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1979

A GENERALIZED SYSTEM SIMULATION MODEL FOR THE MANAGEMENT OF FOOD GRAINS IN THE REPUBLIC OF KOREA

By

Forrest John Gibson

AN ABSTRACT OF A DISSERTATION

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ABSTRACT

A GENERALIZED SYSTEM SIMULATION MODEL
FOR THE MANAGEMENT OF FOOD GRAINS
IN THE REPUBLIC OF KOREA

By

Forrest John Gibson

Few nations in the world today are free from the chronic problems of formulating and carrying out effective policies and programs regarding the management of food grains. A generalized grain management program (GMP) system simulation model has been developed and tested as part of the Korean Agricultural Sector Study (KASS) project and is designed to address several of the confounding problems facing decision makers in Korea today.

This dissertation describes the general nature of the grain management problem in Korea and provides detailed documentation of the design and development of the GMP model proposed as an approach to this problem. The GMP model is designed to address a wide range of issues such as the development of annual food plans, import scheduling, market price stabilization and control, food grain self-sufficiency, grain reserve programs, and many others. The model is designed to serve as an analytical tool for both policy development and policy implementation. For example, seasonal urban price patterns for food grains can be studied and developed through the use of the GMP model. Once a desirable seasonal price pattern is selected, the GMP model makes use of automatic feedback control techniques to prescribe the timing and quantity of government grain releases required to influence market prices to follow the targeted seasonal patterns.

The dissertation is a self-supporting document which demonstrates clearly the eclectic nature of the general system simulation approach to agricultural planning and policy analysis. It is well organized and written for both technical and nontechnical audiences. Although specifically oriented to the grain management problem in Korea, the GMP model concept as documented in the dissertation is transferable to other countries interested in similar problem-solving approaches.

Credibility testing is described with regard to the GMP model concept, the mathematical model, and the computer program. Model test run results are provided in order to (1) demonstrate validation and verification efforts made throughout model development, (2) establish an objective basis upon which overall credibility of the model (in its current state of development) can be judged, and (3) provide evidence that the GMP model is a computable system simulation program ready for immediate use. The dissertation is completed with a summary discussion of model capabilities and limitations. A constructive review of the approach used in the development of the GMP model is given. Important lessons learned during the experience are pointed out, so that similar modelling efforts in the future might benefit. Several research topics are suggested that could serve well the need to improve the GMP model capabilities (and reduce its limitations) as a potential component in the grain management decision-making process.

To my parents

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Special appreciation is extended to Dr. Thomas J. Manetsch who provided the initial conceptual design for the Grain Management Program (GMP) model and invaluable guidance and overseas consulting throughout the model development. His encouragement and assistance as my major professor during the documentation phase of this undertaking is also appreciated.

Two thesis committees, an *ad hoc* field committee in Korea and my regular committee on campus at Michigan State University, have been very helpful. Making up the field committee in Korea were Dr. Michael H. Abkin (Chairman), Dr. George E. Rossmiller, Dr. Glenn L. Johnson, and Dr. Tom W. Carroll. Making up my campus committee were Dr. Thomas J. Manetsch (Chairman), Dr. Victor E. Smith, Dr. Gerald L. Park, and Dr. Robert A. Schleuter. Special thanks goes to each of these individuals for reviewing and commenting on several GMP working papers written throughout model development, as well as for grinding through the draft and providing many useful suggestions for this final documentation.

The professional assistance of several other individuals throughout the project is acknowledged. Programmers working with the

GMP model were Keith Olson, Bu Kwan Lee, Hyo Buk Lee, Gary Ingvaldson, and Claudia Winer. Dr. Richard Phillips, Food and Feed Grain Institute, Kansas State University, travelled to Seoul on several occasions during model development and provided consultation and many useful suggestions which helped shape the design of the GMP into what it is today. The volunteer assistance of Dr. Alan R. Thodey and Mr. Dong Min Kim, who helped with the preparation and presentation of model demonstration results to top Korean officials, is remembered and appreciated. My thanks goes to Dr. Dong Hi Kim, Director of the [Korean] National Agricultural Economics Research Institute, and his staff for their counterpart assistance in this research. The friendly cooperation and assistance of Dr. Pal Yong Moon, Korean Development Institute, in sharing his research findings, insights, and expertise in the Korean food grain system over the years 1972-1976 is greatly appreciated.

Last, but not least, my deepest appreciation goes to my wife, Barbara, who, aside from doing the typing and editing of this manuscript, accepted the disruption to our family life for so long. Our children, Jenny and Andy, have grown up with the GMP model and this dissertation and, without realizing it, have sacrificed as much as their parents. Since we have all shared the load, we should now all share the credit.

PREFACE

This dissertation documents the design and development of a generalized system simulation model of the food grain operations and management system for the Republic of Korea. The model described herein and referred to as the Grain Management Program (GMP) model was designed, tested, and operationalized as part of the Korean Agricultural Sector Study (KASS) contract project (AID/csd 2975) carried out among Michigan State University, the U.S. Agency for International Development, and the Korean government.

Michigan State University involvement in Korea began in 1971 when MSU undertook a nine-month contract project with USAID to carry out a comprehensive agricultural sector study in South Korea, having two major objectives:

(1) to provide a sound analytical base from which the Korean Ministry of Agriculture and Fisheries (MAF) could make improved planning, programming, and policy decisions for agricultural development;

(2) to provide the basis for an AID agricultural sector loan or agricultural project loans through identification of agricultural sector investment priorities.

At the end of the original nine-month contract period, a comprehensive sector study report was completed [42]. This report, published in mid 1972, provided a comprehensive study and analysis of the components comprising the Korean agricultural sector; identified priority investment areas in agriculture (published separately [13]); provided insight into consequences of following alternative agricultural

development strategies over a fifteen-year planning horizon (1971-1985); and recommended specific strategies, policies, and programs to achieve specific development goals for the agricultural sector. A rudimentary system simulation model was developed and utilized in producing the 1972 KASS report. That model, designed specifically for use in producing the original KASS report, was credited for lending analytical depth to the original study. It was clear to all concerned, however, that the rigidity and specialized nature of the original KASS model did not lend itself well to becoming an ongoing agricultural policy development tool. For this, a more generalized and comprehensive simulation model would be required which could be adjusted to fit the changing real situation and problem. Areas of special interest in agricultural planning were also identified during the original KASS study where further research and model development would be required in order to address planning and policy development issues of great importance to decision makers. The ensuing KASS project, which took place as a continuation of the original contract, concerned itself with this further model generalization and development. Listed below are component areas where further model development efforts were concentrated during the continuing contract period 1972-1976.

