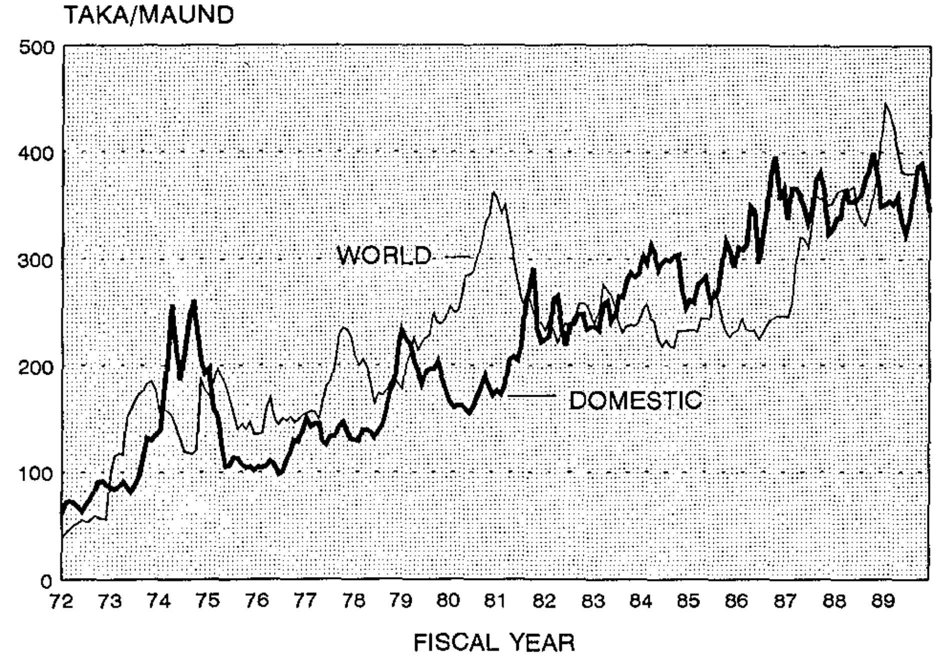
Table 18—Correlation matrix of world and domestic price differences for rice and wheat

Item	World Price of Rice	World Price of Wheat	Domestic Price of Rice	Domestic Price of Wheat
World price of rice	1.00	0.18	-0.04	-0.01
World price of wheat		1.00	-0.04	-0.05
Domestic price of rice			1.00	0.52
Domestic price of wheat				1.00

Source: Based on data from Bangladesh Bureau of Statistics, Monthly Statistical Bulletin, various dates; and World Bank, Commodity Trade and Price Trends (Washington, D.C.: World Bank, various years).

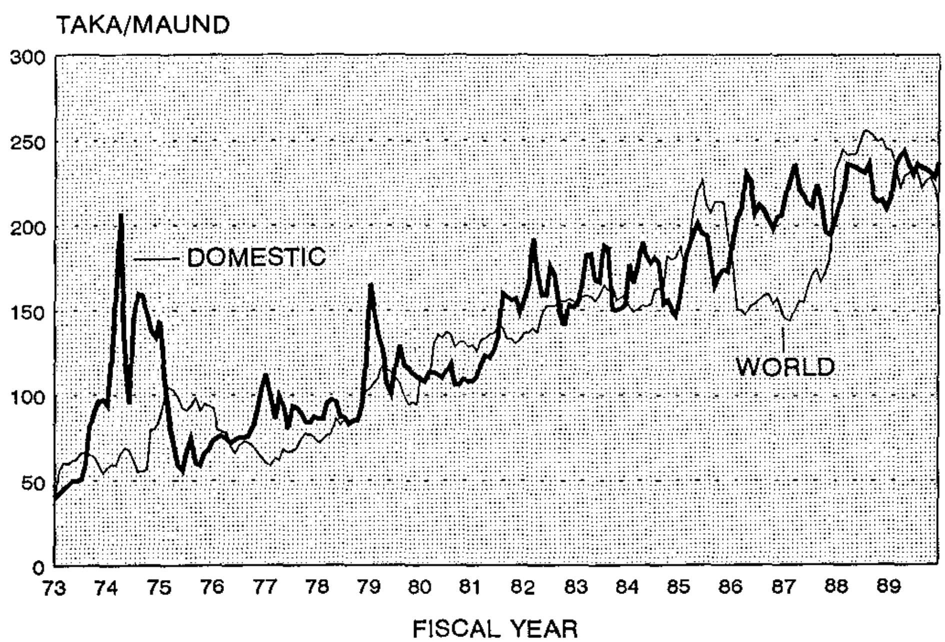
Notes: World price of rice: 5 percent broken, white, milled, government standard, f.o.b. Bangkok export price. World price of wheat: from July 1973 to September 1973, no.1 Canadian Western Red Spring; from October 1973 to March 1985, no.1 Canadian Western Red Spring, 13.5 percent protein; from April 1985 to June 1990, St. Lawrence export. C.v. is the coefficient of variation of monthly prices.

Figure 8—Rice prices, 1972-89



Source: Based on data from Bangladesh Bureau of Statistics, Monthly Statistical Bulletin, various dates; and World Bank commodity prices.

Figure 9—Wheat prices, 1973-89



Source: Based on data from Bangladesh Bureau of Statistics, Monthly Statistical Bulletin, various dates; and World Bank commodity prices.

Table 19—Yearly imports of rice and wheat, 1972/73-1989/90

Year*	Rice	Rice per capita	Wheat	Wheat per capita
	(1,000 metric tons)	(grams)	(1,000 metric tons)	(grams)
1972/73	396	5,417	2,475	33,643
1973/74	83	1,115	1,635	21,690
1974/75	270	3,480	2,130	27,542
1975/76	394	4,990	1,094	13,848
1976/77	195	2,402	630	7,743
1977/77	304	3,676	1,361	16,410
1978/79	57	664	1,108	13,045
1979/80	723	8,322	2,086	23,924
1980/81	85	957	1,004	11,302
1981/82	148	1,620	1,085	11,941
1982/83	316	3,411	1,524	16,416
1983/84	185	1,938	1,884	19,781
1984/85	695	7,159	1,885	19,391
1985/86	35	352	1,163	11,663
1986/87	260	2,539	1,507	14,767
1987/88	583	5,606	2,328	22,359
1988/89	75	705	2,063	19,305
1989/90	300	2,767	1,234	11,335

Source: Based on data from Bangladesh Bureau of Statistics, Statistical Yearbook 1989, (Dhaka: BBS, 1990).

* The fiscal year starts in July.

5. A MODEL OF THE PUBLIC FOODGRAIN DISTRIBUTION SYSTEM IN BANGLADESH

INTRODUCTION

Foodgrain prices are determined by the interrelationship between private sector decisions concerning production, consumption, storage, and marketing, and government sector decisions related to public distribution, procurement of domestic production, imports, and stock management. Whereas, in describing the behavior of the private sector, prices may be assumed as given, for the public sector this is not the case, since a large number of options for affecting prices are available to the government. Therefore, in modeling the interaction between the government and private sectors, there is an asymmetry of behavior in relation to prices. The design of stock policy should take into account this kind of asymmetry.

The foodgrain sector in Bangladesh is represented mainly by rice and wheat. Whereas rice is predominant in production, contributing more than 95 percent of total foodgrains, wheat is predominant in public distribution, mainly because of the quantities made available by food aid. Given the substitutability of rice and wheat (the cross price elasticity of demand for rice with respect to wheat is 0.13 according to Bouis 1989), the demand for these grains has to be determined simultaneously. Government operations, in both distribution and procurement activities, affect prices of rice and wheat. Both commodities are storable and, especially for rice, there is a very active network of intermediaries between farmers and consumers (Crow and Murshid 1989). One fundamental aspect of this network is the presence of storage along with a demand for storage generated by profit motives.

THE MODEL

In equilibrium, demand for foodgrains is equal to marketable supply,

$$d_{\tau}^{i} = ms_{\tau}^{i}, \qquad (4)$$

where d_{τ}^{i} is the demand for grain i at time τ, and ms_{τ}^{i} is the marketable supply of grain i at time τ.

Marketable supply is given by production plus the net distribution from the government, since exports of foodgrains are either not allowed or are not yet feasible, and imports are monopolized by government. The distribution by the government consists of monetized distribution through rationing and open market sales, and in nonmonetized distribution such as food-for-work, gratuitous relief, and vulnerable group feeding. To obtain the net distribution from public stock, procurement has to be subtracted from total offtakes. Therefore,

$$ms^i_\tau = q^i_\tau + mof^i_\tau + nmof^i_\tau + oms^i_\tau - qp^i_\tau, \qquad (5)$$

where

q^i_τ = production of grain i at time τ,

mof^i_τ = monetary offtakes of grain i at time τ,

$nmof^i_\tau$ = nonmonetary offtakes of grain i at time τ,

oms^i_τ = open market sales of grain i at time τ, and

qp^i_τ = procurement of grain i at time τ.

Note that this equation allows computation of the demand for foodgrains, which consists of both demand for consumption and demand for storage. This can also be expressed by saying that the marketable supply of foodgrains is either consumed or stored; that is,

$$ms^i_\tau = c^i_\tau + \Delta x^i_\tau, \qquad (6)$$

where

ms^i_τ = the marketable supply of grain i as of time τ,

c^i_τ = consumption of grain i as of time τ, and

Δx^i_τ = $x^i_{\tau+1} - x^i_\tau$ = variation of private stocks of grain i as of time τ.

As it is, data on either consumption or private stock are not available on an aggregate basis. Therefore, both consumption and private stock changes have to be expressed in terms of underlying variables such as prices and income.

In particular, consumption of grain i will be expressed as a function of its own price, p^i_τ, the price of the substitute grain, p^j_τ (where $i \neq j$), and income, y_τ:

$$c^i_\tau = g^i_1(p^i_\tau, p^j_\tau, y_\tau). \qquad (7)$$

Private storage will depend on the difference between expected prices for the next period and current prices, so the change in private storage can be expressed as follows:

$$\Delta x^i_{\tau+1} = g^i_2(\Delta p^i_{\tau+1,\tau}, \Delta p^i_\tau), \tag{8}$$

where Δ is the difference operator, and $p^i_{\tau+1,\tau}$ is the price of grain i expected to prevail at time $\tau+1$, based on the information available at time τ.

The expression for the change in private stocks can be derived from an underlying model of private storage that is reported in Appendix 3. As a result of this analysis, the behavior of the private sector can be described by the following set of equations:

$$\hat{p}^i_{\tau+1} = f^i_0(\sigma^i_\tau, \eta^i_{0,\tau}), \text{ and} \tag{9}$$

$$p^i_\tau = f^i_1(p^i_{\tau-1}, \hat{p}_{\tau+1}, y, p^j_\tau, ms^i_\tau, \eta^i_{1,\tau}), \tag{10}$$

where the η's are error terms.

The set σ^i_τ of instrumental variables is

$$\sigma^i_\tau = (stock^i_{\tau-1}, m^i_\tau, y_\tau, losses_\tau) \tag{11}$$

where $stock^i_\tau$ is ending period public stocks of grain i at time τ, m^i_τ denotes imports of grain i at time τ, and $losses^i_\tau$ denotes rice losses at time τ.

A three-stage least squares estimation of the system is implemented to take into account the simultaneity of the price of rice and wheat.

The complete specification of the foodgrain dynamic system is given below:

$$\hat{p}^r_{\tau+1} = a_1 + a_2 stock^r_{\tau-1} + a_3 m^r_\tau + a_4 losses_\tau + a_5 y_\tau, \tag{12}$$

$$\hat{p}^w_{\tau+1} = b_1 + b_2 stock^w_{\tau-1} + b_3 m^w_\tau + b_4 losses_\tau + b_5 y_\tau, \tag{13}$$

$$p^r_\tau = c_1 + c_2 p^r_{\tau-1} + c_3 \hat{p}^r_{\tau+1} + c_4 p^w_\tau + c_5 ms^r_\tau + c_6 y_\tau, \tag{14}$$

$$p^w_\tau = d_1 + d_2 p^w_{\tau-1} + d_3 \hat{p}^w_{\tau+1} + d_4 p^r_\tau + d_5 ms^w_\tau + d_6 y_\tau, \tag{15}$$

$$stock^r_\tau = \delta^r stock^r_{\tau-1} + m^r_\tau + qp^r_\tau - mof^r_\tau - nmof^r_\tau - oms^r_\tau, \tag{16}$$

$$stock^w_\tau = \delta^w stock^w_{\tau-1} + m^w_\tau + qp^w_\tau - mof^w_\tau - nmof^w_\tau - oms^w_\tau, \qquad (17)$$

$$ms^r_\tau = q^r_\tau + mof^r_\tau + nmof^r_\tau + oms^r_\tau - qp^r_\tau, \text{ and} \qquad (18)$$

$$ms^w_\tau = q^w_\tau + mof^w_\tau + nmof^w_\tau + oms^w_\tau - qp^w_\tau. \qquad (19)$$

Equations (12) and (13) try to forecast the next period price by using opening public stocks, imports, forecast of rice losses, and income. Equations (14) and (15) relate the current prices of both rice and wheat to the lagged price, the forecast of future price, the marketable surplus defined in equations (18) and (19), and income. Note that income and current price of the alternative foodgrain come from the demand for consumption, whereas the lagged and expected future prices come from the demand for private stocks. Equations (16) and (17) give the law of motion for public stocks.

ESTIMATION OF THE MODEL

The system specified above has been estimated by three-stage least squares using seasonal observations from 1975/76 to 1989/90. Each year contains 4 seasons, and 59 seasons have been used in the estimation. Prices are deflated by the index of manufactured goods and quantities are in per capita terms. For a description of the data see Appendix 4.

The first two equations reported in Table 20 give the instrumental variable estimation of future price, $p^i_{\tau+1}$. All the variables have the expected sign and most of them are significant. In particular, opening stocks have an important negative effect on future prices. Since imports add to the available supply, their coefficients are expected to be negative; nevertheless, the coefficients are not statistically significant. Losses in rice production that originate from cyclone, drought, and flood affect future prices because of an expected shortfall over the upcoming period. For rice, the effect of losses on prices is significant, whereas the opposite is true for wheat, mainly because the behavior of expected wheat prices is not so heavily influenced by the production of rice, given the predominant role of wheat imports in the public distribution. Income positively affects future prices by increasing current consumption and lowering the supply available during the coming period.

In terms of goodness of fit, the price equations explain a good deal of the total variation of prices. For rice, the speculative effect of future prices on current price is particularly important, as demonstrated by the coefficient of $p^r_{\tau+1}$ in Table 20. In fact, the coefficient of future price is of the same order of magnitude as the coefficient of lagged prices, indicating a support for the hypothesis of profit maximizing demand for storage (Goletti 1990). Both wheat prices

Table 20—Estimated equations of the foodgrain system, 1975/76-1989/90

Variable	Coefficient	t-Value
Equation for lead price of rice		
Constant	-0.0777	-1.1509
$stock_t^R$	-0.0090	-3.9992
m_t^R	-0.0043	-1.1459
$losses_t$	0.0031	3.4254
y_t	0.0648	6.5778
Valid cases	59	
R^2	0.60	
SEE	0.0314	
Equation for lead price of wheat		
Constant	-0.0520	-1.2435
$stock_t^W$	-0.0040	-3.3182
m_t^W	-0.0011	-1.3023
$losses_t$	0.0004	0.7166
y_t	0.0413	6.4386
Valid cases	59	
R^2	0.46	
SEE	0.02	
Rice price equation		
Constant	0.0133	0.3500
p_{t-1}^R	0.3577	6.2749
$\hat{p}_{t+1}^R$	0.3767	4.4274
p_t^W	0.8059	5.1137
ms_t^R	-0.0007	-8.6816
y_t	-0.0094	-1.1840
Valid cases	59	
R^2	0.88	
SEE	0.17	
Wheat price equation		
Constant	-0.0174	-0.4951
p_{t-1}^W	0.2218	1.8096
$\hat{p}_{t+1}^W$	-0.0673	-0.3135
p_t^R	0.3014	2.2013
ms_t^W	-0.0013	-1.3566
y_t	0.0145	1.8839
Valid cases	59	
R^2	0.65	
SEE	0.16	

(continued)

Table 20—Continued

Source: Estimated by the authors, with seasonal data.

Definitions of terms:

$stock_t^i$	=	stock of grain i at time t;
m_t^i	=	imports of grain i at time t;
$losses_t$	=	losses of rice during time t;
y_t	=	income at time t;
p_t^i	=	price of grain i at time t;
$\hat{p}_{t+1}^i$	=	instrumental variable estimation of price of grain i at time t+1;
ms_t^i	=	marketable supply of grain i time t;
t	=	refers to season (season 1, July-October; season 2, November-February; season 3, March-April; season 4, May-June); and
SEE	=	standard error of estimation.

and marketable supply have the expected signs. Wheat prices have a positive effect on rice price due to the substitutability of rice and wheat in consumption.

Income does not have a significant effect on current prices, mainly because its influence is captured by future prices p_{T+1}^r. For wheat, it is noteworthy that the speculative effect is not significant, as pointed out by the coefficient of future price p_{T+1}^w (Table 20). This suggests a reestimation of the model with the constraint of zero coefficient of future wheat prices. The reduced form of this estimation is the one that is used in the simulations. The coefficients of the estimation are reported in Table 21.

The model tracks the price of rice and wheat quite well. For rice and wheat, the root mean square error for the overall period is 11 and 12 percent, respectively. For more recent samples, the performance improves. For example, for the period 1985/86-1989/90 it is 4 and 5 percent, respectively. Within this model, the tracking of stock variables depends on the accuracy of the data on both procurement and offtakes. The balance equations for stock (given by equations [16] and [17]) are the basis for the tracking of stock variables. The less than perfect match between predicted values and actual values is due to unreported storage losses. By applying a storage decaying factor of 6 percent it is possible to improve the dynamic simulation of stocks considerably.

Table 21—Three-stage least squares estimation of price equations of foodgrain system, constrained, 1975/76-1989/90

Variable	Coefficient	t-Statistic
Rice price equation		
Constant	0.0130	0.3436
p^R_{t-1}	0.3648	6.4014
$\hat{p}^R_{t+1}$	0.3789	4.4535
p^W_t	0.7784	4.9369
ms^R_t	-0.0007	-8.7219
y_t	-0.0090	-1.1298
N	59	
R^2	0.8834	
SEE	0.0170	
Wheat price equation		
Constant	-0.0171	-0.4868
p^W_{t-1}	0.2385	-2.4379
p^R_t	0.2777	3.4312
ms^W_t	-0.0012	-1.9158
y_t	0.0129	1.9261
N	59	
R^2	0.6546	
SEE	0.0164	

Source: Estimated by the authors.