- Population
- National Economy
- Technical Change
- Resource Allocation and Production
- Demand-Price-Trade
- Grain Management Program

An overall account of these KASS efforts and others in Korea can be found in the final project report published in 1978 [41].

The major portion of the research and development effort on the Grain Management Program component of the KASS models was performed by the author of this dissertation while in Korea from July 1972 to April 1976. As with any research and development activity, the task of conceptualizing, designing, computerizing, and testing of the GMP model was an iterative process with the final (most recent) version of the model quite different than earlier versions. This dissertation will address itself mainly to the current version of the GMP model, thus leaving much unsaid about development efforts, problems, and difficulties which had to be reckoned with throughout the research period to bring the GMP model to its current state. The reader who wishes a more evolutionary account of the GMP model development may refer to various working papers and publications written during the development period [15, 16, 17, 18, 32, 40].

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CHAPTER 1

THE PROBLEM

Introduction

Food grains play a predominant role in Korean agriculture, the diet and welfare of the Korean people, and the state of the national economy. The need for effective and consistent grain management planning and operations has expressed itself throughout the history of the Republic of Korea.

Since the original Grain Management Law was enacted in 1950, the basic objectives for all grain management programs in Korea have been to assure (1) adequate food supplies for the people and (2) stabilization of the national economy insomuch as it is affected by domestic food grain prices. Although these objectives are clear and simple, the complexities, uncertainties, limitations, and subtle interrelationships of the real world food grain system have incessantly plagued decision makers over the years, making the realization of these basic objectives a monumental challenge year after year. The Korean grain management problem is further complicated by development objectives and goals which are oftentimes conflicting in nature, with the movement toward one or more objectives seemingly obtainable only at the sacrifice of others. Decision makers are, therefore, constantly faced with compromises and always striving to formulate alternative grain management policies and programs which, aside from achieving the bottom line objectives of the original Grain

Management Law, will enhance the achievement of multiple goals for national development.

Although policy makers do capitalize on past experience and analytical studies, the Korean (and world) food grain situation is constantly changing. Studies which may be available are generally done on an *ad hoc* basis, partial in nature, requiring too many unrealistic assumptions, or else too theoretical to have any value in attacking real world problems. The only proving ground for testing the results of proposed alternative grain management programs is, therefore, the real world grain system which is (as shown by past experience) a very costly game board for trial-and-error experiments in policy formulation.

The research undertaken and documented in this dissertation is an effort toward the development of a generalized simulation model of the real world Korean grain system, which can be adjusted to fit the ever-changing food grain situation in Korea, and used as an analytical tool by which policy analysts and decision makers can investigate the consequences (good and bad) of alternative grain management programs and policies. More will be said about specific objectives of the model in Chapter 2.

The primary purpose of this dissertation is to show evidence of original and significant research. The author feels confident that such research has been accomplished; however, the size and real world nature of the topic do require some limitations being placed on this dissertation to keep it within reasonable bounds of expectation. Therefore, a brief description of what this document will do, will not do, and how it is organized seems appropriate at this time.

Thesis Organization and Limitations

In this beginning chapter, the general nature of grain management problems in Korea will be established. This will be done by first giving sufficient background information on the role of food grains in Korea, past and current food grain situations, and trends which may or may not point toward problems in the future. To help establish a quantitative view of the Korean food grain system and its related problems, some numbers and tables will have to be used. These will be kept to a minimum in order to serve the purpose at hand. The reader interested in more detail and analysis of the food grain situation in Korea can find it in a number of other sources [22, 36, 44, 46, 47, 48]. Next, a brief review of past grain management problems, policies, and programs in Korea will serve to point out difficulties of the past and potential difficulties in the future. This discussion will help establish the felt need for much more analytical support than currently available to policy analysts and decision makers seeking solutions to various grain management problems. The first chapter will conclude with a discussion of some of the important grain management problem issues in Korea today.

In Chapter 2 the Grain Management Program (GMP) model will be introduced as an analytical tool which can be used to (1) study many of the problem issues described in Chapter 1, and (2) lend on-line computerized support to many government grain programs and activities. Specific model objectives will be given, and the overall model design conceptualization will be described in nonmathematical terms.

Chapters 3 through 7 comprise the main body of this dissertation. These chapters describe in detail the important structure and attributes

of the real world food grain system (i.e., how it works) and indicate the mathematical equations and relationships used in the GMP model design to replicate this real world system behavior.

Chapter 8 describes some of the important efforts made in testing the GMP model. Emphasis in this chapter will be to describe the iterative stages by which GMP model components were conceptualized, designed, tested, linked together, and brought to an operational state as a fully integrated computerized system model. Because of the size of the overall model and wide range of potential applications in its design, it will not be possible to give detailed experimental evidence of testing and validation on all aspects of the GMP model. Test run results will demonstrate to a great extent the fact that the model is fully computerized and operational. Highlights from historical tracking runs, which seek to re-create past time series of important system variables, will serve to demonstrate model credibility and the extent of model tuning. Other test runs will demonstrate capabilities of the GMP model to serve as an on-line grain management tool, through which various programs, such as urban price control through government grain releases, can be computerized.

In Chapter 9 the overall GMP model design, testing, and research effort will be reviewed. Several areas exist in the current model design where further research, development, and refinement are needed. Some of those important areas for further research will be discussed in that final chapter.

Setting

In this section the Korean food grain situation will be described in terms of domestic food grain production base; land, land uses, and

trends in food grain production. The role of food grains in Korea will be established in terms of the farm economy, Korean diet, household expenditures, and the national economy. Korea's population growth and redistribution patterns will be described. And, finally, food grain balance sheets for selected years from 1961 to 1975 will be given to indicate trends in Korea's food grain requirements, and how these requirements are being met.

Food Grain Production Base

Land Areas and Uses

South Korea has a total land area of 9.8 million hectares, or roughly the same area as the state of Illinois. Characterized mainly by forests and rugged mountainous terrain, cultivated land area occupies less than 25 percent, or 2.3 million hectares, of this total land area. Total cultivated land area has remained fairly constant over the past fifty years, increasing only 9.5 percent since 1921. Large government projects in upland development and tidal land reclamation are in progress, or in planning stages, to increase arable land area, but losses of agricultural land due to rapid urban sprawl and industrialization are cancelling most of these additions.

Of the total cultivated land area in South Korea, approximately 56 percent is paddy land used for growing the principal crop--rice, and 44 percent is classified as upland. A second crop, mainly barley, is grown on a considerable portion of paddy land in the southern regions of the country, making total utilized land area around 3.5 million hectares. Climate and temperature patterns preclude growing two rice crops in one year. Double-cropping areas fluctuate due to the feasibility of raising a second crop on marginal paddy land.

Rice is transplanted in early June each year and harvested in the fall, while barley and wheat are planted in the fall and harvested in May and June the following year. A very tight sequencing pattern between crops exists in double-cropping areas and this sequencing pattern tightens to the point of infeasibility as one moves north from southern regions and climatic conditions change. New seed varieties being developed in both rice and barley are relaxing the double-cropping sequence constraints in marginal areas.

Some seventy individual crops are grown in Korea. If ranked on the basis of percentage of total utilized land area, statistics for 1970 show the following five crops to head the list: rice--34.6 percent, barley--26.0 percent, soybeans--8.5 percent, wheat--4.5 percent, and sweet potatoes--3.7 percent, for a total of 77.3 percent of the total utilized land area in 1970 of 3.5 million hectares. In 1968 the same crops made up the top five and accounted for 80 percent of total utilized land area.

Trends in Land Use

Trends in land areas allocated to rice, barley, and wheat production are indicated in Table 1.1. It can be seen that rice area has remained quite stable, while barley and wheat areas show much more significant changes. A full analysis of these trends is not the subject of this study; however, some brief insight will be given. Rice area remains constant (at near full potential) because no competition exists between rice and other food grains. Rice production per hectare is approximately 2 1/2 times as valuable as wheat and barley production. Barley is the primary second crop grown on double-cropped paddy land areas. This is because current available wheat

Table 1.1. Land Area Trends for Food Grains, 1966-1975.

Year	Rice	Barley	Wheat	Total
		- 1000 hectares -		
1966	1231	961	153	2345
1967	1235	971	152	2358
1968	1151	978	157	2286
1969	1220	942	154	2316
1970	1203	904	158	2265
1971	1190	833	142	2165
1972	1191	868	102	2161
1973	1182	816	70	2068
1974	1204	859	67	2130
1975	1206	885	62	2153
		- percentage indices 1970 = 100 -		
1966	102	106	97	104
1967	103	107	96	104
1968	96	108	99	101
1969	101	104	97	102
1970	100	100	100	100
1971	99	92	90	96
1972	99	96	65	95
1973	98	90	44	91
1974	100	95	42	90
1975	100	98	39	95

Source: Ministry of Agriculture and Fisheries.

varieties require a longer growing season than barley, thus conflicting to a greater extent with rice production. A new high-yielding rice variety (IR667) introduced in 1971 has diffused rapidly throughout Korea. Although its growing season is not significantly shorter than traditional varieties, it has been found that it can be transplanted earlier, thus harvested earlier. This shift forward in the growing season of rice has opened up more marginal double crop area for barley production. New shorter season barley varieties recently introduced also contribute to the recovery of barley area since 1971 [43]. The steady decline of wheat production area since 1970 must be attributed to price competition between wheat, barley, and other summer crops. A dual price policy for barley in effect since 1968 has kept barley prices roughly one-half that of rice prices. Wheat prices have not been so supported and have fallen 20 percent relative to rice prices since 1968.

Trends in Food Grain Production

Improved farming practices, increased use of fertilizer, and new seed varieties have caused a steady increase in food grain productivity since 1966. Table 1.2 indicates food grain yields and trends from 1966 through 1975.

Even with the declining trend in land area allocated to food grain production as was indicated in Table 1.1, marked increases in rice yields since 1970 have carried total food grain production to 9 percent above its 1966 level. Table 1.3 indicates food grain production data and trends from 1966 through 1975.

Table 1.2. Food Grain Yields, 1966-1975.

Year	Rice	Barley	Wheat	Total Average *
		- metric tons per hectare -		
1966	3.18	2.10	2.06	2.66
1967	2.92	1.97	2.05	2.47
1968	2.78	2.13	2.19	2.46
1969	3.35	2.19	2.39	2.82
1970	3.27	2.18	2.26	2.76
1971	3.36	2.23	2.26	2.85
1972	3.32	2.26	2.37	2.85
1973	3.56	2.18	2.31	2.97
1974	3.69	1.98	2.03	2.95
1975	3.82	2.35	2.20	3.17
		- percentage indices 1970 = 100 -		
1966	97	96	91	96
1967	89	90	91	89
1968	85	98	97	89
1969	102	100	106	102
1970	100	100	100	100
1971	103	102	100	103
1972	102	104	105	103
1973	109	100	102	108
1974	113	91	90	107
1975	117	108	97	115

* Average yield derived by dividing total production by total area.

Source: Ministry of Agriculture and Fisheries.

Table 1.3. Food Grain Production, 1966-1975.

Year	Rice	Barley	Wheat	Total
		- 1000 metric tons -		
1966	3915	2018	315	6248
1967	3606	1913	312	5831
1968	3200	2083	344	5627
1969	4087	2063	368	6538
1970	3934	1971	357	6262
1971	3998	1858	321	6177
1972	3954	1962	242	6158
1973	4208	1779	162	6149
1974	4443	1701	136	6280
1975	4607	2080	136	6823
		- percentage indices 1970 = 100 -		
1966	100	102	88	100
1967	92	97	87	93
1968	81	106	96	90
1969	104	105	103	104
1970	100	100	100	100
1971	102	94	90	99
1972	101	100	68	98
1973	107	90	45	98
1974	113	86	38	100
1975	117	106	38	109

Source: Ministry of Agriculture and Fisheries.

The Role of Food Grains

Food grains play a major role in farm income, the Korean diet, household expenditures, and the national economy.