Note: The coefficient of future prices in the wheat price equation has been set equal to zero.

Definitions of terms:

y_t = income at time t;
p^i_t = price of grain i at time t;
$\hat{p}^i_{t+1}$ = instrumental variable estimation of price of grain i at time t+1;
ms^i_t = marketable supply of grain i time t;
t = refers to season (season 1, July-October; season 2, November-February; season 3, March-April; season 4, May-June); and
SEE = standard error of estimation.

6. POLICY CONSTRAINTS AND POLICY OBJECTIVES

With reference to the general approach of Chapter 3, so far only equation (1) has been made explicit by introducing the response of the private foodgrain sector in Chapter 5. The specification of the policy constraints, as in equation (2), and the objective function, as in equation (3) of problem (P), remains to be done. This task is taken up in this chapter.

THE POLICY CONSTRAINTS

The endogenous variables in the general framework introduced above are constrained as in equation (2). Some of these constraints simply state the nonnegativity of some endogenous variables, namely, prices and stocks. Some other constraints are capacity constraints, imposed upon stock variables to take into account the physical storage facilities constraints. The capacity constraints are expressed as follows:

$$stock_{\tau}^{i} \leq G_{max}^{i}, \tag{20}$$

where i stands for either rice or wheat, $\tau = t,...,T$, and G_{max}^{i} is the maximum stock of grain i (assumed independent of time).

A third set of constraints on stock variables takes into account minimum stock requirements that may be related both to deadstocks (the amount of stock needed for the system to be operational) and to the minimum stock levels needed for food security considerations. An example of the latter is that the public food distribution system must hold sufficient stocks to meet three months of offtake requests (505,000 tons), allowing the time frame necessary for importing foodgrains to replenish the stock facilities.

These minimum stock requirements can be expressed as follows:[5]

$$stock_{\tau}^{i} \geq G_{min}^{i}. \tag{21}$$

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[5] Note that both minimum and maximum stock requirements imply constraints for decision variables. For example, assuming that the decision variables are open market sales (oms_{τ}^{i}), then

$$G_{\tau}^{i} \leq G_{max}^{i}$$

is equivalent to

$$OMS_{\tau}^{i} \geq \delta^{i}G_{\tau-1}^{i} + m_{\tau}^{i} + qp_{\tau}^{i} - mof_{\tau}^{i} - nmof_{\tau}^{i} - G_{max}^{i}.$$

A fourth set of constraints is related to maximum domestic procurement and can be expressed as follows:

$$qp_{\tau}^{i} \leq \gamma \cdot q_{\tau}^{i}, \tag{22}$$

where qp_{τ}^{i} is procurement of grain i at time τ, and q_{τ}^{i} is production of grain i at time τ, that is, maximum procurement is just a fraction, γ, of total production.

Finally, a fifth set of constraints that are considered in the following policy exercises is related to foreign reserves. This type of constraint can be expressed as follows:

$$wop_{\tau}^{i} \cdot m_{\tau}^{i} \leq F_{\tau}^{i}, \tag{23}$$

where wop_{τ}^{i} is the world price of grain i at time τ, and F_{τ}^{i} is the maximum amount of foreign exchange allocated to food imports m_{τ}^{i}.

THE OBJECTIVE FUNCTION

The objective function specification depends on the type of policy pursued. In the following policy exercises, two main objectives are considered: price stabilization and cost minimization.[6]

The objective of price stabilization is to be understood as minimization of the variance of prices around a target price. In order for such an objective to be made precise, a target price θ_{τ} has to be specified for the period of the policy exercise going from τ=t to τ=T. The objective can then be expressed as follows:

$$\sum_{\tau=t}^{T} (p_{\tau}^{r} - \theta_{\tau})^2/(T - t+1) \ . \tag{24}$$

The difficulty lies with an appropriate specification of the target price. Several elements will be taken into account in the specification of the target price. First, a long-term trend of domestic prices; second, a concern for seasonality fluctuations; third, the behavior of

[6] Note that a third important objective of food stock policy is poverty reduction. This objective can be expressed by means of one commonly used poverty measure, such as that proposed by Foster, Greer, and Thornbecke (1984). In order to do that, a value for the parameter α of the severity of poverty has to be chosen. Moreover, some parameters relative to rice and wheat consumption of subgroups of the population have to be provided to make operational the computation of the poverty index. In this context, note also that the objective of food security has already been incorporated in the policy constraints, related to minimum stock requirements.

world prices. The target becomes a weighted average of these elements, where the weights reflect the relative importance attributed to them by the government.[7]

The objective of cost minimization can be readily specified, once an expression for the cost is provided. The relevant cost expression here is the operating balance of the food accounts. Basically this cost refers to the difference between expenditures and revenues, as these items have been defined in Appendix 5. For the time period of the policy exercise, the expression of the cost is given by

$$\sum_{\tau=t}^{T} \sum_{i=r,w} \beta^{\tau-t}[wop_\tau^i m_\tau^i + pp_\tau^i qp_\tau^i - p_\tau^i oms_\tau^i - pr_\tau^i mof_\tau^i]. \qquad (25)$$

Expenditures are here simply given by the value, at international prices, of food imports (the term $wop_\tau^i \cdot m_\tau^i$) and by the cash outlays for domestic procurement (the term $pp_\tau^i \cdot qp_\tau^i$). Revenues are given by the monetary offtakes evaluated at ration prices (the term $pr_\tau^i \cdot mof_\tau^i$) and by the value of open market sales, evaluated at market prices (the term $p_\tau^i \cdot oms_\tau^i$). Note that β is the parameter used to discount the future.

[7] The expression for the weighted average is

$$\ln(\theta_\tau) = A_1 \cdot \ln(p_\tau^l) + A_2 \cdot \ln(p_\tau^s) + A_3 \cdot \ln(wop_\tau^r),$$

where p_τ^l denotes the long-term domestic price of rice, p_τ^s is the seasonal factor, and wop_τ^r is the world price of rice. Note that the target price considered here is the target for rice prices.

7. OPEN MARKET OPERATIONS

In most of the policy exercises presented in the text, the policy instruments controlled by the government are open market operations (omo_τ^i). Open market operations are conducted at market prices. It is possible to express open market operations in terms of both open market sales (oms_τ^i) and open market purchases (omp_τ^i) as follows:

$$omo_\tau^i = oms_\tau^i - omp_\tau^i. \tag{26}$$

Both open market sales and open market operations are positive, but their difference can be any sign. From this observation, it follows the convention that positive open market operations have to be interpreted as open market sales, and negative open market operations have to be interpreted as domestic procurement.

The way the government has implemented open market sales and domestic procurement so far can be schematically represented as follows:

sell oms_τ^i at price $poms_\tau^i$;

buy qp_τ^i at price pp_τ^i.

The prices $poms_\tau^i$ are called "oms prices," and the prices pp_τ^i are called "procurement prices." Note that both oms prices and procurement prices are preannounced.

At this point there are some conceptual and practical problems. What follows refers to procurement, but similar observations apply to open market sales.

The basic conceptual problem is, How can government ensure that an amount qp_τ^i is procured at price pp_τ^i? Procurement depends on the capacity and willingness of the farmers and traders to sell. Unless some forced arrangement is put into effect, procurement is constrained by the supply decisions of traders and farmers. These supply decisions depend, among other things, on the differential between procurement prices and open market prices. Following the model of Appendix 1, one can postulate a relation of the type

$$qp_\tau^i = f(p_\tau^i, pp_\tau^i, q_\tau^i, qp_{\tau-1}^i). \tag{27}$$

The basic point to be made here is that the government can decide upon either pp_τ^i or qp_τ^i. Within this contractual arrangement, it cannot decide upon both pp_τ^i and qp_τ^i.

The procurement policy of the government then is reduced mainly to the setting of procurement prices, while taking into account both the effect of procurement prices on quantities actually procured (see equation (27)) and the effect of procurement quantities on market prices (see equations [5] and [10]). In fact, both these effects have to be considered simultaneously, as is done in Appendix 2. The results given in Table 45 in Appendix 2 show, among other things, that procurement prices have not been a significant determinant of procurement.

Now a practical problem emerges. Even though the fit of price equations is reasonably high (Figures 10a and 10b), in any estimation of procurement supply and monetary offtakes as in equation (27), the goodness of fit is very low (Table 45, Appendix 2; Figures 10c-10f). This implies that use of such equations for planning purposes and for the evaluation of different policies is bound to be very uncertain, resulting in a large margin of error. Moreover, because of the linear specification of equation (27) that is often used in many other studies, there is no reason for the predicted value of this equation to be positive. It may perfectly be the case that the predicted value of procurement is negative, an outcome that does not make sense.

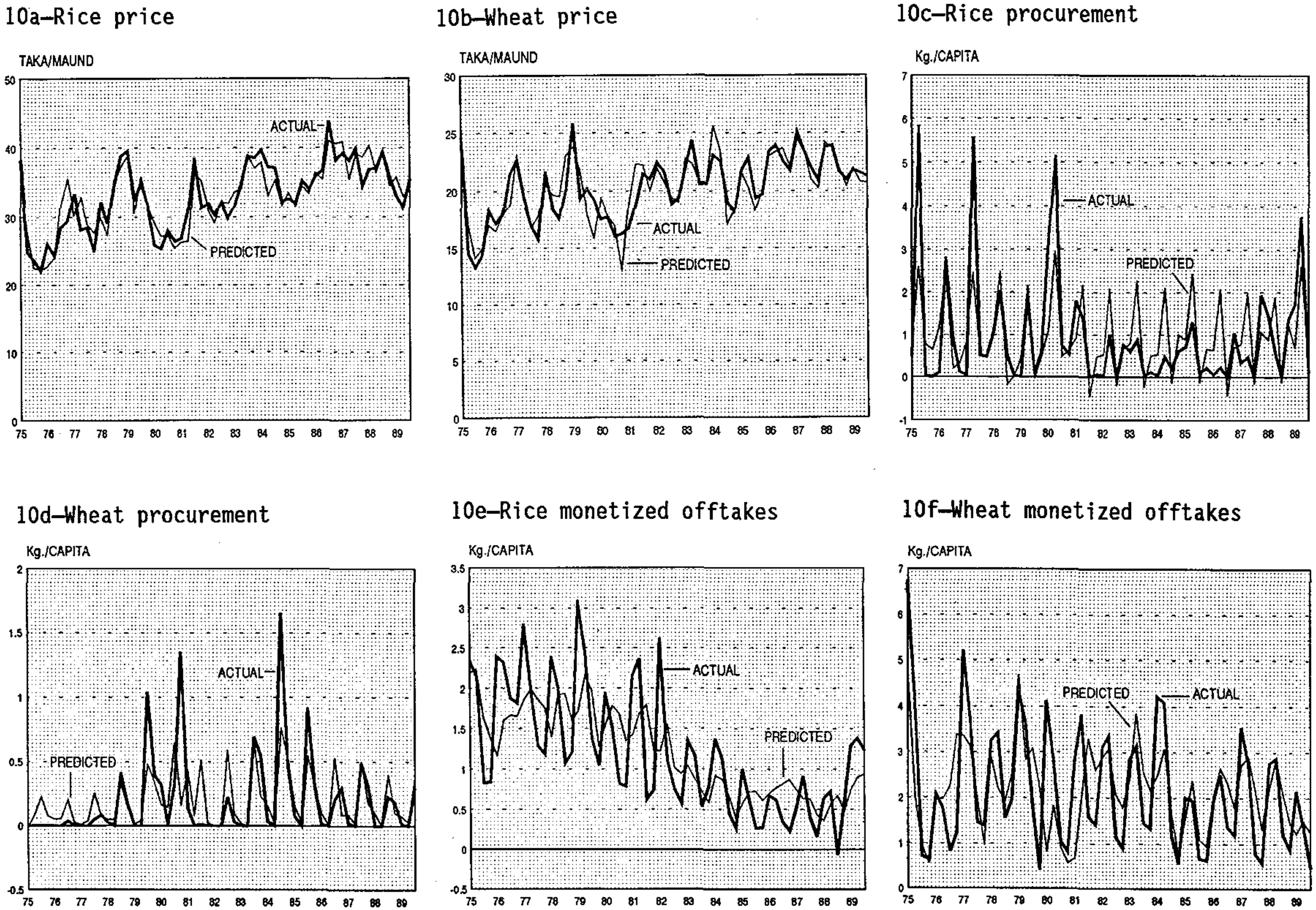
Supposedly, the intention of the government in setting procurement prices is to support domestic prices, especially in periods immediately after harvest. By announcing procurement prices in advance of harvest time, the government cannot really know the level of market prices. However, based on some predictions, it may still establish a reasonable level of procurement prices. Yet, as observed above, there is no reliable way of estimating how much grain could be procured. This would make any estimate of its impact on market prices even more unreliable. Moreover, one should keep in mind that the way procurement activities are actually implemented, mainly through a system of licensed dealers, always generates rent-seeking activities that produce waste and make any evaluation of the effects of procurement prices again very unreliable.

Because of all these observations, it seems appropriate to consider open market purchases as an instrument to replace domestic procurement (that is, in terms of the notation introduced above, $qp_\tau^i = omp_\tau^i$). This would achieve the same purported effect of procurement activities as they are currently conducted, namely to support prices, and their effect on prices could be calculated with a relatively higher degree of reliability. Finally, this would reduce the opportunities for rent-seeking activities, since the purchases will be conducted at market prices.

In view of these considerations, by recalling that marketable supply, ms_τ^i, is equal to domestic production, q_τ^i, plus offtakes (both monetary and nonmonetary) plus open market sales minus domestic procurement, the following equation is developed:

$$ms_\tau^i = q_\tau^i + offtakes_\tau^i + oms_\tau^i - omp_\tau^i. \qquad (28)$$

Figure 10—Actual and simulated values of the foodgrain system with public distribution, 1975-89



Since open market operations affect the domestic supply of foodgrains, they directly affect prices, as can be seen from the price equation (10) derived in Chapter 4. It is reproduced here for convenience:

$$p_\tau^i = f_1^i(p_{\tau-1}^i, \hat{p}_{\tau+1}, y, p_\tau^j, ms_\tau^i, \eta_{1,\tau}^i).$$

Therefore, it is expected that open market operations ($oms_\tau^i - omp_\tau^i$) have a negative effect on prices insofar as they contribute to augmentation of the domestic supply.

8. SPECIFICATION OF POLICY OPTIONS

In the simulations of policy options for the foodgrain sector of Bangladesh, two types of exercises can be done. In the first type, counterfactual simulations of various policy options can be examined, based on the historical values of exogenous variables. In the second type, ex ante simulations can be performed, using stochastic simulation for the exogenous variables. In this paper, only the first type of simulation is reported.

Several elements have to be clarified at the outset of the exercises. Among these elements are the time period of the simulations, the initial conditions, the exogenous variables, the endogenous variables, the control variables, and the objective of the policy. In each policy, a baseline is computed in order to compare the effect of different policies.

Six policies are evaluated: price band; optimal price stabilization; import approach to price stabilization; cost minimization; price stabilization cum cost minimization (this is is called the benchmark policy in this paper); and approximation to optimal price stabilization.

A summary of these options is given in Figure 11. A detailed description of each policy follows.

PRICE BAND POLICY

Establishing a price band mechanism implies setting a target price, a price band, and a rule of intervention.

The target price is denoted by θ_τ, where the time index τ varies over the period of the policy exercise. Generally, the target price chosen is a weighted average that takes into account the long-term trend of domestic prices, seasonality, and the long-term trend of world prices (Ahmed 1990). It is constructed in the same way as the target price described in the definition of the price stabilization objective (see Chapter 6).

The price band is defined with reference to the target price and the specification of an upper and a lower intervention price that should trigger open market operations. Usually, the upper and lower trigger prices are symmetrical in relation to the target price.[8]

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[8] Denoting these trigger prices by phigh and plow, they are related to the target price, θ_τ, as follows:

$$phigh_\tau = (1 + \beta) \cdot \theta_\tau, \text{ and}$$

$$plow_\tau = (1 + \beta) \cdot \theta_\tau.$$

Figure 11—Policy options considered in the simulation exercises

Baseline	Simulation of the foodgrain model for the period July 1985-June 1988. All exogenous and control variables are taken at their historical value.
Price Band	Uses open market operations to maintain a real price band of plus or minus 4 percent around the target.
Optimal Price Stabilization	Uses open market operations to minimize variance of prices around the target.
Import	Uses imports to minimize the variance of rice prices around target.
Cost Minimization	Uses open market operations to minimize the total cost of food operations.
Benchmark	Uses open market operations and imports to minimize the total cost of food operations subject to price stabilization and foreign reserves constraints.
Approximation	Approximates the optimal price stabilization. It is obtained by stochastic simulation of production shocks, and by expressing open market operations as a function of rice and wheat production and of their own past.

Under the rule of intervention, open market sales are undertaken by the government until either prices drop to the ceiling of the band or public stocks reach the minimum operational level. The minimum stock requirement is the same as the one mentioned in Chapter 6 that would guarantee food security, and translates into equation (21).

Similarly, when prices in the absence of intervention tend to go below the lower price of the band, open market purchases are undertaken by the government until either the maximum stock capacity is reached or prices rise to the lower level of the band. The maximum stock requirement translates into equation (22).

Finally, when prices are within the band, no open market operations are undertaken unless stock constraints are binding. When this is the case, open market operations are undertaken in order to satisfy the constraints.

The main advantage of a price band rule seems to be that the rule can be simply stated, is relatively easy to implement, and is readily understandable. Therefore, it has desirable features from an operational point of view. Nevertheless, the outcome is not optimal, because it does not use all the available information. A price band rule is a fixed rule, clearly suboptimal with respect to the rule that can be computed as a solution of an optimization problem (Buiter 1981).

OPTIMAL PRICE STABILIZATION POLICY

The objective of this policy is to minimize the variance of rice prices around a target price path as it was defined in Chapter 6. As in the case of price band policy, the underlying motivation is to stabilize prices. But, unlike price band policy, the objective of price stabilization is stated explicitly, and the policy is the outcome of an optimization exercise.

The instruments available to the government are open market operations. Following the general approach of Chapter 3, the constraints are given by the foodgrain model of Chapter 5, and the constraints on open market operations that are implicit in equations (21) and (22).