Farm Income

Farm household survey data indicate that net farm income in 1970 averaged 194,000 won (or $US 625) per household. With an average of 5.92 persons per farm household, this figure amounts to approximately 33,000 won (or $US 105) per farm household member. According to the survey, crop production accounts for 81 percent of total farm receipts, with food grains (rice, barley, and wheat) contributing 60 percent to total farm receipts. Rice alone contributes 51 percent to total farm receipts.

Korean Diet

The Korean diet consists of a wide variety of foods; however, rice, barley, and wheat (including wheat products) comprise approximately 53 percent of this diet by weight measure [44]. The average Korean diet for farm and urban populations for 1974 is indicated in Table 1.4.

Table 1.5 indicates food grain consumption levels for rural and urban populations from 1966 through 1975. The table also indicates the proportion of total food consumption comprised of food grains for the same period.

Household Expenditures

A large portion of the Korean household total expenditure budget goes toward the purchase of food, with food grains, especially rice, taking up a sizable share of the food budget. Although increased

Table 1.4. Korean Diet, 1974.

Commodity	Farm	Urban	Average	Percent
	- kilograms per capita per year -			
Rice	114	130	124	30
Barley	65	47	54	13
Wheat	37	43	41	10
Misc. grains	8	6	7	2
Pulses	6	9	8	2
Fruits	6	21	15	4
Vegetables	60	79	72	17
Potatoes	64	20	37	9
Industrial crops	1	2	1	--
Beef	--	2	1	--
Milk	--	6	4	1
Pork	1	3	3	1
Poultry	--	2	1	--
Eggs	--	7	4	1
Fish & seaweed	19	57	42	10
Total	381	434	414	100

Source: KASS Special Report 11 [44].

Table 1.5. Per Capita Food Grain Consumption, 1966-1974.

Year	Total Food (A)	Rice	Barley	Wheat	Total (B)	(B/A)
		- kilograms per capita per year -				
		Farm Population				
1966	372	106	66	18	190	.51
1967	393	114	75	26	215	.55
1968	354	108	75	33	216	.61
1969	381	110	76	32	218	.57
1970	396	113	70	34	215	.54
1971	423	120	73	40	233	.55
1972	408	105	68	53	226	.55
1973	393	105	69	52	226	.58
1974	392	114	65	37	216	.55
		Urban Population				
1966	367	117	35	27	179	.49
1967	393	125	40	38	203	.52
1968	409	119	39	50	208	.51
1969	424	121	40	57	218	.51
1970	419	136	30	49	215	.51
1971	457	147	34	63	244	.53
1972	448	131	43	60	234	.52
1973	436	124	44	59	227	.52
1974	453	130	47	43	220	.49

Source: KASS Special Report 11 [44].

incomes have caused a decline in the food portion of the consumer budget over the past fifteen years, the Korean household food (and food grain) expenditures still remain high relative to total income. Table 1.6 indicates monthly expenditure budgets for farm and urban households for selected years from 1963 through 1972.

National Economy

Korea has undergone tremendous economic growth since 1962 when the First Five Year Economic Development Plan was initiated. The average annual growth rate in terms of GNP for the entire economy (including agriculture) during the first two five-year plans exceeded 14 percent. A slowdown in economic growth has been experienced in recent years, due mainly to large foreign exchange deficits caused by increased world oil prices and heavy dependence on foreign grain imports. Nevertheless, national growth still remains near 10 percent per annum. Growth has also been experienced in the agricultural sector since the first five-year plan, but it has been at a much slower pace than the national economy. The average annual growth rate in Korean agriculture in terms of contribution to GNP over the ten-year period from 1961-1972 was slightly over 3 percent. This increasing gap between the agricultural and nonagricultural sectors of the economy is likely to continue into the future; however, the Third Five Year Economic Development Plan for 1972-1976 did contain increased emphasis on agricultural sector development. In 1972 Korean agriculture's contribution to GNP was 21 percent, as opposed to 41 percent in 1961. These comparisons, and others, regarding the contributions of agriculture, cultivated crops, and food grain commodities to the national economy are detailed in Table 1.7 for selected years between 1961-1972.

Table 1.6. Monthly Consumption Expenditures Per Household, 1963-1974.

Year	Urban Households				Rural Households			
	Total Expenditure	Food	Food Grains	Rice	Total Expenditure	Food	Food Grains	Rice
	- won -							
	(percent)							
1963	7080	3840	2710	2400	6455	3893	3057	1728
	(100)	(54)	(34)	(31)	(100)	(60)	(47)	(27)
		(100)	(71)	(63)		(100)	(79)	(45)
1966	13,666	6668	3683	3119	9157	4595	3595	2265
	(100)	(49)	(27)	(23)	(100)	(50)	(39)	(25)
		(100)	(55)	(47)		(100)	(78)	(49)
1969	26,070	10,670	4800	3952	14,281	6628	5063	3451
	(100)	(41)	(18)	(15)	(100)	(46)	(36)	(24)
		(100)	(45)	(37)		(100)	(76)	(52)
1972	38,573	15,722	7715	6728	25,805	12,438	9215	6952
	(100)	(41)	(20)	(17)	(100)	(48)	(36)	(27)
		(100)	(49)	(43)		(100)	(74)	(56)

Sources: Economic Planning Board; Ministry of Agriculture and Fisheries.

Table 1.7. Industrial Origin of GNP at 1970 Constant Prices.

Year	GNP	GNP Growth Rate	Agri-culture	Agri-cultural Growth Rate	Cultivated Crops			
					Total	Rice	Barley	Other
	- billion won - (percent)							
1961	1184	3.1	484	-7.4	436	261	69	105
	(100)		(41)		(37)	(22)	(6)	(9)
			(100)		(90)	(54)	(14)	(22)
1966	1719	9.0	601	4.8	527	297	92	137
	(100)		(35)		(31)	(18)	(5)	(8)
			(100)		(87)	(49)	(15)	(23)
1969	2400	13.2	646	2.5	589	310	94	184
	(100)		(27)		(25)	(13)	(4)	(8)
			(100)		(91)	(48)	(15)	(28)
1972	3027	8.7	645	-0.1	572	302	86	184
	(100)		(21)		(19)	(10)	(3)	(6)
			(100)		(89)	(47)	(13)	(29)

Source: Bank of Korea.