IMPORT POLICY

In this context, trade policy is similar to the optimal price stabilization policy, insofar as the objective is to minimize the variance of rice prices around a target price path. The only difference is in the instruments used. The control variables are now given by imports of foodgrains. It is assumed that no exports take place.

COST MINIMIZATION POLICY

In this case the explicit objective of the policy is to minimize the present value of cost, as given in equation (25). The basic policy issue here is to see how the public food distribution assumed in the baseline can be carried out at minimum cost. The instruments chosen are again given by open market operations.

BENCHMARK: PRICE STABILIZATION CUM COST MINIMIZATION POLICY

In this policy option all the previous considerations regarding cost efficiency, price stability, and food security are included. The objective is again to minimize the cost of operations, but new policy instruments and constraints are now added.

The policy instruments are given by both open market operations and imports. Besides the reaction of the private sector, given by the system of equations in Chapter 5, constraints on minimum and maximum stock requirements are specified. In addition to these constraints, two more constraints related to price variability and foreign exchange reserves are considered. The constraint on price variability requires that prices move in a plus or minus 4 percent band around the target price. The foreign exchange constraint imposes a ceiling on foreign exchange that can be spent on imports. The ceiling is given by the foreign exchange equivalent of foodgrain imports in the baseline. The formal expression of this policy is reported in Appendix 6.

APPROXIMATION POLICY

In general, the optimal paths of the policy instruments used for the previous policies are not easily related to the underlying variables of the system. It would be interesting to approximate the optimal policies, with "simpler" policies, easily understood and implementable (Pinckney 1988, 1989).[9] Examples of these approximation policies are linear feedback rules, expressed in terms of the current state of the system. One specific way to get such an approximation is described in Appendix 7.

[9] To make this intuition clear, one should introduce a norm in some metric space of functions.

9. EVALUATION OF COUNTERFACTUAL SIMULATIONS

In this case, the model of the foodgrain sector is used ex post to do counterfactual simulations. The three-year period 1985/86-1987/88 is considered in this exercise, for a total of 12 seasons, characterized by the first two years as just above average in terms of production, and the third as a "bad" production year (see rice production in Figure 3).

The baseline for these simulations is constructed by taking exogenous values and predetermined variables at their historical values (Tables 22-25) and running the reduced form of the model in order to get the endogenous variables (prices and stocks). In the policy options presented below, open market operations and imports are policy instruments that, as such, are choice variables in the optimization problems considered. Their counterparts in the baseline are open market sales, procurement quantities, and imports actually performed by the government during the period 1985/86-1987/88. The total cost for the pipeline is more than Tk 17 billion, and the average foodgrain stock level is nearly 1.1 million tons.

The insight gained from this type of exercise facilitates comparison of different policy options with the one that is already in place from the perspective of the government's objectives of ensuing price stability, cost efficiency, and food security.

The detailed results for each policy are given in Tables 26-39 at the end of this chapter. The summary statistics of the various policy options appear in Chapter 10.

PRICE BAND POLICY

This policy is very effective at stabilizing prices (the coefficient of variation goes from 6.0 percent in the baseline to 4.4 percent), yet it is not cost-effective (Tables 26 and 27; Figure 12). The total cost of operations is Tk 19.6 billion, which represents an increase of 15 percent in relation to the baseline cost, mainly due to the increased role of procurement (that is, open market purchases). Note that by intervening to buy when prices are lower than the target, the overall price path is altered, causing an accumulation of stocks that puts a downward pressure on prices. The average foodgrain stock for this policy is nearly 1.5 million tons. Therefore, the attempt to stabilize prices above the floor of the band is frustrated by the rule of operations of the policy. Clearly, this outcome could be avoided if the government were allowing stocks to accumulate indefinitely, but this is not possible given that public storage facilities have a limited capacity (2 million tons is the level used in the simulations).

Table 22—Variables in the baseline, 1985-88

Year/ Season[a]	Price[b] Rice	Price[b] Wheat	Stock Rice	Stock Wheat	Open Market Operations[c] Rice	Open Market Operations[c] Wheat	Imports Rice	Imports Wheat
	(Tk/maund)		(kilograms/capita)					
1985/86								
Aus	33.7	20.9	3.67	6.66	0.07	0.35	0.12	4.42
Aman	30.7	20.5	3.98	3.22	0.01	0.14	0.09	1.39
Winter	35.0	20.7	3.64	4.39	0.06	0.00	0.14	2.78
Boro	36.0	22.2	3.32	6.12	0.04	0.00	0.00	3.08
1986/87								
Aus	37.5	23.0	2.17	7.72	0.50	0.64	0.23	5.19
Aman	35.6	22.3	2.17	3.59	0.03	0.40	0.55	2.10
Winter	38.4	22.0	1.92	3.38	0.48	0.04	0.79	3.21
Boro	38.3	23.2	3.29	5.63	0.30	0.03	0.97	4.27
1987/88								
Aus	37.9	23.1	4.87	7.84	0.88	0.68	2.90	8.43
Aman	36.2	22.4	5.55	10.14	0.19	0.12	1.61	9.23
Winter	37.5	22.0	5.04	10.27	0.10	0.03	0.32	2.36
Boro	36.3	22.7	7.24	10.68	0.04	0.00	0.77	2.34
Mean	36.1	22.1	3.90	6.64	0.22	0.20	0.71	4.07
Standard deviation	2.2	0.9	1.56	2.74	0.27	0.25	0.83	2.47

Source: Estimated by the authors.

Note: The baseline is obtained by simulating the foodgrain model for the period July 1985-June 1988.

[a] The seasons are defined as follows: aus, July-October; aman, November-February; winter, March-April; and boro, May-June.
[b] Prices are deflated by the index of manufactured goods.
[c] Positive open market operations have to be interpreted as open market sales; negative open market operations have to be interpreted as domestic procurement.

Some of these undesirable outcomes may be avoided by planning a more adequate price band width and a different target price. All that is pointed out here is a caveat against an enthusiastic support of fixed rules of operations that do not allow for a necessary degree of flexibility in reacting to new information in an efficient way. The substance that emerges from this analysis is that price bands are a very complex policy to plan. One main criticism of price bands that should be kept in mind is that, unless the band itself is changed periodically, the buffer stock either tends to deplete to a very low level or to accumulate, at times, to an unmanageably high level. In the simulation presented here, for example, the capacity constraints are binding, since the maximum stock level of almost 2 million tons is reached.

Table 23—Costs in the baseline, 1985-88

Year/ Season[a]	Procurement Cost	Imports	Ration Sales	Open Market Sales	Total Cost[b]	Foreign Exchange	Cash Outflow[c]
			(Tk million)			(US$ million)	(Tk million)
1985/86							
Aus	524	2,308	1,619	211	1,002	77	-1,087
Aman	888	862	1,366	70	313	28	-461
Winter	492	1,682	518	50	1,607	56	90
Boro	303	1,673	515	35	1,426	55	-98
1986/87							
Aus	47	2,353	1,515	813	72	78	-1,918
Aman	169	1,237	1,790	244	-628	40	-1,550
Winter	107	1,913	984	472	564	62	-865
Boro	1,021	2,464	804	313	2,367	80	516
1987/88							
Aus	292	5,720	2,346	1,242	2,424	185	-684
Aman	404	5,765	2,296	249	3,624	186	212
Winter	273	1,452	803	112	810	46	-67
Boro	1,860	2,120	479	37	3,463	67	2,286
Total	6,380	29,548	15,035	3,848	17,045	959	-3,623
Standard deviation	489	1,535	642	351	1,274	50	1,047

Source: Estimated by the authors.

Note: The baseline is obtained by simulating the foodgrain model for the period July 1985-June 1988.

[a] The seasons are defined as follows: aus, July-October; aman, November-February; winter, March-April; boro, May-June.
[b] Total cost = procurement cost + import cost - ration sales - open market sales.
[c] Cash outflow = total cost - foreign exchange.

OPTIMAL PRICE STABILIZATION POLICY

In this case the objective is to minimize the variance of prices around the target price; the policy instruments are open market operations (Figures 13a, 13b, and 13c). Stabilization is perfect (Figure 13a) and is achieved at approximately half the cost of the baseline, that is, about Tk 8.4 billion (Tables 28 and 29). This remarkable result was mainly due to an intensive use of open market sales and domestic procurement. The variability of total cost is very high across seasons in the simulation period. The standard deviation of total cost is almost three times the level in the baseline. Note that in this case both imports and monetary offtakes are kept at their historical levels. If imports were eliminated it would not be possible to sustain the level of offtakes specified in the simulation. This is because domestic procurement of wheat is insufficient to meet the demand of wheat through both monetized and nonmonetized channels of the public food distribution system. It will also be seen in the following policy exercises that if both open market operations and imports are rationally used as policy instruments, wheat imports can be reduced substantially.

Table 24—Historical values of prices used in the baseline, 1985-88

Year/ Season[a]	Rice Price	Wheat Price	Rice Procurement Price	Wheat Procurement Price	Rice Ration Price	Wheat Ration Price	Rice World Price[b]	Wheat World Price[b]
				(Tk/maund)				
1985/86								
Aus	278	173	263	162	262	173	235	191
Aman	259	173	255	162	268	179	255	216
Winter	303	178	255	175	269	181	238	214
Boro	317	196	260	180	273	187	228	201
1986/87								
Aus	336	207	265	180	283	192	235	157
Aman	318	199	274	180	283	192	230	156
Winter	340	194	284	190	283	192	244	157
Boro	362	219	300	200	283	192	246	154
1987/88								
Aus	346	211	300	198	288	196	279	149
Aman	334	207	308	200	301	201	331	166
Winter	351	206	308	200	313	204	357	170
Boro	347	218	308	200	315	208	351	206

Source: Based on data from Bangladesh Bureau of Statistics, Monthly Statistical Bulletin, various dates.

[a] The seasons are defined as follows: aus, July-October; aman, November-February; winter, March-April; boro, May-June.
[b] World prices are converted from U.S. dollars.

The result obtained from this policy analysis is that a flexible policy approach to price stabilization, where open market operations are used more intensively than in the case of price bands, brings about substantial improvements. The average foodgrain stock level is about 1.1 million tons.

IMPORT POLICY

Here imports are used to stabilize prices. Open market sales are kept at their historical levels so that the effect of imports is felt through future prices. Since imports negatively affect the expectations of future prices, they also moderate current prices. The reduction of price level and price variability is remarkable (Tables 30 and 31; Figure 14). Compared with the case where open market operations were the only policy instrument (that is, in the optimal price stabilization option), the total cost associated with the import policy is now higher (Tk 14.7 billion versus Tk 8.4 billion).

Table 25—Historical values of quantities in the baseline, 1985-88

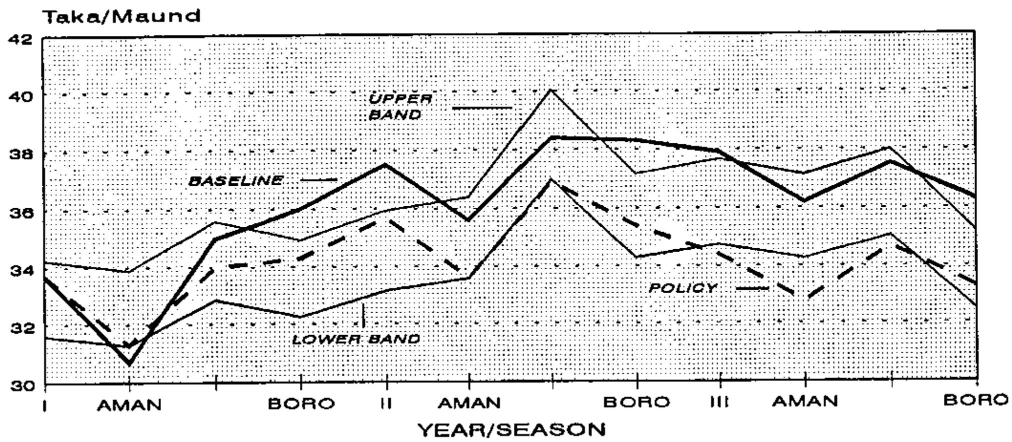
Year/ Season[a]	Production		Imports		Procurement		Monetary Offtake		Open Market Sales		Stock	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
	(1,000 metric tons)											
1985/86												
Aus	3,084	0	12	437	70	7	99	199	7	35	378	620
Aman	8,286	0	9	138	130	0	61	193	1	13	413	275
Winter	367	1,042	14	278	9	92	27	67	6	0	344	401
Boro	3,304	0	0	310	22	31	27	63	4	0	351	619
1986/87												
Aus	3,378	0	23	525	6	1	68	194	50	65	178	728
Aman	8,019	0	56	214	23	0	62	256	3	41	175	274
Winter	401	1,091	81	329	0	21	35	139	49	4	119	268
Boro	3,609	0	100	439	107	30	24	121	31	3	241	506
1987/88												
Aus	3,224	0	300	872	35	2	54	367	91	70	329	633
Aman	7,459	0	168	962	49	0	96	284	20	12	415	825
Winter	473	1,048	34	248	0	51	43	81	10	3	277	654
Boro	4,258	0	81	246	204	33	17	60	4	0	640	849

Source: Based on data from Bangladesh Bureau of Statistics, Monthly Statistical Bulletin, various dates.

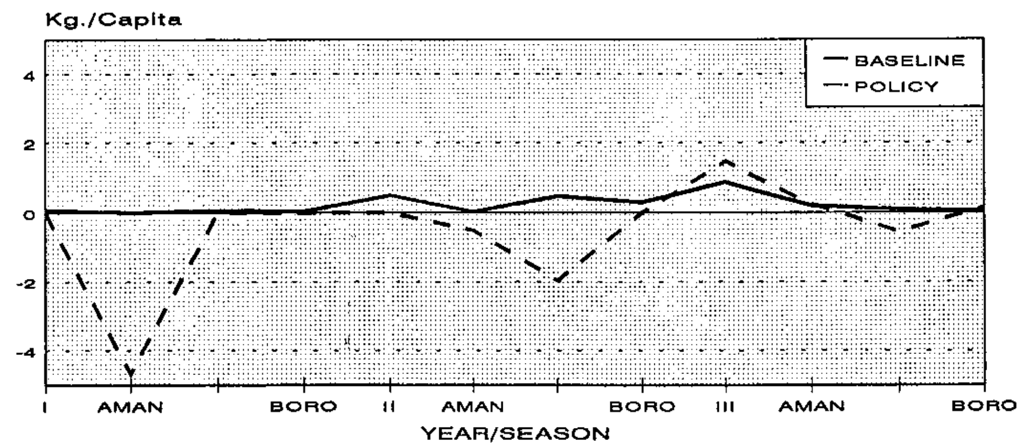
[a] The seasons are defined as follows: aus, July-October; aman, November-February; winter, March-April; boro, May-June.

Figure 12—Price band policy

12a—Prices of rice



12b—Open market operations of rice



12c—Open market operations of wheat

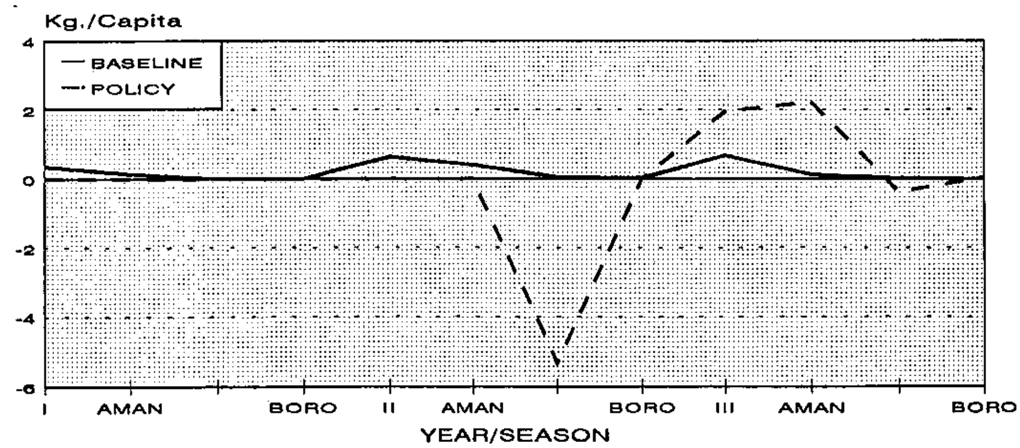
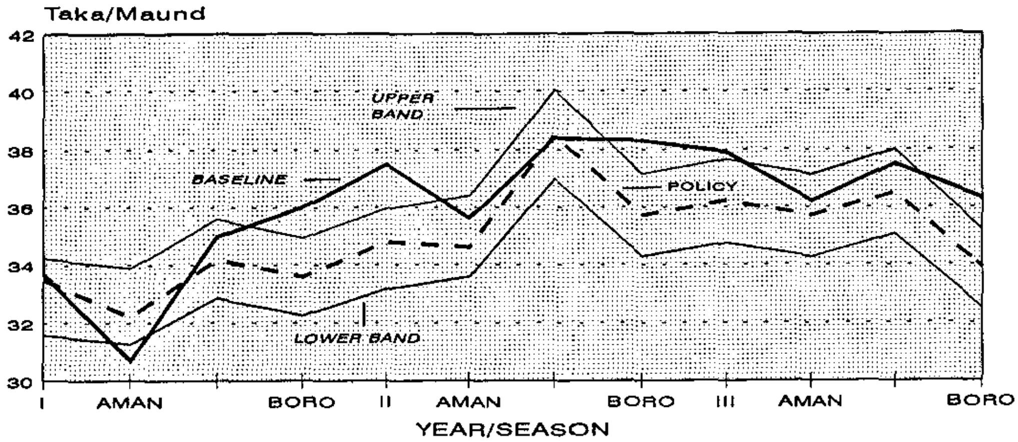
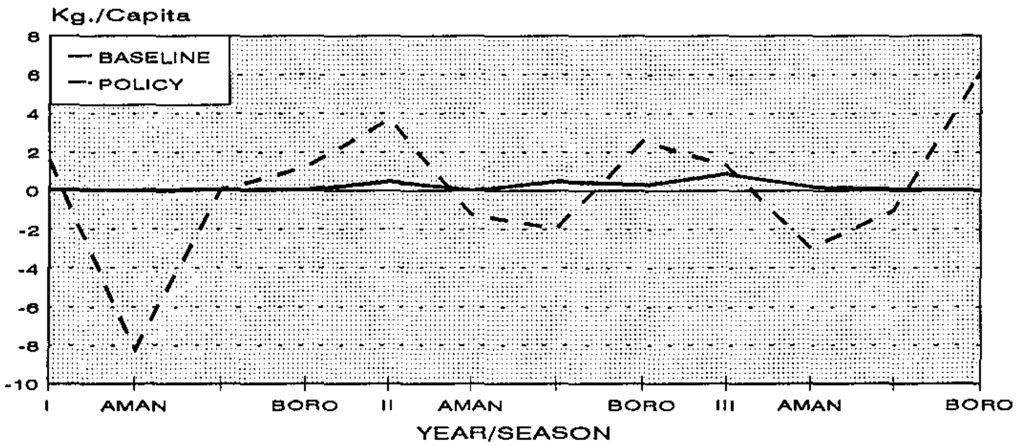