Population Trends

Rapid economic growth in the industrial sector, beginning in the early 1960's, has caused strong pressure on the Korean farm population to migrate into concentrated urban areas. The four largest cities in Korea--Seoul, Pusan, Taegu, and Inchon--accounted for 19 percent of the total Korean population in 1960 and now account for over 30 percent. The capital city of Seoul has grown from about 2.5 million in 1960 to over 7 million in the mid 1970's. Total population growth in Korea is currently about 1.7 percent per year, and because of this heavy farm-to-urban migration, the farm population has declined since about 1967. Table 1.8 indicates best estimates of Korean population and distribution from 1965 through 1974.

Table 1.8. Population, 1965-1985.

Year	Farm	Nonfarm	Total	Farm as % of total
	- million persons -			
1965	15.5	13.6	29.1	53.3
1966	15.7	14.1	29.8	52.8
1967	15.4	15.0	30.4	50.7
1968	15.2	15.9	31.1	48.8
1969	14.9	16.8	31.7	46.9
1970	14.6	17.7	32.3	45.1
1971	14.3	18.6	32.9	43.5
1972	14.1	19.5	33.6	41.9
1973	13.8	20.4	34.2	40.4
1974	13.6	21.2	34.8	39.0
1975	13.3	22.0	35.3	37.7
1976	13.1	22.8	35.9	36.5
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
1985	8.7	30.8	39.5	22.0

Source: Combination of EPB estimates for total population and KASS estimates.

Food Grain Supply and Requirements: Self-Sufficiency

Despite an upward trend in overall food grain production in Korea since 1965, demand for food grains has increased at a much faster pace. Statistics indicate that 1975 domestic production of food grains was 9 percent higher than the 1966 level, but domestic food grain requirements for food, seed, and livestock feed in 1975 were 30 percent greater than the 1966 level. Rice production, the target of government program goals for self-sufficiency for the past three five-year plans, has increased an impressive 30 percent since 1966. Domestic requirements for rice, however, have increased at a still higher rate, resulting in a self-sufficiency indicator for rice in 1974 of 90.8 percent, as compared to 99.1 percent in 1966. The self-sufficiency indicator for total grains declined from 95.1 percent in 1966 to 71.4 percent in 1974, or some 25 percent. To put the food grain supply and requirements situation for Korea more in perspective, balance sheet calculations for rice, barley, and wheat are shown for selected years from 1961 through 1974 in Table 1.9.

Food Grain Policy

Food grain problems have occurred in Korea from the time of Japanese colonial rule to the present. Oftentimes serious food grain problems are brought about by unexpected emergency situations such as war, crop failures, etc., but, more often than not, the basis of many food grain problems is the lack of consistent and manageable food grain policies and programs. A review of past food grain problems and government policies and programs implemented to confront these difficulties will help establish a good backdrop for the subject of

Table 1.9. Food Grain Balance Sheets for Selected Crop Years, 1961-1974.

Supply					Domestic Utilization			Other		
Crop Year	Carry-in	Production A	Imports	Total	Human Consumption	Other	Subtotal B	Exports	Carry-out	Percent Self-Sufficiency
					- Rice - (1000 metric tons)					%
1961	60	3047	--	3107			3062	22	23	99.5
1966	71	3501	31	3603			3531	63	9	99.1
1971	325	3939	907	5171	4597	180	4777	--	394	82.5
1974	711	4212	206	5129	4455	186	4641	--	488	91.0
					- Barley -					
1961	745	1478	123	2346			1535	--	811	96.3
1966	983	2018	--	3001			1874	--	1127	107.7
1971	1127	1858	--	2985	1724	268	1992	--	993	93.3
1974	1183	1706	299	3188	1931	158	2089	--	1099	84.7
					- Wheat -					
1961	191	280	348	819			616	--	203	45.5
1966	166	315	461	942			774	--	168	40.9
1971	338	322	1532	2192	1854	100	1954	--	238	16.5
1974	109	136	1592	1837	1488	66	1554	--	283	8.8
					- Total -					
1961	996	4805	471	6272			5213	22	1037	92.2
1966	1220	5834	492	7546			6179	63	1304	94.4
1971	1790	6119	2439	10,348	8175	548	8723	--	1625	70.1
1974	2003	6054	2097	10,154	7874	410	8284	--	1870	73.1

Source: Ministry of Agriculture and Fisheries.

this research. The product of this review should give concrete evidence that the effectiveness of Korea's grain management system could be improved considerably if managers had at their disposal more analytical capacity to study problem issues and alternative courses of action.

Historical Review[1]

Prior to World War II

First governmental controls in the management of food grains came to Korea in 1939. Prior to this, an essentially free market existed, and Korea was a rice exporting country with Japan being the principal recipient. Heavy Japanese military demand combined with a serious crop failure in 1939 due to drought prompted Japanese colonial authorities to enact several control measures designed to achieve more equitable distribution of food supplies as well as to assure continued exportation of rice to Japan. Government control organizations were formed and instructions were issued requiring farmers to sell a portion of their rice to the government. Several other regulations were also implemented requiring lower polishing rates, curtailment of the use of rice in alcoholic beverages and other rice-saving measures. This series of compulsory measures along with low purchase prices paid to farmers had a negative effect on rice production and resulted in a short supply of rice in Korea. To maintain Korean exports of rice to Japan, cheap noncereal grains such as millet, corn, and sorghum were brought into Korea to fill the food grain gap.

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[1]Information in this section draws heavily on a paper by Moon [36], entitled "A Brief Review of the Evolution of Rice Policy in Korea."

During World War II

The food situation in Korea deteriorated drastically after Japan's subsequent involvement in World War II in 1941 and food control measures were greatly intensified to cope with the situation. In 1943 the Food Control Law was promulgated to completely close down the free market for grains. The government was given full authority to purchase and market all domestic grain except that needed by farmers for home consumption and seed. In 1944 compulsory grain delivery quotas were assigned to all farmers, and all consumers were rationed at an average of .360 kilograms per day. Prices paid to farmers were so low that farmers' main concern was to minimize actual delivery of grains. Prices paid by consumers were also established by the government. This total control system continued in effect until the end of World War II.