Figure 13—Price stabilization policy

13a—Prices of rice



13b—Open market operations of rice



13c—Open market operations of wheat

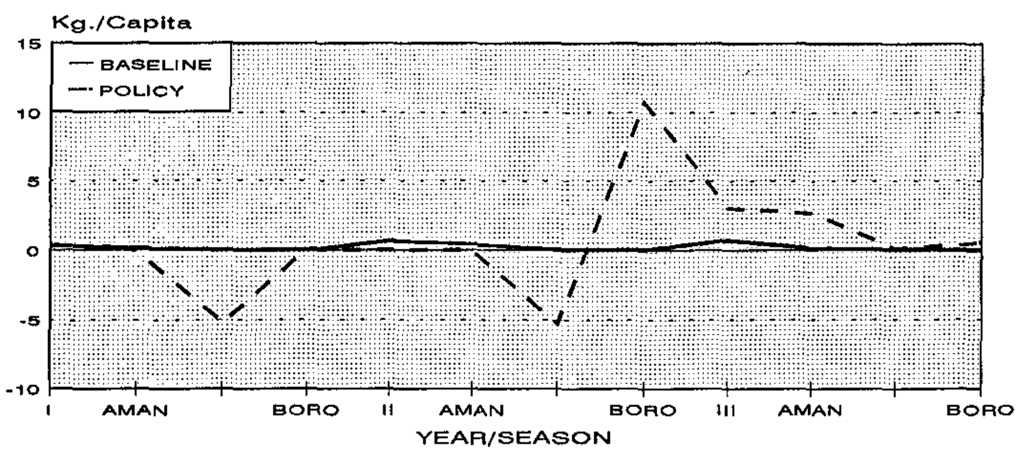
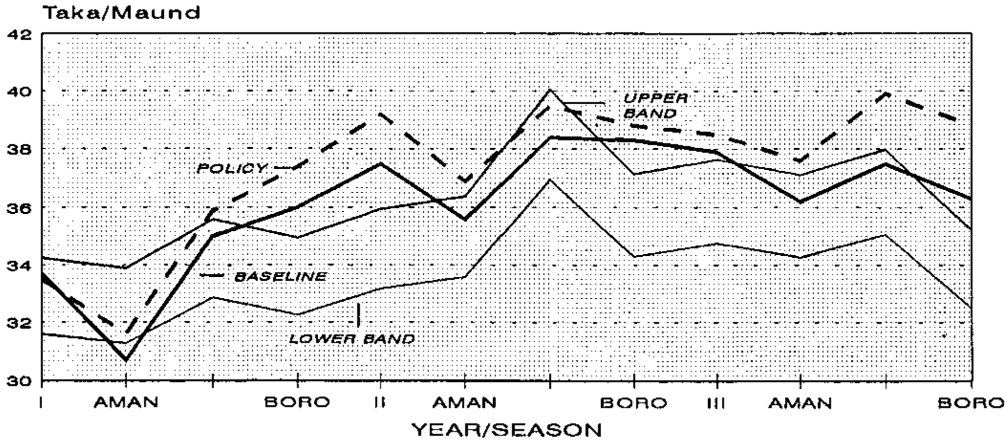
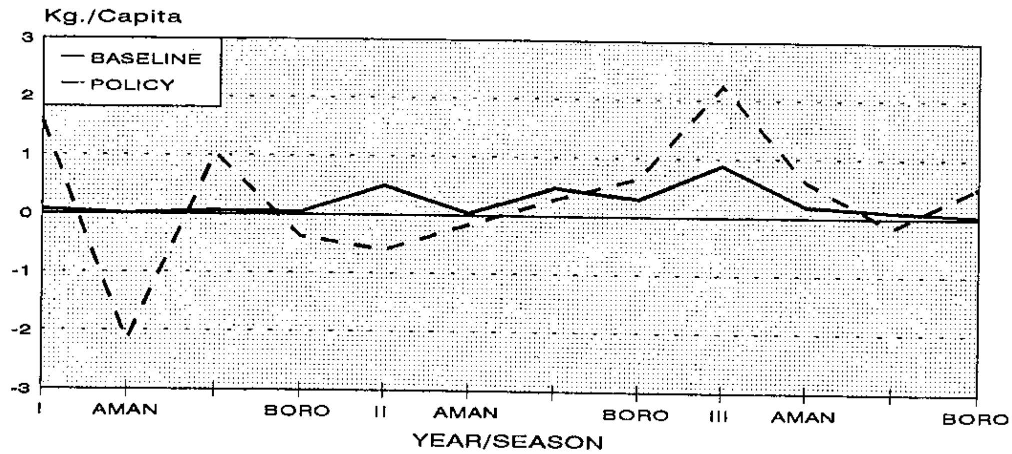


Figure 14—Import policy

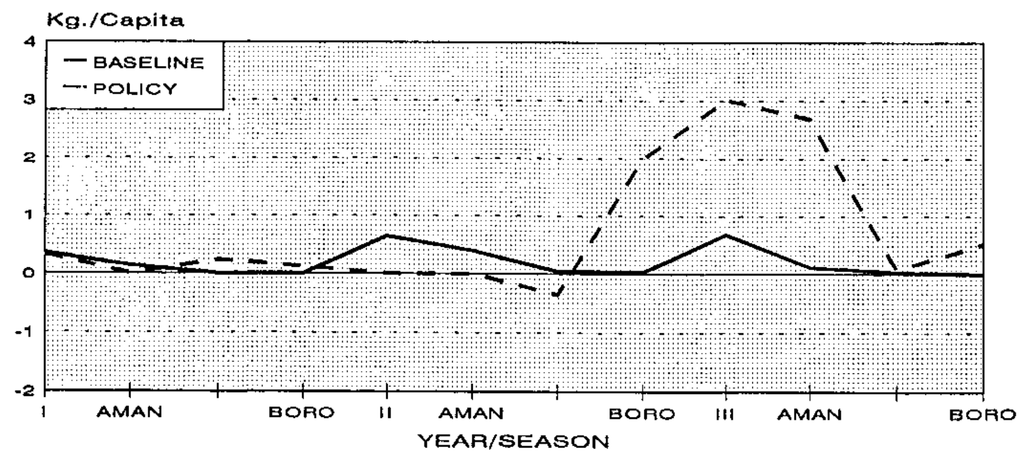
14a—Prices of rice



14b—Imports of rice



14c—Imports of wheat



Nevertheless, the total cost of this policy option still represents a 14 percent saving in relation to the baseline. The main reason for this relatively high cost is that stocks are not used efficiently. In other words, an import policy divorced from a stock policy is not an effective tool. This suggests that in order to look for a real improvement in both cost and stabilization, both trade and stock policy have to be used judiciously. The average foodgrain stock level for this policy is 847,000 tons.

COST MINIMIZATION POLICY

In this case the only objective of the policy is to minimize total cost to carry out public distribution. The outcome is a policy path that results in a total cost equal to just 35 percent of the original baseline cost, that is, Tk 6 billion (Tables 32 and 33; Figure 15). The main instrument to be used intensively to get this result is open market sales. Under this scenario, the government allows the prices to move up to a relatively high level so as to make profits by selling part of the imported grains in the open market. Note also that in this case open market purchases (that is, domestic procurement) are very small in comparison with all previous cases. The average foodgrain stock level in this case is only 686,000 tons. The effect of cost minimization is to reduce the amount of public stock considerably.

BENCHMARK: PRICE STABILIZATION CUM COST MINIMIZATION POLICY

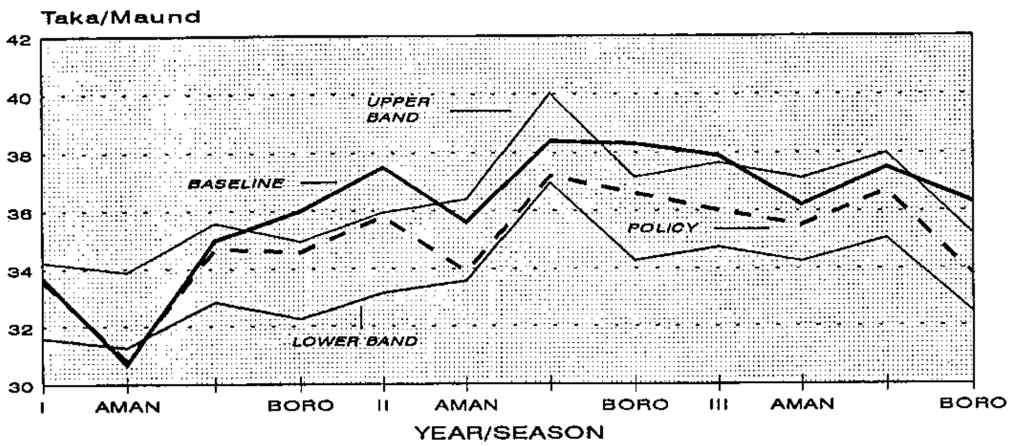
With a total cost equal only to 30 percent of the baseline (that is, Tk 5.1 billion), it is possible to achieve perfect stabilization around the target price (Tables 34 and 35; Figure 16). The flexibility of this policy allows use of both imports and open market operations to take advantage of both the domestic and the international grain markets. This implies a more effective import policy and more active open market operations. The average foodgrain stock is 724,000 tons.

As in previous policy options, the capacity to implement the benchmark policy depends on being able to predict the exogenous variables of the policy exercise accurately enough. For this reason, sensitivity analysis with respect to production and world prices deserves some attention.

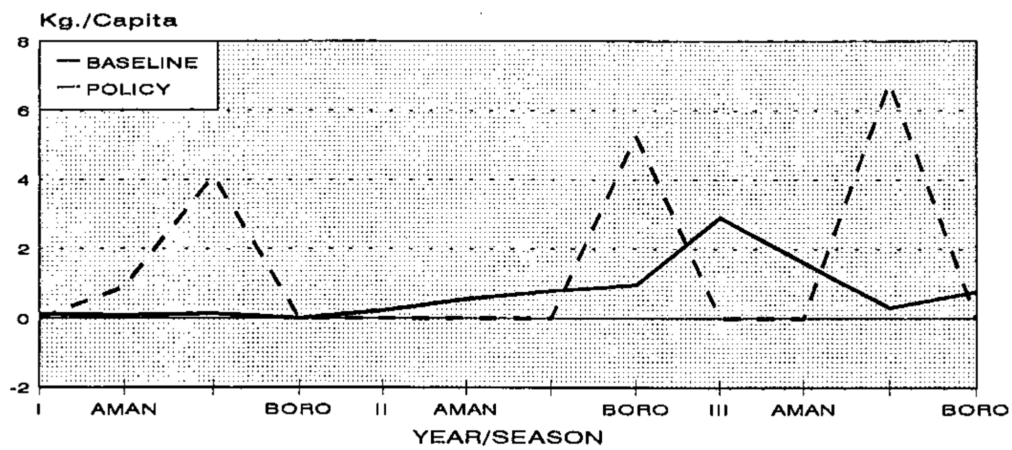
Given the extreme variability of world prices, it is important to see how this policy is affected by different levels of world prices. In particular, it is interesting to perform a simple exercise to compute the benchmark policy when world prices are 30 percent higher. The results are reported in Tables 36 and 37. The total cost of the policy rises from Tk 5.1 billion to Tk 12.9 billion. Therefore, when world prices rise by 30 percent across the period of the simulation, total costs rise by 251 percent. This is mainly the result of lower revenues from open market sales.

Figure 15—Cost minimization policy

15a—Prices of rice



15b—Open market operations of rice



15c—Open market operations of wheat

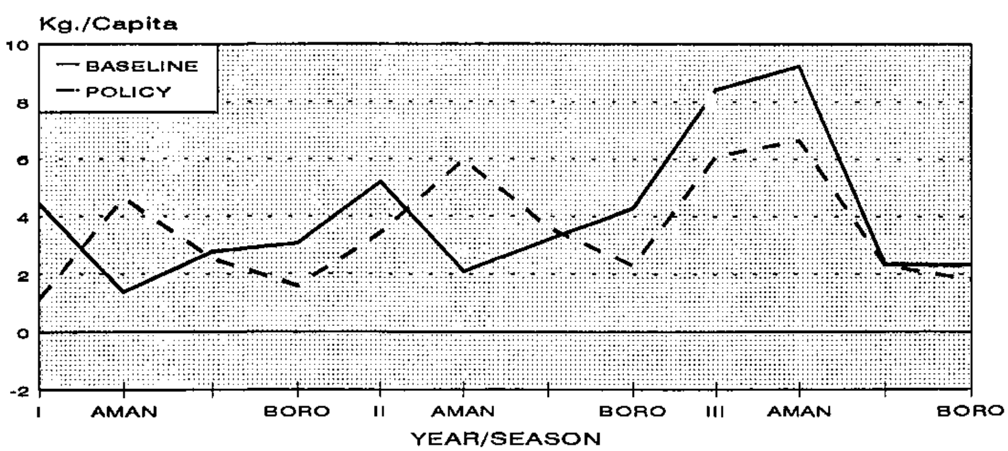
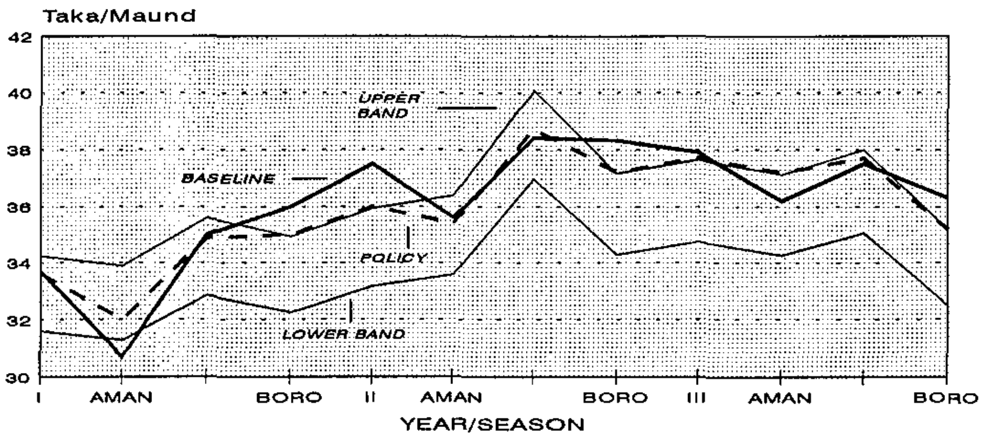
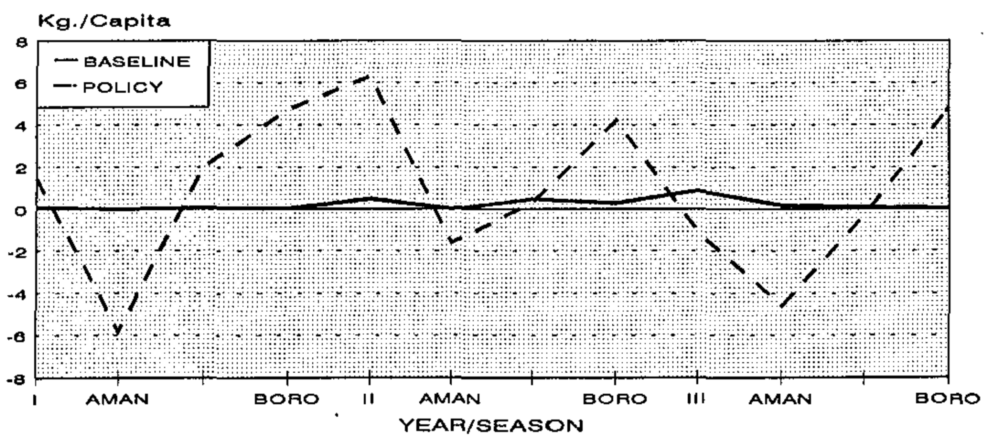