U.S. Military Government

After liberation in August 1945, U.S. military authorities issued Ordinance No. 1 which discontinued the food rationing system and restored free market transactions for all grains. This action was influenced by Korea's rice export records to Japan which indicated Korea had a substantial food grain surplus. The result of this abrupt change in food grain management policy was an aggravation of the imbalance of supply and demand. Repatriation of approximately 1.2 million Koreans from abroad, the influx of refugees from the North, combined with the popular sense of being freed from tight food control, caused a sharp rise in rice consumption. Wholesale price of rice rose from 1.0 won (per 80-kilogram bag, polished) in October 1945, to 3.5 won in 1946, to 6.0 won in 1947; six times during a two-year period. In trying to reckon with soaring prices, the U.S. military government

was forced to reconsider the free market system, and set ceiling prices on eleven major consumer items, including rice. The Central Price Administration was organized to take full charge of implementing the price control, such as official setting of ceiling prices, market inspection, and provision of regulations for punishing violators. The government-set price ceilings were never honored. Hoarding and black marketing prevailed. Consumers who had been completely dependent on the rationing system found themselves with no adequate supply of food grain available.

In 1946, after recognizing the failure of the ceiling price system, the U.S. military government again revised grain policy by enacting the Rice Collection Decree which permitted government intervention in the grain market. The free market for grains was once again closed, and compulsory rice collection from farmers and a complete rationing system for urban consumers were enforced. Aside from administrative details, this new grain management system (after liberation) was essentially identical to the total control system employed by the Japanese during World War II.

Subsequent to issuing the above decree, the U.S. military government instituted a program to collect 761,000 MT of rice (polished equivalent) from the 1945 crop, but it was too late. Most of the rice had already left farmers' hands by February 1946 when the program began, and actual collection was only 81,000 MT, or 11 percent of the goal. The remaining part of the crop was dissipated into the black market. Military authorities had to resort to imports of rice in the spring of 1946 to provide minimum supplies to consumers. After a more successful collection program had been carried out on the 1946 rice

crop and rice imports were stepped up to adequate levels, the full control program carried out by the U.S. military government did help to balance the overall supply and demand for staple food and alleviate the inflationary forces arising from the grain sector of the economy. Although this system reminded the Korean public of the compulsory rationing system under Japanese rule, it remained in effect throughout the U.S. military period.

1948-1960

U.S. military government operations were terminated and the government of the Republic of Korea was established in August 1948. Shortly afterwards, the Ministry of Agriculture and Forestry was set up with the Food Administration Bureau to administer the government food grain program. The government abolished the old U.S. military decree and replaced it with the Grain Purchase Law which was essentially the same as the U.S. military decree. The major provisions of this law are summarized below.

(1) Grain producers and land owners were required to sell to the government all their grain other than that required for home consumption and seed.

(2) Free market transactions and transportation of grains except for home use were prohibited.

(3) The government purchase price of grain was to be determined on the basis of production cost, cost of living, the general price level, and other pertinent economic factors.

The policy under this legislation was intended to improve farm income through government purchase and at the same time secure a smooth supply of food grain for urban consumers.

Contrary to the original intentions, however, the government could not procure sufficient rice to implement an overall rationing

system. The main reason for this is reported to be unreasonably low purchase price--much lower than that in the private market. Official records indicate that the government planned to secure 1,087,000 MT of domestic rice in 1948, but despite a bumper crop, the actual quantity purchased was only 560,000 MT, 52 percent of the intended target. With this shortage in government rice stocks, it was necessary to replace the overall rationing system with a priority rationing system. A temporary Food Counter-Emergency Law was enacted in July 1949, under which the overall control system was lifted, free market transactions were allowed, and the priority rationing system established. First claim to limited government-controlled grains was given to military, police, government employees, and workers in critical industries. Rations were reduced in other categories in proportion to the amount of food grain supply available for rationing. Urban consumers not receiving rations were left to themselves to obtain their food grain requirements from the open market.

The Grain Management Law replaced the temporary Food Counter-Emergency Law in February 1950. This law remains today as the basic legal authority for government food grain policy. The principal provisions of this law are as follows.

(1) Producers can be required to sell a proportion of their harvest to the government. Grain for family consumption and seed use is excluded from this compulsory sale.

(2) The government is required to formulate, subject to approval of the National Assembly, an annual plan for food grain operation. The quantity of grain to be purchased domestically and imported, along with the purchase price, is subject to approval by the National Assembly.

(3) The government is required to keep grain stocks on hand to meet emergencies.

(4) The Government may, if necessary, regulate all phases of all transactions in grains.

(5) The government budget required to carry out grain programs is to be made into a special account.

The Grain Management Law also gives the government full enforcement authority on all aspects of the law with punishments for violations ranging from the death penalty for illegal hoarding, cornering, or exports to fines and/or imprisonment for lesser offenses. The primary intent of the Grain Management Law has been to assure adequate food supplies for the people and to assure stablilization of the national economy insomuch as it is affected by domestic food grain prices. Later in 1963, and again in 1967, the above provisions of the law were affirmed and additional authority was given to the government in conjunction with the operational aspects, but the basic direction has remained the same to the present day.

Since the enactment of the Grain Management Law, the grain market in Korea is characterized until today by a dualistic system of combining free market transactions and government control, though the degree of government intervention has varied from year to year. Actually, the government has full legal authority for complete regulation of the food grain system under the Grain Management Law. Even with this authority afforded the government, however, the lack of consistent grain policies has been evidenced over the past twenty-five years.

The outbreak of the Korean War in June 1950 led Korea into troubled times for grain management. Rice needed for government operations was estimated at about 700,000 MT. Due to the enormous wartime budget, monetary inflation, and upward spiralling grain

prices, the government had to discontinue its direct purchase of rice from farmers during the 1952-1953 period. Instead, an attempt was made to secure rice from farmers through various in-kind payment programs. Programs such as farmland reimbursement for land distributed to tenant farms at the time of land reform of 1949, a provisional Farmland Tax Law (a measure to collect farmland tax in kind), and rice-fertilizer barter schemes were implemented to secure needed government grain supplies. Successive crop failures in 1951 and 1952, however, made it impossible for the government to collect the required amount of rice.