Figure 16—Benchmark policy: price stabilization cum cost minimization

16a—Prices of rice



16b—Open market operations of rice



16c—Open market operations of wheat

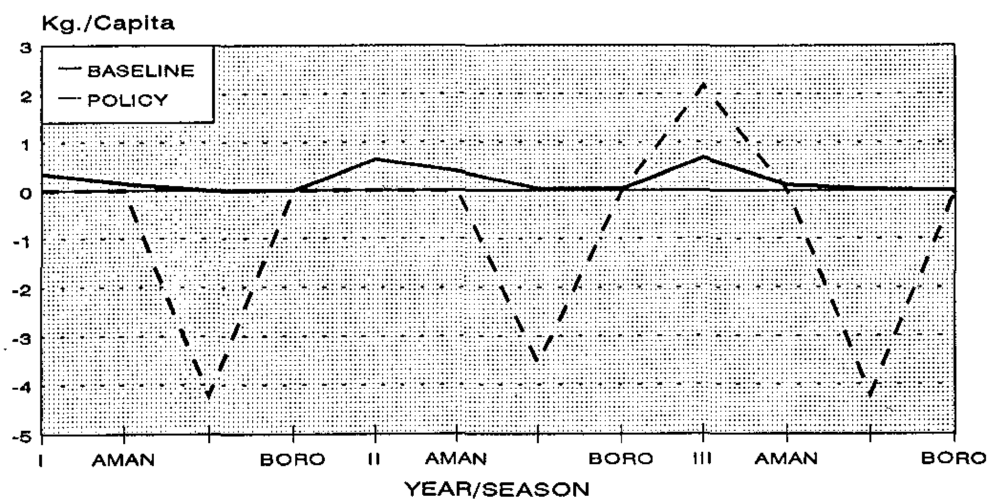
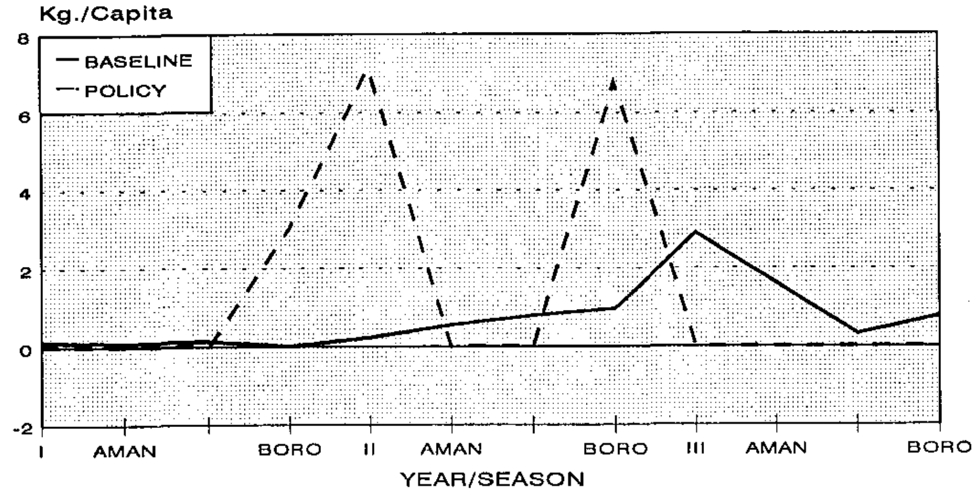
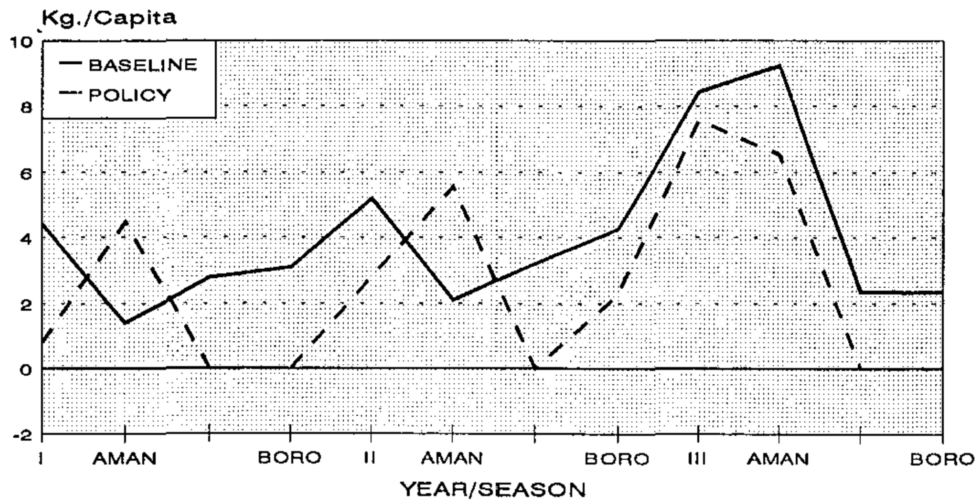


Figure 16—Continued

16d—Imports of rice



16e—Imports of wheat



Another interesting sensitivity analysis of the benchmark case is done by considering the situation where no ration distribution takes place (Tables 38 and 39). The saving in total cost is noteworthy, about 50 percent of the benchmark case (the total cost is Tk 2.7 billion). Yet the saving is not comparable to the loss of ration sales, which was much higher (Tk 15 billion, as seen in Table 37). What is the explanation for this overcompensation of the revenue loss from ration sales?

Clearly, procurement activities are lower than in the benchmark case, because a lesser amount of public stock is needed for distribution (only 690,000 tons). The import cost is almost the same, since the same ceiling on foreign reserves is binding. The big difference lies in the open market sales, since part of the stock that was previously distributed at ration shops can now be sold in the open market.

APPROXIMATION POLICY

In the attempt to find an approximation to the optimal policies, the methodology described in Appendix 7 has been applied to approximate the optimal stabilization policy, pursued only with open market operations. It is remarkable that the approximate policy tracks the optimal solution quite well (Figure 17) and also that the total cost of almost Tk 8.5 billion is extremely close to the level obtained in the optimal policy (Tables 40 and 41). The average foodgrain stock level is 876,000 tons. This amount is less than in the optimal stabilization policy, mainly because on average the open market sales are higher in the approximation policy than in the optimal policy.

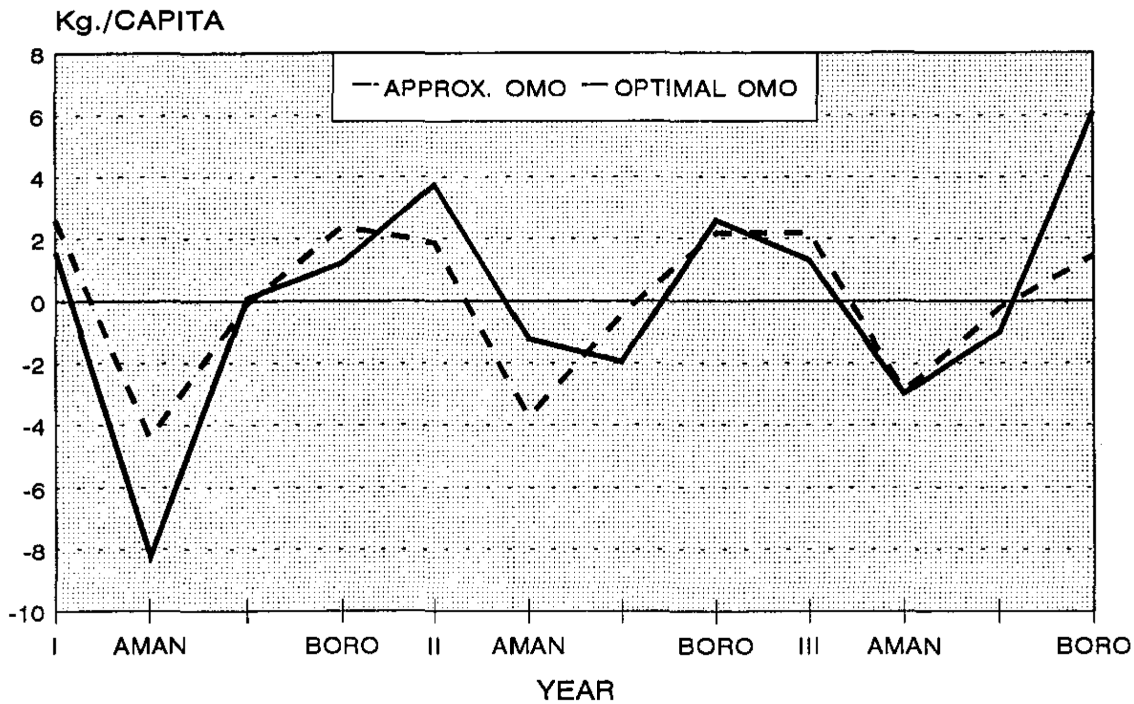
The result is very promising insofar as only a very limited number of variables have been included as independent variables in approximation. In fact, the feedback expression of the approximation policy is the truncated (see Appendix 7) version of

$$oms^i_\tau = f^i(q^r_\tau, q^w_\tau, omo^i_{\tau-1}). \tag{29}$$

Therefore, only production and past open market operations are in the feedback expression. If imports also are a policy instrument, then one should include world prices as independent variables in equation (29).

Figure 17—Approximate versus optimal open market operations

17a—Rice



17b—Wheat

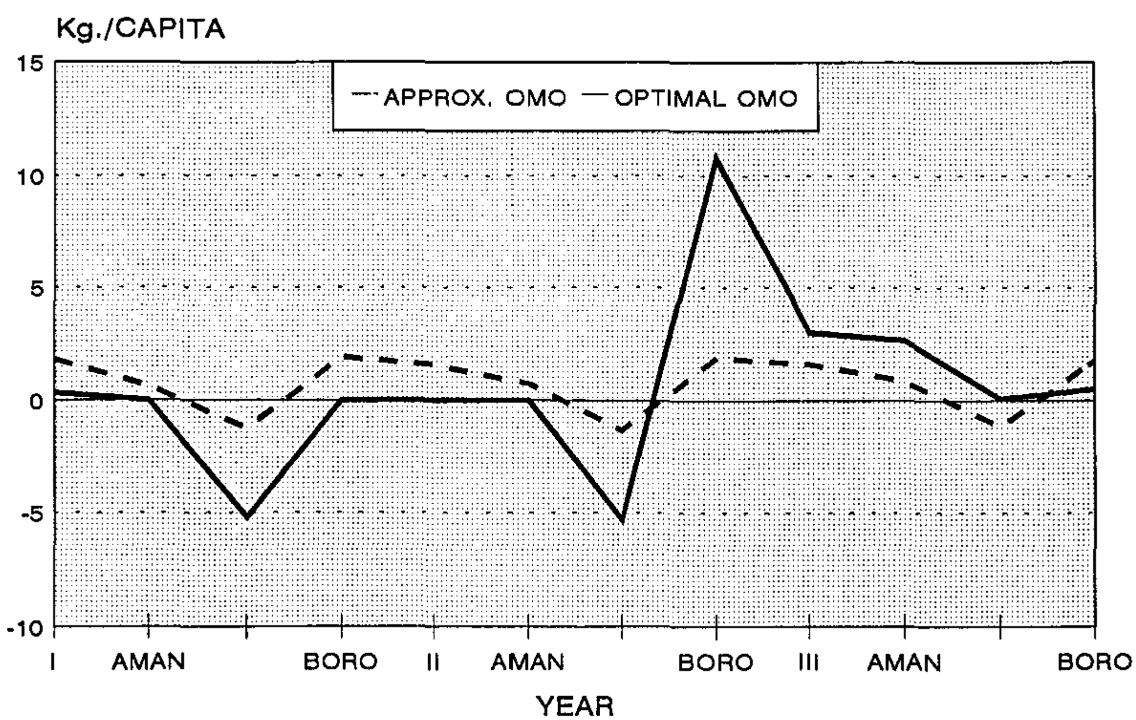


Table 26—Variables in the price band policy, 1985-88

Year/ Season[a]	Price[b] Rice	Price[b] Wheat	Stock Rice	Stock Wheat	Open Market Operations[c] Rice	Open Market Operations[c] Wheat	Imports Rice	Imports Wheat
	(Tk/maund)				(kilograms/capita)			
1985/86								
Aus	33.7	20.9	3.03	6.94	0.00	0.00	0.12	4.42
Aman	31.3	20.7	6.77	3.63	-4.68	0.00	0.09	1.39
Winter	34.0	20.3	6.23	3.85	0.00	0.00	0.14	2.78
Boro	34.3	21.6	5.57	5.31	0.00	0.00	0.00	3.08
1986/87								
Aus	35.7	22.5	4.73	7.60	0.00	0.00	0.23	5.19
Aman	33.6	21.7	4.87	3.87	-0.5	0.00	0.55	2.10
Winter	36.9	22.0	6.90	8.80	-1.96	-5.32	0.79	3.21
Boro	35.4	22.4	7.23	10.46	0.00	0.00	0.97	4.27
1987/88								
Aus	34.4	21.7	7.65	11.09	1.47	1.95	2.90	8.43
Aman	32.8	20.9	7.65	11.09	0.24	2.22	1.61	9.23
Winter	34.7	20.8	7.65	11.09	-0.54	-0.38	0.32	2.36
Boro	33.3	21.5	7.65	11.09	0.15	0.05	0.77	2.34
Mean	34.2	21.4	6.33	7.9	-0.49	-0.12	0.71	4.07
Standard deviation	1.5	0.7	1.49	3.12	1.53	1.83	0.83	2.47

Source: Estimated by the authors.

Note: The price band is defined by a plus or minus 4 percent margin around the target price.

[a] The seasons are defined as follows: aus, July-October; aman, November-February; winter, March-April; boro, May-June.
[b] Prices are deflated by the index of manufactured goods.
[c] Positive open market operations have to be interpreted as open market sales; negative open market operations have to be interpreted as domestic procurement.

Table 27—Costs in the price band policy, 1985-88

Year/ Season[a]	Procurement Cost	Imports	Ration Sales	Open Market Sales	Total Cost[b]	Foreign Exchange	Cash Outflow[c]
			(Tk million)			(US$ million)	(Tk million)
1985/86							
Aus	0	2,308	1,619	0	689	77	-1,400
Aman	3,304	862	1,366	0	2,799	28	2,025
Winter	0	1,682	518	0	1,164	56	-352
Boro	0	1,673	515	0	1,158	55	-366
1986/87							
Aus	0	2,353	1,515	0	838	78	-1,152
Aman	407	1,237	1,790	0	-146	40	-1,068
Winter	4,607	1,913	984	0	5,536	62	4,107
Boro	0	2,464	804	0	1,660	80	-191
1987/88							
Aus	0	5,720	2,346	2,352	1,022	185	-2,086
Aman	0	5,765	2,296	1,391	2,078	186	-1,334
Winter	703	1,452	803	0	1,352	46	475
Boro	0	2,120	479	159	1,482	67	305
Total	9,020	29,548	15,035	3,902	19,632	959	-1,036
Standard deviation	1,473	1,535	642	720	1,366	50	1,634

Source: Estimated by the authors.

Note: The price band is defined by a plus or minus 4 percent margin around the target price.

[a] The seasons are defined as follows: aus, July-October; aman, November-February; winter, March-April; boro, May-June.
[b] Total cost = procurement cost + import cost - ration sales - open market sales.
[c] Cash outflow = total cost - foreign exchange.

Table 28—Variables in the optimal price stabilization policy, 1985-88

Year/ Season[a]	Price[b] Rice	Price[b] Wheat	Stock Rice	Stock Wheat	Open Market Operations[c] Rice	Open Market Operations[c] Wheat	Imports Rice	Imports Wheat
	(Tk/maund)				(kilograms/capita)			
1985/86								
Aus	33.5	20.9	1.47	6.61	1.56	0.33	0.12	4.42
Aman	32.2	20.9	8.83	3.32	-8.21	0.00	0.09	1.39
Winter	34.2	21.0	8.07	8.76	0.09	-5.20	0.14	2.78
Boro	33.6	21.6	6.08	9.93	1.23	0.00	0.00	3.08
1986/87								
Aus	34.8	22.2	1.47	11.94	3.73	0.00	0.23	5.19
Aman	34.6	21.9	2.53	7.95	-1.22	0.00	0.55	2.10
Winter	38.5	22.5	4.70	12.63	-1.96	-5.32	0.79	3.21
Boro	35.7	21.3	2.58	3.32	2.58	10.75	0.97	4.27
1987/88								
Aus	36.2	21.9	3.47	3.32	1.29	3.01	2.90	8.43
Aman	35.7	21.7	6.93	3.32	-2.98	2.68	1.61	9.23
Winter	36.5	21.5	7.42	3.32	-0.99	0.08	0.32	2.36
Boro	33.9	21.8	1.47	3.32	6.12	0.52	0.77	2.34
Mean	35.0	21.6	4.58	6.48	0.10	0.57	0.71	4.07
Standard deviation	1.7	0.5	2.77	3.65	3.64	4.09	0.83	2.47

Source: Estimated by the authors.

Note: The optimal price stabilization policy uses open market operations to minimize the variance of rice prices around the target.

[a] The seasons are defined as follows: aus, July-October; aman, November-February; winter, March-April; boro, May-June.
[b] Prices are deflated by the index of manufactured goods.
[c] Positive open market operations have to be interpreted as open market sales; negative open market operations have to be interpreted as domestic procurement.

Table 29—Costs in the optimal price stabilization policy, 1985-88

Year/ Season[a]	Procurement Cost	Imports	Ration Sales	Open Market Sales	Total Cost[b]	Foreign Exchange	Cash Outflow[c]
			(Tk million)			(US$ million)	(Tk million)
1985/86							
Aus	0	2,308	1,619	1,288	-599	77	-2,688
Aman	5,955	862	1,366	0	5,450	28	4,677
Winter	2,549	1,682	518	72	3,641	56	2,125
Boro	0	1,673	515	983	175	55	-1,349
1986/87							
Aus	0	2,353	1,515	3,151	-2,314	78	-4,304
Aman	1,026	1,237	1,790	0	473	40	-449
Winter	4,742	1,913	984	0	5,671	62	4,242
Boro	0	2,464	804	8,368	-6,707	80	-8,558
1987/88							
Aus	0	5,720	2,346	2,843	531	185	-2,577
Aman	2,737	5,765	2,296	1,497	4,710	186	1,298
Winter	951	1,452	803	46	1,554	46	677
Boro	0	2,120	479	5,834	-4,193	67	-5,370
Total	17,961	29,548	15,035	24,083	8,392	959	-12,276
Standard deviation	1,979	1,535	642	2,560	3,682	50	3,769

Source: Estimated by the authors.

Note: The optimal price stabilization policy uses open market operations to minimize the variance of rice price around the target.

[a] The seasons are defined as follows: aus, July-October; aman, November-February; winter, March-April; boro, May-June.
[b] Total cost = procurement cost + import cost - ration sales - open market sales.
[c] Cash outflow = total cost - foreign exchange.

Table 30—Variables in the import policy, 1985-88

Year/ Season[a]	Price[b]		Stock		Open Market Operations[c]		Imports	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
	(Tk/maund)				(kilograms/capita)			
1985/86								
Aus	33.6	20.9	2.84	3.32	0.07	0.35	0.00	1.16
Aman	30.8	20.5	2.71	3.32	0.01	0.14	0.90	4.62
Winter	34.7	20.5	6.31	3.32	0.06	0.00	4.10	2.53
Boro	34.6	21.7	5.61	3.32	0.04	0.00	0.00	1.60
1986/87								
Aus	35.8	22.4	4.04	3.32	0.50	0.64	0.00	3.43
Aman	33.9	21.7	3.15	3.32	0.03	0.40	0.00	5.97
Winter	37.2	21.4	2.05	3.32	0.48	0.04	0.00	3.61
Boro	36.6	22.6	6.65	3.32	0.30	0.03	5.25	2.31
1987/88								
Aus	36.0	22.4	4.80	3.32	0.88	0.68	0.00	6.09
Aman	35.5	22.1	3.40	3.32	0.19	0.12	0.00	6.66
Winter	36.7	21.6	9.50	3.32	0.10	0.03	6.81	2.31
Boro	33.8	21.9	8.73	3.32	0.04	0.00	0.00	1.82
Mean	34.9	21.6	4.98	3.32	0.22	0.20	1.42	3.51
Standard deviation	1.8	0.7	2.42	0.00	0.27	0.25	2.47	1.90

Source: Estimated by the authors.

Note: The imports policy uses open market operations to minimize the variance of prices around the target.

[a] The seasons are defined as follows: aus, July-October; aman, November-February; winter, March-April; boro, May-June.
[b] Prices are deflated by the index of manufactured goods.
[c] Positive open market operations have to be interpreted as open market sales; negative open market operations have to be interpreted as domestic procurement.

Table 31—Costs in the import policy, 1985-88

Year/ Season[a]	Procurement Cost	Imports	Ration Sales	Open Market Sales	Total Cost[b]	Foreign Exchange	Cash Outflow[c]
			(Tk million)			(US$ million)	(Tk million)
1985/86							
Aus	0	584	1,619	210	-1,245	19	-1,777
Aman	0	3,277	1,366	70	1,840	107	-1,035
Winter	0	4,077	518	50	3,510	135	270
Boro	0	866	515	33	318	29	-471
1986/87							
Aus	0	1,459	1,515	783	-840	48	-2,115
Aman	0	2,536	1,790	237	509	82	-1,708
Winter	0	1,555	984	457	114	50	-1,245
Boro	0	4,530	804	300	3,426	146	1,102
1987/88							
Aus	0	2,512	2,346	1,189	-1,023	81	-2,744
Aman	0	3,092	2,296	245	552	100	-1,565
Winter	0	7,924	803	110	7,012	252	4,047
Boro	0	1,058	479	35	544	34	-181
Total	0	33,469	15,035	3,719	14,716	1,083	-7,421
Standard deviation	0	1,966	642	336	2,288	63	1,744

Source: Estimated by the authors.

Note: The imports policy uses open market operations to minimize the variance of rice prices around the target.

[a] The seasons are defined as follows: aus, July-October; aman, November-February; winter, March-April; boro, May-June.
[b] Total cost = procurement cost + import cost - ration sales - open market sales.
[c] Cash outflow = total cost - foreign exchange.

Table 32—Variables in the cost minimization policy, 1985-88

Year/ Season[a]	Price[b] Rice	Price[b] Wheat	Stock Rice	Stock Wheat	Open Market Operations[c] Rice	Open Market Operations[c] Wheat	Imports Rice	Imports Wheat
	(Tk/maund)				(kilograms/capita)			
1985/86								
Aus	33.5	20.9	1.47	6.68	1.56	0.33	0.12	4.42
Aman	31.6	20.8	2.80	3.39	-2.18	0.00	0.09	1.39
Winter	35.9	21.0	1.47	4.30	1.03	0.24	0.14	2.78
Boro	37.4	22.7	1.47	5.92	-0.37	0.12	0.00	3.08
1986/87								
Aus	39.2	23.7	1.47	8.18	-0.60	0.00	0.23	5.19
Aman	36.9	22.9	1.47	4.42	-0.16	0.00	0.55	2.10
Winter	39.5	22.4	1.47	4.56	0.28	-0.36	0.79	3.21
Boro	38.8	23.2	1.47	4.77	0.65	1.99	0.97	4.27
1987/88								
Aus	38.5	23.0	1.47	4.71	2.24	3.01	2.90	8.43
Aman	37.6	22.5	1.47	4.62	0.61	2.68	1.61	9.23
Winter	39.9	22.7	1.47	5.03	-0.17	0.08	0.32	2.36
Boro	38.8	23.5	1.47	5.24	0.52	0.52	0.77	2.34
Mean	37.3	22.4	1.58	5.15	0.28	0.72	0.71	4.07
Standard deviation	2.5	1.0	0.39	1.26	1.13	1.15	0.83	2.47

Source: Estimated by the authors.

Note: The cost minimization policy uses open market operations to minimize the total cost of food operations.

[a] The seasons are defined as follows: aus, July-October; aman, November-February; winter, March-April; boro, May-June.
[b] Prices are deflated by the index of manufactured goods.
[c] Positive open market operations have to be interpreted as open market sales; negative open market operations have to be interpreted as domestic procurement.

Table 33—Costs in the cost minimization policy, 1985-88

Year/ Season[a]	Procurement Cost	Imports	Ration Sales	Open Market Sales	Total Cost[b]	Foreign Exchange	Cash Outflow[c]
			(Tk million)			(US$ million)	(Tk million)
1985/86							
Aus	0	2,308	1,619	1,289	-599	77	-2,688
Aman	1,558	862	1,366	0	1,053	28	279
Winter	0	1,682	518	980	184	56	-1,332
Boro	327	1,673	515	65	1,420	55	-104
1986/87							
Aus	571	2,353	1,515	0	1,409	78	-581
Aman	141	1,237	1,790	0	-412	40	-1,334
Winter	195	1,913	984	265	859	62	-569
Boro	0	2,464	804	1,863	-203	80	-2,054
1987/88							
Aus	0	5,720	2,346	3,931	-557	185	-3,664
Aman	0	5,765	2,296	2,138	1,332	186	-2,080
Winter	179	1,452	803	49	779	46	-98
Boro	0	2,120	479	860	781	67	-396
Total	2,971	29,548	15,035	11,438	6,046	959	-14,622
Standard deviation	430	1,535	642	1,156	748	50	1,149

Source: Estimated by the authors.

Note: The cost minimization policy uses open market operations to minimize the total cost of food operations.

[a] The seasons are defined as follows: aus, July-October; aman, November-February; winter, March-April; boro, May-June.
[b] Total cost = procurement cost + import cost - ration sales - open market sales.
[c] Cash outflow = total cost - foreign exchange.

Table 34—Variables in the benchmark policy: price stabilization cum cost minimization, 1985-88

Year/ Season[a]	Price[b]		Stock		Open Market Operations[c]		Imports	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
	(Tk/maund)				(kilograms/capita)			
1985/86								
Aus	33.6	20.9	1.47	3.32	1.44	0.00	0.00	0.80
Aman	32.0	20.9	6.37	3.32	-5.84	0.00	0.00	4.48
Winter	34.9	21.1	3.69	5.02	2.03	-4.23	0.00	0.00
Boro	35.0	22.0	1.47	3.32	4.75	0.00	3.03	0.00
1986/87								
Aus	36.0	22.6	1.47	3.32	6.30	0.00	7.13	2.79
Aman	35.4	22.2	2.38	3.32	-1.61	0.00	0.00	5.57
Winter	38.7	22.4	1.47	3.32	0.34	-3.57	0.00	0.00
Boro	37.2	23.0	3.69	3.32	4.22	0.00	6.76	2.28
1987/88								
Aus	37.7	22.8	3.98	3.32	-1.09	2.17	0.00	7.58
Aman	37.2	22.6	7.43	3.32	-4.60	0.00	0.00	6.54
Winter	37.7	22.5	6.86	5.26	-0.28	-4.22	0.00	0.00
Boro	35.2	22.5	1.47	3.32	4.81	0.00	0.00	0.00
Mean	35.9	22.1	3.48	3.62	0.87	-0.82	1.41	2.50
Standard deviation	1.9	0.7	2.28	0.71	3.81	2.02	2.73	2.86

Source: Estimated by the authors.

Note: The benchmark policy uses open market operations and imports to minimize the total cost of food operations subject to price stabilization and foreign reserves constraints.

[a] The seasons are defined as follows: aus, July-October; aman, November-February; winter, March-April; boro, May-June.
[b] Prices are deflated by the index of manufactured goods.
[c] Positive open market operations have to be interpreted as open market sales; negative open market operations have to be interpreted as domestic procurement.

Table 35—Costs in the benchmark policy: price stabilization cum cost minimization, 1985-88

Year/ Season[a]	Procurement Cost	Imports	Ration Sales	Open Market Sales	Total Cost[b]	Foreign Exchange	Cash Outflow[c]
			(Tk million)			(US$ million)	(Tk million)
1985/86							
Aus	0	406	1,619	1,054	-2,267	14	-2,636
Aman	4,220	2,588	1,366	0	5,442	84	3,084
Winter	2,080	0	518	1,649	-86	0	-86
Boro	0	1,864	515	3,942	-2,592	62	-3,953
1986/87							
Aus	0	5,728	1,515	5,491	-1,278	189	-4,195
Aman	1,390	2,366	1,790	0	1,965	77	-103
Winter	1,946	0	984	319	643	0	643
Boro	0	5,541	804	4,087	650	179	-2,087
1987/88							
Aus	1,035	3,127	2,346	1,249	567	101	-1,575
Aman	4,400	3,034	2,296	0	5,138	98	3,060
Winter	2,768	0	803	0	1,965	0	1,965
Boro	0	0	479	4,530	-5,009	0	-5,009
Total	17,839	24,654	15,035	22,321	5,137	803	-10,893
Standard deviation	1,566	1,995	642	1,977	2,905	65	2,667

Source: Estimated by the authors.

Note: The benchmark policy uses open market operations and imports to minimize the total cost of food operations subject to price stabilization and foreign reserves constraints.

[a] The seasons are defined as follows: aus, July-October; aman, November-February; winter, March-April; boro, May-June.
[b] Total cost = procurement cost + import cost - ration sales - open market sales.
[c] Cash outflow = total cost - foreign exchange.

Table 36—Variables in the benchmark policy with 30 percent increase in world prices, 1985-88

Year/ Season[a]	Price[b]		Stock		Open Market Operations[c]		Imports	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
	(Tk/maund)		(kilograms/capita)					
1985/86								
Aus	33.6	20.9	1.47	3.32	1.44	0.00	0.00	0.8
Aman	32.1	20.9	7.33	3.32	-6.80	0.00	0.00	4.48
Winter	34.6	21.1	5.69	5.02	0.93	-4.23	0.00	0.00
Boro	35.0	22.0	4.95	3.32	0.11	0.00	0.00	0.00
1986/87								
Aus	36.0	22.6	1.47	3.32	3.27	0.00	0.82	2.79
Aman	35.3	22.2	2.25	3.32	-1.48	0.00	0.00	5.57
Winter	38.8	22.4	1.47	3.32	0.22	-3.57	0.00	0.00
Boro	37.2	23.0	3.52	3.32	4.45	0.00	6.82	2.28
1987/88								
Aus	37.7	22.7	3.94	3.32	-1.21	2.91	0.00	8.32
Aman	37.2	22.6	7.42	3.32	-4.63	0.00	0.00	6.54
Winter	37.7	22.5	6.85	5.26	-0.28	-4.22	0.00	0.00
Boro	35.2	22.5	1.47	3.32	4.81	0.00	0.00	0.00
Mean	35.9	22.1	3.99	3.62	0.07	-0.76	0.64	2.57
Standard deviation	1.9	0.7	2.41	0.71	3.41	2.13	1.96	2.98

Source: Estimated by the authors.

[a] The seasons are defined as follows: aus, July-October; aman, November-February; winter, March-April; boro, May-June.
[b] Prices are deflated by the index of manufactured goods.
[c] Positive open market operations have to be interpreted as open market sales; negative open market operations have to be interpreted as domestic procurement.

Table 37—Costs in the benchmark policy with 30 percent increase in world prices, 1985-88

Year/ Season[a]	Procurement Cost	Imports	Ration Sales	Open Market Sales	Total Cost[b]	Foreign Exchange	Cash Outflow[c]
			(Tk million)			(US$ million)	(Tk million)
1985/86							
Aus	0	527	1,619	1,054	-2,145	18	-2,636
Aman	4,923	3,364	1,366	0	6,921	110	3,787
Winter	2,073	0	518	749	807	0	807
Boro	0	0	515	92	-607	0	-607
1986/87							
Aus	0	2,222	1,515	2,851	-2,144	73	-3,910
Aman	1,276	3,075	1,790	0	2,561	100	-216
Winter	1,947	0	984	203	760	0	760
Boro	0	7,257	804	4,309	2,144	234	-2,286
1987/88							
Aus	1,148	4,462	2,346	1,669	1,596	144	-1,785
Aman	4,430	3,944	2,296	0	6,078	127	3,090
Winter	2,769	0	803	0	1,967	0	1,967
Boro	0	0	479	4,527	-5,006	0	-5,006
Total	18,567	24,852	15,035	15,453	12,931	806	-6,035
Standard deviation	1,679	2,285	642	1,628	3,219	74	2,615

Source: Estimated by the authors.

[a] The seasons are defined as follows: aus, July-October; aman, November-February; winter, March-April; boro, May-June.
[b] Total cost = procurement cost + import cost - ration sales - open market sales.
[c] Cash outflow = total cost - foreign exchange.

Table 38—Variables in the benchmark policy when monetary offtakes are eliminated, 1985-88

Year/ Season[a]	Price[b]		Stock		Open Market Operations[c]		Imports	
	Rice	Wheat	Rice	Wheat	Rice	Wheat	Rice	Wheat
	(Tk/maund)		(kilograms/capita)					
1985/86								
Aus	33.8	21.2	1.47	4.53	2.44	0.00	0.00	0.00
Aman	32.3	21.2	4.87	3.32	-3.73	0.00	0.00	1.40
Winter	35.6	21.3	1.47	4.35	3.10	-2.89	0.00	0.00
Boro	35.0	22.1	1.47	3.32	8.53	0.00	8.62	0.00
1986/87								
Aus	36.0	22.9	1.47	3.32	7.84	0.00	8.00	0.87
Aman	35.6	22.6	1.47	3.32	-0.10	0.00	0.00	3.06
Winter	39.0	22.6	1.47	3.32	1.12	-2.21	1.29	0.00
Boro	37.2	23.1	3.75	3.32	5.38	0.47	7.75	1.57
1987/88								
Aus	37.7	22.7	4.55	3.32	-1.07	6.11	0.00	7.98
Aman	37.2	22.9	7.24	3.32	-2.96	0.00	0.00	3.82
Winter	37.8	22.5	7.12	4.65	-0.31	-2.84	0.00	0.00
Boro	35.2	22.6	1.47	3.32	5.22	0.00	0.00	0.00
Mean	36.0	22.3	3.15	3.62	2.12	-0.11	2.14	1.56
Standard deviation	1.9	0.7	2.29	0.54	4.01	2.31	3.63	2.41

Source: Estimated by the authors.

[a] The seasons are defined as follows: aus, July-October; aman, November-February; winter, March-April; boro, May-June.
[b] Prices are deflated by the index of manufactured goods.
[c] Positive open market operations have to be interpreted as open market sales; negative open market operations have to be interpreted as domestic procurement.

Table 39—Costs in the benchmark policy when monetary offtakes are eliminated, 1985-88

Year/ Season[a]	Procurement Cost	Imports	Ration Sales	Open Market Sales	Total Cost[b]	Foreign Exchange	Cash Outflow[c]
			(Tk million)			(US$ million)	(Tk million)
1985/86							
Aus	0	0	0	1,800	-1,800	0	-1,800
Aman	2,716	809	0	0	3,525	26	2,788
Winter	1,437	0	0	2,576	-1,138	0	-1,138
Boro	0	5,303	0	7,077	-1,774	175	-5,645
1986/87							
Aus	0	5,466	0	6,836	-1,370	180	-3,803
Aman	83	1,299	0	0	1,382	42	247
Winter	1,216	861	0	1,060	1,017	28	661
Boro	0	5,914	0	5,489	425	191	-2,329
1987/88							
Aus	1,016	3,291	0	3,516	791	106	-1,464
Aman	2,835	1,773	0	0	4,608	57	3,394
Winter	1,987	0	0	0	1,987	0	1,987
Boro	0	0	0	4,913	-4,913	0	-4,913
Total	11,291	24,717	0	33,267	2,741	806	-12,016
Standard deviation	1,054	2,220	0	2,618	2,490	73	2,803

Source: Estimated by the authors.

[a] The seasons are defined as follows: aus, July-October; aman, November-February; winter, March-April; boro, May-June.
[b] Total cost = procurement cost + import cost - ration sales - open market sales.
[c] Cash outflow = total cost - foreign exchange.

Table 40—Variables in the approximation policy, 1985-88

Year/ Season[a]	Price[b] Rice	Price[b] Wheat	Stock Rice	Stock Wheat	Open Market Operations[c] Rice	Open Market Operations[c] Wheat	Imports Rice	Imports Wheat
	(Tk/maund)				(kilograms/capita)			
1985/86								
Aus	33.3	20.6	1.15	5.20	2.58	1.81	0.12	4.42
Aman	31.9	20.7	6.06	1.35	-4.43	0.64	0.09	1.39
Winter	34.9	20.8	5.73	3.88	-0.08	-1.25	0.14	2.78
Boro	34.6	21.6	2.93	3.73	2.39	1.92	0.00	3.08
1986/87								
Aus	36.7	22.6	0.45	4.57	1.86	1.55	0.23	5.19
Aman	36.1	22.3	4.31	0.27	-3.73	0.75	0.55	2.10
Winter	37.9	22.0	4.82	1.65	-0.41	-1.35	0.79	3.21
Boro	36.5	22.5	4.14	2.14	2.18	1.89	0.97	4.27
1987/88								
Aus	36.3	22.3	4.38	3.65	2.18	1.60	2.90	8.43
Aman	35.7	22.0	8.17	5.43	-2.89	0.88	1.61	9.23
Winter	36.2	21.6	7.81	7.03	-0.21	-1.16	0.32	2.36
Boro	34.1	21.8	8.42	5.86	1.46	1.77	0.77	2.34
Mean	35.3	21.7	4.86	3.73	0.08	0.75	0.71	4.07
Standard deviation	1.7	0.7	2.57	2.04	2.52	1.29	0.83	2.47

Source: Estimated by the authors.

Note: The approximating policy was computed by doing stochastic simulations of production shocks and ordinary least squares over rice production, wheat production, and a lagged term.

[a] The seasons are defined as follows: aus, July-October; aman, November-February; winter, March-April; boro, May-June.
[b] Prices are deflated by the index of manufactured goods.
[c] Positive open market operations have to be interpreted as open market sales; negative open market operations have to be interpreted as domestic procurement.

Table 41—Costs in the approximation policy, 1985-88

Year/ Season[a]	Procurement Cost	Imports	Ration Sales	Open Market Sales	Total Cost[b]	Foreign Exchange	Cash Outflow[c]
			(Tk million)			(US$ million)	(Tk million)
1985/86							
Aus	0	2,308	1,619	2,695	-2,006	77	-4,095
Aman	3,187	862	1,366	298	2,385	28	1,611
Winter	673	1,682	518	0	1,838	56	321
Boro	0	1,673	515	2,955	-1,797	55	-3,321
1986/87							
Aus	0	2,353	1,515	2,498	-1,660	78	-3,651
Aman	3,280	1,237	1,790	408	2,319	40	1,396
Winter	1,100	1,913	984	0	2,029	62	600
Boro	0	2,464	804	3,175	-1,515	80	-3,366
1987/88							
Aus	0	5,720	2,346	2,902	472	185	-2,636
Aman	2,659	5,765	2,296	498	5,630	186	2,218
Winter	852	1,452	803	0	1,501	46	624
Boro	0	2,120	479	2,362	-722	67	-1,899
Total	11,751	29,548	15,035	17,791	8,473	959	-12,195
Standard deviation	1,254	1,535	642	1,305	2,228	50	2,253

Source: Estimated by the authors.