A solution for securing an adequate stock of grain, coupled with the objective of stabilizing consumer prices in urban areas, was the importation of foreign grain. In 1951, 210,000 MT of rice was imported, followed by 450,000 MT imported in 1952. These imports were a major factor in somewhat alleviating food shortages, but achieved little effect on soaring grain prices. In 1953 the government imported 960,000 MT of rice, an unprecedented amount, causing this time adverse effects on rice prices. Combined with a bumper crop in 1953, the excessive supply of rice resulted in a sharp decline in the price of rice and other grains. In contrast with previous efforts to check rising grain prices, policy makers now had to prevent further decline in rice prices. The falling rice prices put the farm economy in an extreme state of poverty. To cope with this situation, a farm support program was implemented, and the direct purchase scheme which had been defunct came to be resumed, and, ironically enough, the export of rice to Japan was planned by the government. This grain management program was successful in stabilizing prices during the fall harvest

season of 1954, but stable rice prices did not last long. In May 1955 urban rice prices began soaring again, and the government was forced to release huge amounts of rice in major cities, including those once reserved for export to Japan, in order to cope with the situation.

Korea's food grain program was subjected to a drastic change with the signing of the U.S. Farm Surplus Importation Agreement in 1955. The acquisition of grain for government use, though not rice, became relatively easy from this aid source. U.S. farm products imported under this agreement were wheat, barley, raw cotton, corn, sorghum, and tallow, of which wheat and barley accounted for 50 to 60 percent of the total value of imports. During the period of 1956-1960, Korea's average annual food grain deficit was estimated at about 600,000 MT. To cover this shortage, a total of 3,170,000 MT of foreign grain was imported, of which 2,954,000 MT was imported under PL480, roughly 93 percent. From 1956 through 1964, the total value of grain brought into Korea under PL480 amounted to 425 million dollars, an average of 47 million dollars worth every year. The availability of large quantities of aid grain from the U.S. permitted a major easing of foreign exchange constraints.

Growth Period (1961-Present)

Two revolutions--the Student Revolution in April 1960 and the Military Revolution in May 1961--extensively influenced the political, social, and economic aspects of Korea. A price freeze was imposed on all commodities subsequent to these revolutions and remained in effect for rice, barley, and wheat flour until the fall of 1962. Soaring prices in the fall of 1962 caused by a serious rice crop failure compelled the government to abandon the freeze at that

time. A subsequent barley crop failure in the summer of 1963 caused further deterioration in the food situation. In anticipation of a drastic decline in the summer crop, market supplies of grain became scarce in June 1963, due to hoarding by both farmers and dealers. Rice prices rose 60 percent in June and July. As a countermeasure to check this upward spiral of prices comparable to those once seen in 1950, the government released its stocks in major cities through public auction. However, this indirect measure failed to stabilize prices because of insufficient government stock of rice. The government this time initiated direct measures, including the setting of a ceiling price for rice, production and distribution quotas for all flour mills, and control of rice consumption of restaurants. In spite of a normal rice crop in the fall of 1963, rice prices increased even more sharply in early 1964. The reason for this rice price increase was an increased inventory demand by both grain dealers and urban consumers. The government was thus compelled to raise the ceiling price from the original on several occasions. Finally, in June 1964, the government lifted the price ceiling. The price of rice continued to rise until after the new harvest came in the fall of 1964.

From 1965 to the present, overall grain production has shown a normal trend increase, and Korea's food grain system has been relatively free from catastrophic disturbances brought about by large variations in domestic productions. Nevertheless, problems in the management of food grains have continued. In the following section we will examine some of the important food grain issues facing Korea in recent years.

Present Day Grain Management Policies, Problems, and Issues

Phenomenal economic growth, especially in the nonfarm subsector, has brought with it a new era of challenge in the management of Korea's grain system. Past experience demonstrates clearly the necessity for governmental monitoring and some degree of regulation of Korea's grain system. One issue of primary importance, and subject to little disagreement, is the necessity for careful monitoring of the overall food grain demand and supply situation and assuring adequate food grain supplies are available in the country. A chronic food grain deficit, steadily increasing over the past decade, dictates the necessity of supplementing domestic production with imported foreign grains. Since assuring close correspondence between supplies and requirements demands a vast amount of information, coordination throughout the entire grain system, and an absence of excess profit motivation, the task of regulating the quantity and timing of grain imports (some say) is a task best left to government authority.

Another basic issue deserving some examination is the question of government regulation and involvement in domestic food grain markets. Development plans and goals for increased domestic production, movement toward self-sufficiency in rice and barley, upgrading farm income position, improving urban consumer welfare, and minimizing the effects of food grain prices on the general economy--all are connected with domestic food grain prices. If left to operate in a purely *laissez faire* environment, consumer preferences among food grains, domestic production limitations, and interests of private grain dealers would combine and equilibrate domestic food grain markets at price levels which would not be consistent with these economic development plans

and goals. A dual barley price policy enacted in 1968, and still in effect, is an example of a price structure decision makers obviously feel is consistent with multiple goals of development plans. This price structure could never be realized in a totally free market situation. Under this policy, farmers are paid premium prices for barley in an effort by the government to stimulate domestic barley production. The government then releases barley during the marketing year at relatively low price levels to stimulate urban consumption of barley. The result of such a price policy, it is hoped, is increased domestic barley production, increased farm income position, improved consumer welfare, and substitution of some rice consumption for less-preferred barley. All these expected results are consistent with development objectives; but the cost of such a pricing system is very high. During the 1974-1975 period, government costs for operating the dual barley price system exceeded 4000 won ($US 10) per 76.5-kilogram bag handled by the government. During this period, the government handled over fifteen million bags of barley, or roughly seven million bags per year, at an estimated cost of 28 billion won ($US 70 million) per year. Whether or not this program has been successful, or if the degree of success is worth the cost, is not the subject of this discussion. However, it is interesting to note that under the dual barley price policy for 1974, barley planting for the 1975 barley crop increased only 3 percent; average rice consumption increased 8.1 kilograms per capita from 1973, and barley consumption decreased 1.7 kilograms per capita.[2]

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[2]The Korea Times, January 30, 1975, p. 4.

The general price level and relative price levels among food grains is another issue with which Korean policy makers are keenly concerned. Korea has followed a policy in the past of isolating domestic prices of food grains from world prices. This too has oftentimes been a very costly policy to follow, especially in the 1973-1975 period when world food grain prices soared, and Korea was required to import large amounts of foreign grain to fill the gap between domestic production and requirements. For example, in 1975 the Korean government imported 3.04 million tons of foreign grain at a cost of $US 841 million. Market value of this grain in Korea was approximately $US 120 million less than import costs.