Note: The approximating policy was computed by doing stochastic simulations of production shocks and ordinary least squares over rice production, wheat production, and a lagged term.

[a] The seasons are defined as follows: aus, July-October; aman, November-February; winter, March-April; boro, May-June.
[b] Total cost = procurement cost + import cost - ration sales - open market sales.
[c] Cash outflow = total cost - foreign exchange.

10. CONCLUSIONS

The paper has presented a general approach to analyzing the optimal stock problem for Bangladesh. The approach chosen is responsive to the needs of a policymaker whose broad concern is to guarantee food security and price stability at minimum cost.

A dynamic model of the foodgrain sector has been constructed, taking into account the decisions of the private sector regarding consumption and private storage. A set of policies, characterized by different objectives and constraints, have been defined and evaluated.

The summary statistics of the various policy options are given in Tables 42 and 43. The main conclusions are as follows:

- The higher the number of policy instruments available to the government, the more effective the policy becomes in achieving the objectives of price stabilization, cost efficiency, and food security. The policy instruments that have been analyzed in the paper are open market sales, domestic procurement, and food imports.

- In order to keep the foodgrain distribution system going, imports, especially of wheat, cannot be eliminated. At the same time, a policy that would rely only on imports to stabilize prices would not be as cost-effective as a policy that relied on an effective management of open market operations (that is, domestic purchase and sale).

- The benchmark for optimal policy is given by a policy whose objective is to minimize cost, subject to several constraints including food security, price stabilization, and the reaction of the private sector. The benchmark is characterized by its flexibility in adapting to changes in both the domestic economy (for example, production shocks) and in the world economy (for example, world commodity prices). Fixed rules, such as price band schemes, even if effective in reducing price variability, are not likely to be cost-effective, and, vice versa, when they are cost effective, they are not likely to stabilize prices.

- Price stabilization around a target can be effectively achieved at a relatively low cost in comparison with historical performance. The main instruments to be used for this purpose are open market operations and imports. In particular, open market operations have to be used much more intensively than in the past.

Table 42—Summary of various policies

Policy	Baseline[a]		Price Band[b]		Price Stabilization[c]		Approimation to Price Stabilization[d]		Cost Minimization[e]		Import Policy[f]		Benchmark[g]		Bencha30[h]		No ration[i]	
	Avg	Std	Avg	Std	Avg	Std	Avg	Std	Avg	Std	Avg	Std	Avg	Std	Avg	Std	Avg	Std
Variables																		
Rice price	323	19.7	306	13.4	314	15.2	316	15.2	334	22.4	313	16.1	322	17.0	322	17.0	323	17.0
Wheat price	198	8.1	192	6.3	194	4.5	194	6.3	201	9.0	194	6.3	198	6.3	198	6.3	200	6.3
Open market sales	44		52		289		216		135		44		221		154		342	
Open market purchases	0		114		220		132		33		0		216		224		137	
Rice stock	398	159.1	646	152.0	467	282.5	496	262.1	161	39.8	508	246.8	355	232.6	407	245.8	321	233.6
Wheat stock	677	279.5	806	318.2	661	372.3	380	208.1	525	128.5	339	0	369	72.4	369	72.4	369	55.1
Rice imports	72	84.7	72	84.7	72	84.7	72	84.7	72	84.7	145	251.9	144	278.5	65	199.9	218	370.3
Wheat imports	415	251.9	415	251.9	415	251.9	415	251.9	415	251.9	358	193.8	255	291.7	262	304.0	159	245.8
									(Tk million)									
	Total	Std	Total	Std	Total	Std	Total	Std	Total	Std	Total	Std	Total	Std	Total	Std	Total	Std
Costs																		
Total cost	17,045	1,274	19,632	1,366	8,392	3,682	8,473	2,228	6,046	748	14,716	2,288	5,137	2,905	12,931	3,219	2,741	2,490
Foreign exchange	959	50	959	50	959	50	959	50	959	50	1,083	63	803	65	806	74	806	73
Procurement	6,380	489	9,020	1,473	17,961	1,979	11,751	1,254	2,971	430	0.00	0.00	17,839	1,566	18,567	1,679	11,291	1,054
Cash outflow	-3,623	1,047	-1,036	1,634	-12,276	3,769	-12,195	2,253	-14,622	1,149	-7,421	1,744	-10,893	2,667	-6,035	2,615	-12,016	2,803

Source: Computed by the authors.

Notes: Avg = average; Std = standard deviation.

Prices are in taka/maund, not deflated. Quantities are in 1,000 metric tons. Costs are in million taka.

[a] The baseline is obtained by simulating the foodgrain model for the period July 1985-June 1988.

[b] The price band is defined by a plus or minus 4 percent margin around the target price.

[c] The optimal price stabilization policy uses open market operations to minimize the variance of rice prices around the target.

[d] The approximation to price stabilization was computed through stochastic simulations of production shocks and ordinary least squares over rice production, wheat production, and a lagged term.

[e] The cost minimization policy uses open market operations to minimize the total cost of food operations.

[f] The import policy uses imports to minimize the variance of rice prices around the target.

[g] Benchmark refers to price stabilization cum cost minimization. It uses open market operations and imports to minimize the total cost of food operations subject to price stabilization and foreign reserves constraints.

[h] Bencha30 refers to the benchmark with a 30 percent increase in world prices.

[i] No ration refers to the benchmark when monetary offtakes are eliminated.

Table 43—Average stock and total cost of various policies

Policy	Average Total Foodgrain Stock	Total Cost[a]
	(1,000 metric tons)	(Tk million)
Baseline[b]	1,075	17,045
Price band[c]	1,452	19,632
Optimal price stabilization[d]	1,128	8,392
Approximation to optimal price stabilization[e]	876	8,473
Cost minimization[f]	686	6,046
Import policy[g]	847	14,716
Benchmark: price stabilization cum cost minimization[h]	724	5,137
No ration distribution[i]	690	2,741

Source: Computed from information in Table 42.

[a] Total cost = procurement cost + import cost - ration sales - open market sales.
[b] The baseline is obtained by simulating the foodgrain model for the period July 1985-June 1988.
[c] The price band is defined by a plus or minus 4 percent margin around the target price.
[d] The optimal price stabilization policy uses open market operations to minimize the variance of rice prices around the target.
[e] The approximation to price stabilization was computed through stochastic simulations of production shocks and ordinary least squares over rice production, wheat production, and a lagged term.
[f] The cost minimization policy uses open market operations to minimize the total cost of food operations.
[g] The imports policy uses imports to minimize the variance of rice prices around the target.
[h] Benchmark refers to price stabilization cum cost minimization. It uses open market operations and imports to minimize the total cost of food operations subject to price stabilization and foreign reserves constraints.
[i] No ration refers to the benchmark when monetary offtakes are eliminated.

- The attractiveness of fixed rules as compared with more complex rules is deceiving. A price band, to be effective, may need as much careful planning as a seemingly more complex rule involving an optimization process. Nevertheless, the effort to simplify must be pursued. In particular, what is still interesting is the effort to approximate optimal policies with policies that are more easily implementable and are of a feedback type, that is, they can be formulated as a function of the current state of the system. An attempt in this direction has been made in this report, and the results seem promising.

- The average foodgrain stock needed to support the optimal policy pursued through both open market operations and imports is equal to 724,000 tons. In the case of approximation policy, which has also been considered in the report, the level goes up to 876,000 tons as a consequence of a lesser degree of flexibility allowed to the policy instruments.

APPENDIX 1: PROCUREMENT SUPPLY

The quantity actually procured by the government depends on the capacity and willingness of the former to sell (Gulati and Sharma 1990). The capacity to sell depends on the marketable surplus, whereas the willingness to sell depends on the differential between procurement prices and open market prices. In order to study the procurement supply, a simple model is introduced. For the sake of simplicity, superscripts denoting grains will be dropped in the following discussion.

At the beginning of each time period t, farmers are endowed with an amount, q_t, of foodgrains. They have to decide how much to sell to the market, μ_t, at the market price, p_t, how much to sell to the government procurement station, qp_t, at price pp_t, and how much to store, x_{t+1}.

The objective of farmers is to maximize expected profit, which is given for a two-period problem by

$$p_t\mu_t + pp_t qp_t + \beta p_{t+1,t}x_{t+1} - c_1(qp_t) - c_2(x_{t+1}), \qquad (30)$$

where

$0 < \beta < 1$ = discount parameter,

$p_{t+1,t}$ = price at time t+1, expected to prevail as of time t,

c_1 = cost of bringing crops to the procurement station, and

c_2 = cost of storing stock.

The constraints faced by the farmers are that all the above-mentioned quantities are non-negative and that they do not exceed the initial amount owned by the farmer:

$$q_t \geq \mu_t + x_{t+1} + qp_t. \qquad (31)$$

It is possible to derive a closed-form solution for this problem if the cost functions c_1 and c_2 are taken to be convex in their respective arguments. Namely,

$$c_1(qp_t) = f_0 + f_1 qp_t + 2^{-1} \cdot f_2 qp_t^2, \text{ and} \qquad (32)$$

$$c_2(x_{t+1}) = g_0 + g_1 x_{t+1} + 2^{-1} \cdot g_2 x_{t+1}^2, \qquad (33)$$

where f_2 and g_2 are both positive.

It is then possible to express the solution for this problem as follows:

$$x_{t+1} = \max\ [0,\ -g_1/g_2 + (\beta p_{t+1,t} - p_t)/g_2], \text{ and} \tag{34}$$

$$qp_t = \max\ [0,\ -f_1/f_2 + (pp_t - p_t)/f_2], \tag{35}$$

where

$$\mu_t = q_t - x_{t+1} - qp_t.$$

In this formulation, procurement supply is positively related to the difference between procurement price and market price.

It is conceivable that costs of adjustment must be paid in order to change the amount supplied to the procurement station from period to period, and also that the higher is the amount q_t, the lower is the procurement cost. In such a case, the cost function c_1 can be expressed as

$$c_1(qp_t, qp_{t-1}, q_t) = q_t^{-\alpha} \cdot [f_0 + f_1(qp_t - \gamma qp_{t-1}) + 2^{-1} \cdot f_2(qp_t - \gamma qp_{t-1})^2], \tag{36}$$

where α and γ are positive constants.

With this modification the procurement supply is

$$qp_t = [-\ f_1 + q^{\alpha} \cdot (pp_t - p_t)]/f_2 + \gamma qp_{t-1}. \tag{37}$$

Now the amount procured is positively related to its lagged value, to the difference between procurement price and market price, and to the amount initially owned by farmers.

A procurement equation derived from the previous model has been estimated in the following linear specification:

$$qp_t = f(pp_t, p_t, q_t, qp_{t-1}). \tag{38}$$

For both rice and wheat, procurement prices do not appear with a significant coefficient (Table 44). This seems a bit surprising given that the rationale for introducing procurement prices is to stimulate procurement and support farmers' prices as a result. In Appendix 2 it will be shown that, at least for rice, procurement has been effective in sustaining prices, even though the level of support has been negligible. Here the puzzle of why procurement prices did not stimulate procurement supply, as one would expect a priori, has to be explained. A possible interpretation for the limited significance of procurement prices follows. Since procurement takes place through a system of licensed dealers, rent-seeking behavior may generate a process whereby the level of procurement prices does not become critically important. In any case, profits could be made by altering the quality of rice, the moisture content, and the quantities actually procured. However, it is clear that when market prices increase, the incentives to sell to the procurement station diminish, since the marketplace becomes more attractive.

Table 44—Ordinary least squares estimation of rice and wheat procurement supply

Variable	Coefficient	t-Statistic
Rice		
Constant	0.8416	0.5385
p_t^R	-10.4006	-2.7895
pp_t^R	8.1230	1.1644
q_t^R	0.0274	5.2532
qp_{t-1}^R	0.1363	1.2672
N	59	
R^2	0.5215	
SEE	0.9697	
Wheat		
Constant	-0.1749	-0.4626
p_t^W	-2.7553	-1.8274
pp_t^W	4.1656	1.6868
q_t^W	0.0461	5.2330
qp_{t-1}^W	0.2478	2.2205
N	59	
R^2	0.4512	
SEE	0.2603	

Source: Estimated by the authors.

Definitions of terms:

p_t^i = price of grain i at time t;

pp_t^i = procurement price of grain i at time t;

q_t^i = production of grain i at time t;

qp_{t-1}^i = quantity of grain procured at time t-1; and

SEE = standard error of estimation.

APPENDIX 2: HAS PROCUREMENT BEEN EFFECTIVE AT SUPPORTING PRICES?

To answer this question a simultaneous system is needed where the decisions of the private sector related to consumption and storage are combined with the response to the government activities involving procurement supply and demand for monetary offtakes.

Procurement supply has been modeled in Appendix 1. To model the demand for monetary offtakes (net of open market sales), a distinction in the public distribution system has to be made between channels aimed at poverty alleviation, and those that target relatively high income groups. All of these latter channels have been lumped together in the monetary offtakes category. Since individuals in this group have the option of drawing their quota at the ration price, a model of demand for rationed distribution can be postulated as follows:

$$mof^i_\tau = f(p^i_\tau, pr^i_\tau, y_\tau, mof^i_{\tau-1}), \quad (39)$$

where pr^i_τ refers to the ration price of grain i at time τ. When the difference between market price and ration price decreases, monetary offtakes are also expected to decrease.

Putting together equation (39) with the equations for prices, procurement supply, stocks, and marketable supply, the following foodgrain system is obtained:

$$\hat{p}^i_{\tau+1} = f^i_0(\sigma^i_\tau, \eta^i_{0,\tau}), \quad (40)$$

$$p^i_\tau = f^i_1(p^i_{\tau-1}, \hat{p}_{\tau+1}, y, p^j_\tau, \tilde{ms}^i_\tau, mof^i_\tau, qp^i_\tau, \eta^i_{1,\tau}), \quad (41)$$

$$mof^i_\tau = f^i_2(p^i_\tau, pr^i_\tau, y_\tau, mof^i_{\tau-1}, \eta^i_{2\tau}), \quad (42)$$

$$qp^i_\tau = f^i_3(p^i_\tau, pp^i_\tau, q^i_\tau, qp^i_{\tau-1}, \eta^i_3), \quad (43)$$

$$stock^i_\tau = \delta^i stock^i_{\tau-1} + m^i_\tau + qp^i_\tau - mof^i_\tau - nmof^i_\tau - oms^i_\tau, \text{ and} \quad (44)$$

$$\tilde{ms}^i_\tau = q^i_\tau + nmof^i_\tau + oms^i_\tau. \quad (45)$$

The results in Table 45 show that the coefficient of rice procurement is statistically significant in the price equation. Nevertheless, as was seen in Appendix 1, procurement prices did not show any significant effect on the quantity actually procured. For wheat procurement, as well as for wheat offtakes, it seems that their effect on price is perverse. A possible interpretation of this perverse effect is that the positive effect of procurement on prices is nullified by the contemporaneous public distribution of wheat in the same areas where most of wheat production takes place.

On the other hand, rice ration prices are a significant instrument for controlling the total amount of offtakes. In the case of wheat, monetary offtakes are not affected by ration prices, but by market prices. Nevertheless, the predictive power of the offtakes equation is too low to be used with any reliability in the simulation of policy exercises (see Figures 10e and 10f).

Table 45—Three-stage least squares estimation of foodgrain system with public food distribution

Variable	Coefficient	t-Statistic	Variable	Coefficient	t-statistic
Rice lead price equation			Wheat lead price equation		
Constant	-0.0593	-0.9303	Constant	-0.0542	-1.3078
$stock^R_t$	-0.0097	-5.1157	$stock^W_t$	-0.0052	-4.7093
m^I_t	-0.0047	-1.517	m^W_t	-0.0016	-1.9719
$losses_t$	0.0022	3.2626	$losses_t$	0.0005	0.9579
y_t	0.0628	6.7155	y_t	0.0428	6.7673
N	59		N	59	
R^2	0.59		R^2	0.4789	
SEE	0.03		SEE	0.0198	
Rice price equation			Wheat price equation		
Constant	0.0807	1.2105	Constant	-0.044	-1.5183
p^R_{t-1}	0.2981	4.4211	p^W_{t-1}	-0.0152	-0.2636
p^R_{t+1}	0.3726	3.781	p^W_{t+1}	0.4016	3.7353
p^W_t	1.2418	4.9768	p^R_t	0.2211	3.132
mfs^R_t	-0.0012	-8.0873	mfs^W_t	0.0009	1.6571
mof^R_t	-0.0102	-1.313	mof^W_t	0.0108	5.8335
qp^R_t	0.0178	4.3942	qp^W_t	-0.0243	-2.7853
y_t	-0.0273	-2.3025	y_t	0.011	2.1681
N	59		N	59	
R^2	0.7973		R^2	0.7259	
SEE	0.0225		SEE	0.0146	

(continued)

Table 45—Continued

Variable	Coefficient	t-Statistic	Variable	Coefficient	t-statistic
Rice procurement supply			Wheat procurement supply		
Constant	-0.9602	-0.6918	Constant	0.1383	0.4115
p_t^R	-3.7084	-0.8692	p_t^W	-0.9889	-0.615
pp_t^R	6.2543	0.9443	pp_t^W	0.5059	0.2445
q_t^R	0.0311	6.361	q_t^W	0.0475	5.8107
qp_{t-1}^R	0.1428	1.5733	qp_{t-1}^W	0.2816	3.4151
N	59		N	59	
R^2	0.4732		R^2	0.4259	
SEE	0.9733		SEE	0.2547	
Rice demand for monetary offtakes			Wheat demand for monetary offtakes		
Constant	-0.5399	-0.2682	Constant	2.4591	0.7412
p_t^R	1.5748	0.7632	p_t^W	38.0694	5.564
pr_t^R	-11.3929	-4.1771	pr_t^W	-1.7188	-0.9494
y_t	0.5798	1.5468	y_t	-1.2517	-2.2331
mof_{t-1}^R	0.2401	2.2724	mof_{t-1}^W	0.241	2.6141
N	59		N	59	
R^2	0.4584		R^2	0.3734	
SEE	0.56		SEE	1.0734	

Source: Estimated by the authors.

Definitions of terms:

p_t^i = price of grain i at time t;
q_t^i = production of grain i at time t;
qp_t^i = quantity of grain i procured at time t;
pp_t^i = procurement price of grain i at time t;
rp_t^i = ration price of grain i at time t;
y_t = income at time t;
mof_t^i = monetary offtakes of grain i at time t;
$nmof_t^i$ = nonmonetary offtakes of grain i at time t;
oms_t^i = open market sales of grain i at time t;
ms_t^i = $q_t^i + nmof_t^i + oms_t^i$;
m_t^i = import of grain i at time t;
$stock_t^i$ = stock of grain i at beginning of time t;
$losses_t$ = rice losses at time t; and
SEE = standard error of estimation.

APPENDIX 3: DERIVATION OF STORAGE EQUATION

The agents responsible for private storage are assumed to be risk-neutral and profit-maximizing. That is, they solve the following problem:

$$\max \; E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} [p_\tau(-x_{\tau+1} + x_\tau) - c(x_{\tau+1})],$$

subject to

$$x_\tau \geq 0, \quad x_t \text{ given}, \quad t \geq 1,$$

where

$x_{\tau+1}$ = stock demanded by the end of period τ,

p_τ = price of the grain,

$c(x_{\tau+1})$ = storage cost associated with stock $x_{\tau+1}$, and

E_t = expectation operator, based on information available at time t.

For simplicity of notation, the superscript referring to the grain is omitted.

Assuming the storage cost function to be quadratic in the level of stocks, that is,

$$c(x_{\tau+1}) = b_0 + b_1 x_{\tau+1} + 0.5 b_2 x_{\tau+1}^2, \tag{46}$$

and assuming rational expectations (Wickens 1982; Ravallion 1985; Goletti 1990), so that where $\epsilon_{\tau+1}$ is the expectational error and I_τ is the information available at time τ, it follows that

$$p_{\tau+1,\tau} = p_{\tau+1} + \epsilon_{\tau+1}, \tag{47}$$

with

$$E[\epsilon_{\tau+1} | I_\tau] = 0, \text{ and}$$

$$\Delta x^{i}_{\tau+1,\tau} = g_2(p_{\tau+1}, p_{\tau}, p_{\tau-1}), \tag{48}$$

where g_2 is a linear function of its arguments.

Thus, putting equation (48) together with the expression for consumption contained in equation (7) and the equilibrium condition in equation (6), it is possible to derive a price equation that can be estimated in the form

$$p^{i}_{\tau} \;=\; f^{i}_{1}(p^{i}_{\tau-1}, p_{\tau+1}, y_{\tau}, p^{j}_{\tau}, ms^{i}_{\tau}, \eta^{i}_{\tau}), \tag{49}$$

where

f^{i}_{1} = a linear function,

ms^{i}_{τ} = the marketable supply of grain i at time τ,

y_{τ} = the income at time τ, and

η^{i}_{τ} = the error term.

Note that in the latter equation the error term is bound to be correlated with $p^{i}_{\tau+1}$.

To avoid correlation between the error term η^{i}_{τ} and the price $p^{i}_{\tau+1}$, an instrumental variable estimation for $p^{i}_{\tau+1}$ has been used. Therefore, denoting by σ^{i}_{τ} the set of instrumental variables for $p^{i}_{\tau+1}$, the following simultanous system is readily obtainable:

$$p^{i}_{\tau} \;=\; f^{i}_{1}(p^{i}_{\tau-1}, p_{\tau+1}, y, p^{j}_{\tau}, ms^{i}_{\tau}, \eta^{i}_{1,\tau}), \text{ and} \tag{50}$$

$$\hat{p}^{i}_{\tau+1} \;=\; f^{i}_{0}(\sigma^{i}_{\tau}, \eta^{i}_{0,\tau}), \tag{51}$$

where the η's denote error terms.

APPENDIX 4: NATURE AND SOURCES OF THE DATA

The organization of the data in this paper draws heavily from Shahabuddin (1990). The data related to the monthly distribution by categories under the public food distribution system were collected from the Food Planning and Monitoring Unit, Ministry of Food, for the period 1972/73-1987/88. Those data were converted into seasonal figures corresponding to the different seasons: Season 1, July-October; Season 2, November-February; Season 3, March-April; and Season 4, May-June.

This way of defining the seasons tries to match the ideal basis for defining the seasons with the presentation of the results by fiscal year (see also Shahabuddin 1990). The procurement and ration prices for both rice and wheat, with the effective dates for the different periods, were collected from the Bangladesh Bureau of Statistics *Statistical Yearbooks*, and from *Food Situation Reports* published by the Food Planning and Monitoring Unit. These were distributed over the different seasons using the effective dates for each price. Data on the monthly price of rice (coarse, wholesale variety) were compiled from the Directorate of Marketing, Government of Bangladesh. All these nominal prices were deflated by the index of prices of manufactured consumer goods to convert them into real prices.

Data on foodgrain production, both rice and wheat, as well as income (GNP at constant 1972/73 prices) were available from the Bangladesh Bureau of Statistics *Statistical Yearbooks* annually by fiscal year (July to June). These data were converted into seasonal figures by the following procedure.

Estimates of the quantities of rice harvested each month were derived on the basis of the historical percentages of crops harvested each month in the World Bank (1979) study on food policy issues in Bangladesh.

The following monthly percentages for the three rice crops, aus, aman, and boro, and for wheat have been used.

July:	35 percent of aus	January:	5 percent of aman
August:	55 percent of aus	February:	no harvest
September:	10 percent of aus	March:	55 percent of wheat
October:	3 percent of aman	April:	45 percent of wheat and 10 percent of boro
November:	50 percent of aman		
December:	42 percent of aman	May:	65 percent boro
		June:	25 percent of boro

These monthly percentages were then applied to the yearly production of aus, aman, and boro rice, and to wheat as published in the Bangladesh Bureau of Statistics *Statistical Yearbook*s to derive estimates of the rice harvested by each month, which were then distributed over different seasons as defined earlier.

These monthly percentages of crops harvested provide the following seasonal shares (as defined in this paper) for the different rice crops harvested in Bangladesh: Season 1, 100 percent of aus and 3 percent of aman; Season 2, 97 percent of aman; Season 3, 10 percent of boro and 100 percent of wheat; and Season 4, 90 percent of boro.

The annual figures on GNP (at constant 1972/73 prices) collected from the Bangladesh Bureau of Statistics *Statistical Yearbook*s were distributed over different seasons by taking the average real GNP per capita for every season.

APPENDIX 5: FOOD BUDGET

From a broad, public finance perspective, it is important to accurately assess the aggregate cash deficit on the food account, which is simply the difference between cash revenues and cash expenditures. Cash savings can be used for financing development planning. It is only recently that the government of Bangladesh has started to rearrange the food budget in such a way that it is possible to identify the annual budgetary impact of food operations and integrate it into the consolidated public account.

From an efficiency point of view, the food-security objectives of the government should be pursued, keeping in mind minimization of the total cost of food operations. To measure the total cost, cash revenues have to be subtracted from cash expenditures. For the foodgrain operations, the following definitions have been used:

Cash Expenditures	=	Procurement Cost + Value of Imports
Cash Revenues	=	Revenues from Open Market Sales and Ration Distribution
Total Cost	=	Cash Expenditures - Cash Revenues
Cash Outflow	=	Cash Expenditures - Cash Revenues - Value of Food Aid

Using the notation previously introduced,

$$\text{Cash Expenditures}(\tau) = \Sigma_i\ wop_\tau^i \cdot m_\tau^i + pp_\tau^i \cdot qp_\tau^i, \text{ and}$$

$$\text{Cash Revenues}(\tau) = \Sigma_i\ p_\tau^i \cdot oms_\tau + pr_\tau^i \cdot mof_\tau^i.$$

In the definition of cost adopted here, administrative costs are not included; similarly, other type of costs, such as those related to storage, losses, and pilferage, are not taken into account. Yet this first attempt at looking at the structure of the food budget is still useful to give a first rough idea of the behavior of some of the budget components (see Tables 46 and 47).

Table 46—Foodgrain nominal costs, 1976-89

Year	Procurement Cost[a]	Import Cost[b]	Total Expenditure[c]	Open Market Sales[d]	Ration Sales[e]	Revenue[f]	Total Cost[g]	Food Aid[h]	Cash Outflow[i]
					(Tk million)				
1976	1,039	1,989	3,028	0	2,447	2,447	581	1,531	-950
1977	1,960	3,736	5,696	0	3,348	3,348	2,348	2,692	-344
1978	1,206	2,682	3,888	0	3,352	3,352	536	2,565	-2,029
1979	1,406	9,871	11,277	370	4,317	4,687	6,590	3,906	2,684
1980	4,513	3,805	8,318	0	3,936	3,936	4,382	2,467	1,915
1981	1,447	4,832	6,279	348	5,057	5,405	873	4,012	-3,139
1982	1,021	7,960	8,981	719	5,314	6,034	2,947	4,127	-1,180
1983	1,358	9,238	10,597	852	5,342	6,194	4,403	6,452	-2,049
1984	1,812	12,385	14,197	1,117	6,131	7,248	6,949	5,759	1,190
1985	2,219	6,577	8,795	391	4,012	4,403	4,392	5,949	-1,558
1986	1,349	7,899	9,248	1,763	5,094	6,857	2,392	6,131	-3,739
1987	2,829	15,032	17,861	1,652	5,920	7,572	10,289	8,557	1,732
1988	3,336	14,452	17,788	2,135	6,357	8,493	9,296	9,738	-442
1989	8,500	10,979	19,479	1,320	7,831	9,150	10,329	6,162	4,166

Sources: Based on unpublished data from Bangladesh Ministry of Food; authors' calculations.

[a] Procurement cost is obtained by taking procurement prices times procurement quantities.
[b] Import cost is computed at world prices converted in domestic currency.
[c] Expenditure = procurement cost + import cost.
[d] Open market sales (OMS) revenues are computed by taking OMS prices times OMS quantities.
[e] Ration sales are computed by taking ration prices times monetary offtakes.
[f] Revenue = OMS revenue + ration sales.
[g] Cost = expenditures - revenues.
[h] Food aid is computed from total imports, subtracting the commercial imports.
[i] Cash outflow = cost - food aid.

Table 47—Foodgrain deflated costs, 1976-89

Year	Procurement Cost[a]	Import Cost[b]	Total Expenditure[c]	Open Market Sales[d]	Ration Sales[e]	Revenue[f]	Total Cost[g]	Food Aid[h]	Cash Outflow[i]
				(Tk million)					
1976	243	464	707	0	571	571	136	357	-222
1977	413	787	1200	0	705	705	495	567	-73
1978	259	577	836	0	721	721	115	552	-436
1979	244	1715	1960	64	750	815	1145	679	466
1980	700	590	1290	0	610	611	680	383	297
1981	203	679	882	49	710	759	123	563	-441
1982	132	1032	1164	93	689	782	382	535	-153
1983	181	1234	1415	114	713	827	588	862	-274
1984	228	1561	1789	141	773	913	876	726	150
1985	262	775	1037	46	473	519	518	701	-184
1986	150	877	1027	196	566	762	266	681	-415
1987	306	1626	1932	179	640	819	1113	926	187
1988	342	1482	1825	219	652	871	953	999	-45
1989	789	1019	1808	123	727	850	959	572	387

Sources: Based on unpublished data from Bangladesh Ministry of Food; authors' calculations.

Note: The deflator used is the index of manufactured goods.

[a] Procurement cost is obtained by taking procurement prices times procurement quantities.
[b] Import cost is computed at world prices converted in domestic currency.
[c] Expenditure = procurement cost + import cost.
[d] Open market sales (OMS) revenues are computed by taking OMS prices times OMS quantities.
[e] Ration sales are computed by taking ration prices times monetary offtakes.
[f] Revenue = OMS revenue + ration sales.
[g] Cost = expenditures - revenues.
[h] Food aid is computed from total imports, subtracting the commercial imports.
[i] Cash outflow = cost - food aid.

APPENDIX 6: THE MODEL FOR THE BENCHMARK POLICY

As formally expressed below, the benchmark policy, price stabilization cum cost minimization, consists of choosing a path for imports, open market sales, and open market purchases of both rice and wheat to minimize the cost of food operations:

$$\min \sum_{\tau=t}^{T} \sum_{i=r,w} \beta^{\tau-t}[wop_\tau^i m_\tau^i + p_\tau^i omp_\tau^i - p_\tau^i oms_\tau^i - pr_\tau^i mof_\tau^i],$$

subject to equation (51):

$$\hat{p}_{\tau+1}^i = f_0^i(\sigma_\tau^i, \eta_{0,\tau}^i), \text{ and}$$

$$p_\tau^i = f_1^i(p_{\tau-1}^i, \hat{p}_{\tau+1}, y, p_\tau^j, \tilde{ms}_\tau^i, \eta_{1,\tau}^i), \qquad (52)$$

where

$$\tilde{ms}_\tau^i = q_\tau^i + offtakes_\tau^i - (oms_\tau^i - omp_\tau^i), \qquad (53)$$

$$stock_\tau^i = \delta^i stock_{\tau-1}^i + m_\tau^i - offtakes_\tau^i - (oms_\tau^i - omp_\tau^i), \qquad (54)$$

$$stock_\tau^i \geq G_{min}^i, \qquad (55)$$

$$stock_\tau^i \leq G_{max}^i, \qquad (56)$$

$$\Sigma_i \; wop_\tau^i \cdot m_\tau^i \leq F_\tau, \qquad (57)$$

$$omp_\tau^i \leq \gamma \cdot q_\tau^i, \qquad (58)$$

$$\left| \; p_\tau^i - \theta_\tau \right| \leq 0.04 \cdot \theta_\tau, \text{ and} \qquad (59)$$

$$p_\tau^i, \; m_\tau^i \geq 0, \qquad (60)$$

where $i = r,w$ and $\tau = t,\ldots,T$.

These choices are subject to the constraints given by the dynamic system of the foodgrain private sector (equations [51]-[54]); minimum stock requirements to guarantee the flow of stock operations (deadstocks) and food security (equation [55]); capacity constraints of maximum stocks (equation [56]); foreign exchange constraints (equation [57]); constraints on maximum domestic procurement (equation [58]); constraints on price variability (equation [59]); and non-negativity constraints (equation [60]).

The parameters used in the model are

G^r_{max} = 7.65, corresponding to 805,000 metric tons;

G^w_{max} = 11.09, corresponding to 1,168,000 metric tons;

G^r_{min} = 1.47, corresponding to 155,000 metric tons;

G^w_{min} = 3.32, corresponding to 350,000 metric tons;

γ = 0.5;

δ = 0.94; and

$F\tau$ = 10, corresponding to US$956 million.

APPENDIX 7: APPROXIMATION POLICIES

If x_τ^* is the optimal solution of a policy problem such as the one described in equations (51)-(60) in Appendix 6, the problem becomes the need to find a path x_τ^a that approximates x_τ^*. In particular, one would like to have a feedback policy, expressed as a function of the state variables, that behaves "similarly" to the optimal policy. An appealing approximation would be a linear rule, for its simplicity in calculation. This linear approximation can be expressed as a function of a subset ζ_τ of the set of state variables z_τ. The variables in ζ_τ should be considered particularly useful to convey information upon which an open market operations mechanism can be based. For example, these variables could be production, losses, rainfall, imports, and lagged endogenous variables. Nevertheless, in trying to get a linear feedback rule, the possibility that some inequality constraints may be binding has to be taken into account. Therefore, a truncated version of a linear rule is more likely to be the case.

Using the notation of the general approach of Chapter 3, the control variables, x_τ, have to satisfy the law of motion,

$$z_{\tau+1} = A_\tau \cdot z_\tau + B_\tau \cdot x_\tau,$$

and the inequality constraints,

$$l_\tau \leq z_\tau \leq u_\tau.$$

Then the approximating policy rule is given by

$$x_\tau^a = \begin{cases} L \cdot \zeta_\tau & \text{if } l_{\tau+1} < A_\tau \cdot z_\tau + B_\tau \cdot L\zeta_\tau < u_{\tau+1}, \quad (61) \\ B_\tau^+ \cdot (l_{\tau+1} - A_\tau \cdot z_\tau) & \text{if } l_{\tau+1} \geq A_\tau \cdot z_\tau + B_\tau \cdot L\zeta_\tau, \text{ and} \quad (62) \\ B_\tau^+ \cdot (u_{\tau+1} - A_\tau \cdot z_\tau) & \text{if } u_{\tau+1} \leq A_\tau \cdot z_\tau + B_\tau \cdot L\zeta_\tau, \quad (63) \end{cases}$$

where B^+ is the generalized inverse of B.

The matrix L is obtained by performing a stochastic simulation of exogenous variables in ζ_τ and computing the optimal policy numerically. Then the coefficients of a regression of this numerical solution over the variable in ζ_τ give the vector L. Equations (62) and (63) define a truncated linear rule to take into account the inequality constraints.

GLOSSARY

i	denotes grain; it can be either rice (r) or wheat (w)
τ	denotes time; $\tau = t, \ldots, T$
d_τ^i	demand for grain i at time τ
ms_τ^i	marketable supply of grain i at time τ
q_τ^i	production of grain i at time τ
mof_τ^i	monetary offtakes of grain i at time τ, net of open market sales
$nmof_\tau^i$	nonmonetary offtakes of grain i at time τ
oms_τ^i	open market sales of grain i at time τ
omp_τ^i	open market purchases of grain i at time τ
omo_τ^i	open market operations of grain i at time τ
	$omo_\tau^i = oms_\tau^i - omp_\tau^i$
qp_τ^i	quantity of grain i procured at time τ
C_τ^i	is the consumption of grain i as of time τ
$X_{\tau+1}^i$	ending period private stock of grain i as of time τ
$\Delta X_{\tau+1}^i$	refers to variation, such as $\Delta X_\tau^i = X_{\tau+1}^i - X_\tau^i$
p_τ^i	price of grain i at time τ
y_τ	income at time τ
$p_{\tau+1,\tau}^i$	the price of grain i expected to prevail at time τ+1, based on the information available at time τ
$stock_\tau^i$	stock of grain i at beginning of time τ
$losses_\tau$	rice losses at time τ.
$offtakes_\tau^i$	ration distribution and nonmonetary offtakes (that is, $mof_\tau^i + nmof_\tau^i$) of grain i at time τ
$poms_\tau^i$	oms price of grain i at time τ
pr_τ^i	ration price of grain i at time τ
wop_τ^i	world price of grain i at time τ
m_τ^i	import of grain i at time τ

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