By active participation in the marketplace, the Korean government not only attempts to control free market food grain prices at planned levels, but also is concerned with the relative levels of consumption of the major food grains which, of course, are determined to a large extent by relative prices. Prices of imported grains have not increased uniformly in the past. For example, between January 1972 and January 1974 world prices for rice, barley, and wheat increased 314 percent, 120 percent, and 283 percent, respectively. The relatively lower world barley price increase precipitated extensive efforts by the government to encourage rice conservation and turn consumption patterns toward cheaper (and less-preferred) barley. Much of this effort was done through indirect market price incentives, but also many direct approaches were taken to conserve precious rice. The government began mixing pressed barley with its rice releases (and by 1974 all government rice was released as mixed grain), mandatory "riceless" days were enacted for restaurants, school children

were required to carry bread or mixed grains in their lunchboxes, and extended periods were declared during which only government grain transactions would be legal. Severe penalties threatened violators and those attempting to "unmix" government grain by removing the pressed barley portion. Again, the degree of success of a grain management program such as this is difficult to measure, since the game board used was the real world system with no basis for "what if" type questions. An interesting and instructive lesson for decision makers was learned from the real world grain system early in 1974. The government raised wholesale flour prices by some 60 percent to relieve huge subsidy payments being paid to flour millers. Almost immediately after the flour price hike, flour demand dropped more than 70 percent and rice price went virtually out of control for several months to follow. The government was forced to release some 232,000 metric tons of rice during February, March, and April (eighteen times the amount released during the same period previous years) in order to bring rice prices into control. Despite a pledge by the government not to import foreign rice in 1974, eventualities saw to it that 252,000 metric tons were actually imported at a cost of some $US 130 million.

To this point in our discussion of grain management problem issues in Korea, an attempt has been made to focus attention on problems of (1) balancing deficit domestic supplies with foreign imported grains, and (2) government market activities aimed at maintaining relative price levels among grains and attempting to influence consumption toward cheaper barley. Although not intended for discussion until now, the issue of seasonal price stabilization has already made

itself known. This is one of the hottest and most debated issues in Korean grain policy today. The importance of the problem is expressed in an excerpt from a *Korea Times* newspaper editorial published January 30, 1974, entitled "Rice Price Control."

> . . . As experienced in the past when rice prices go up, other prices follow, because rice price is a basic gauge of commodity prices. When rice prices move, others, such as services and wages, fluctuate and shake the very foundation of the price structure . . .

Further insight into the hard *reality* of the problem of grain price stabilization, as well as other grain management problems, is given in headlines and article captions from the same newspaper over a several-month period.

- "Rice Prices Unusually Low in Harvest Areas," 1-6-74
- "Farmers Hold Back Rice; Prices Soaring," 2-12-74
- "New Price Ceiling Necessary for Rice," 2-19-74
- "Countersteps to Be Taken to Curb Rice Price," 2-21-74
- "Rice Price Hits 16,000 Won Per 80 Kg Bag," 4-12-74
- "Soaring Prices Force Release of Stock Rice," (headline) 4-17-74
- "Businessmen Urge Rice Price Control," 4-18-74
- "$650 Million Required for Grain Import," 4-21-74
- "Strong Action Ordered Against Rice Hoarding," 4-21-74
- "Government Pegs Rice Price at ₩12,000 A Bag," 4-23-74
- "Crackdown Tightens on Illegal Rice Deals," 5-9-74
- "Rice Unavailable in Pochon-Gun," 5-10-74
- "Prices Soaring Beyond Ceiling," 5-10-74
- "Grain Fund Deficit to Hit ₩106.3 Billion," 5-16-74
- "Rice, Barley Prices Jump Nationwide," 6-23-74

The first captions of the above list seem contradictory but point out another perennial grain problem issue in Korea. Farmers in need of cash after harvest are pressured into selling a large portion of their crops to repay production credit loans. This glut of new grain on the market causes farm prices to fall directly after harvest, and many farmers must sell at depressed market prices. Later in the year, as supplies dwindle, farm and urban prices tend to rise . . . and not always in an orderly manner. Government domestic purchase programs are always conducted directly after harvest. Rice purchase programs are conducted from November through January, and barley purchase programs are conducted during July and August. One positive effect (claimed by the government) from these purchase programs is the price support offered farmers who must market directly after harvest. Private market prices tend to be more supportive during government purchase programs, due to additional market demand. Critical decisions are made each year concerning the purchase price to be paid for government grains. These decisions must consider such factors as farm income positions, production costs, effects of government purchase prices on the following year's production decisions made by farmers, competition with private market for farm sales, grain management funds available for domestic purchases, expected margins between purchase and release prices later in the year (impacts on grain management accounts), and purchase program targets. Grain policy analysts in Korea have often proposed alternatives to traditional government purchase programs, such as extending the government purchase program period, changing the time of purchase program periods, letting government purchase price float with private market price, and/or

increasing government purchase price stepwise (or continually) during the purchasing period to cover the costs of on-farm storage and relieve the pressure on government storage requirements. Government decision makers are reluctant to adapt or even try these alternative purchase program strategies--most likely because of apprehension to risk unproven alternatives.

Government release programs to stabilize food grain prices in urban areas are often ineffective (as in 1974), and other times accused of being too effective [37, 46, 47]. A startling lack of consistency is shown in seasonal food grain price patterns over the years. The government has steadily increased its share of the commercialized grain market in Korea since 1966. Figures 1.1 through 1.3 indicate government release amounts, patterns of grain releases, and resulting farm and urban retail price patterns since 1966. As seen in the figures, the degree of inconsistency in urban price patterns appears to be related to the size of government grain operations, indicating poor planning of seasonal market price policies or, more likely, the inability of the government to manage release timing and quantities in a manner which will produce logical and consistent seasonal price patterns and stability. The effect of this unpredictability in market price patterns has been a disincentive for private market operations, and waste of valuable capital in the private market grain handling subsector. The unpopularity of grain hoarding and speculation which naturally occurs in the private sector, especially during periods of unstable prices, is reflected in interviews with government grain officials who often speak of " . . . kill or crush the middleman . . .", " . . . drive them out of business . . .", etc. The ignorance of this

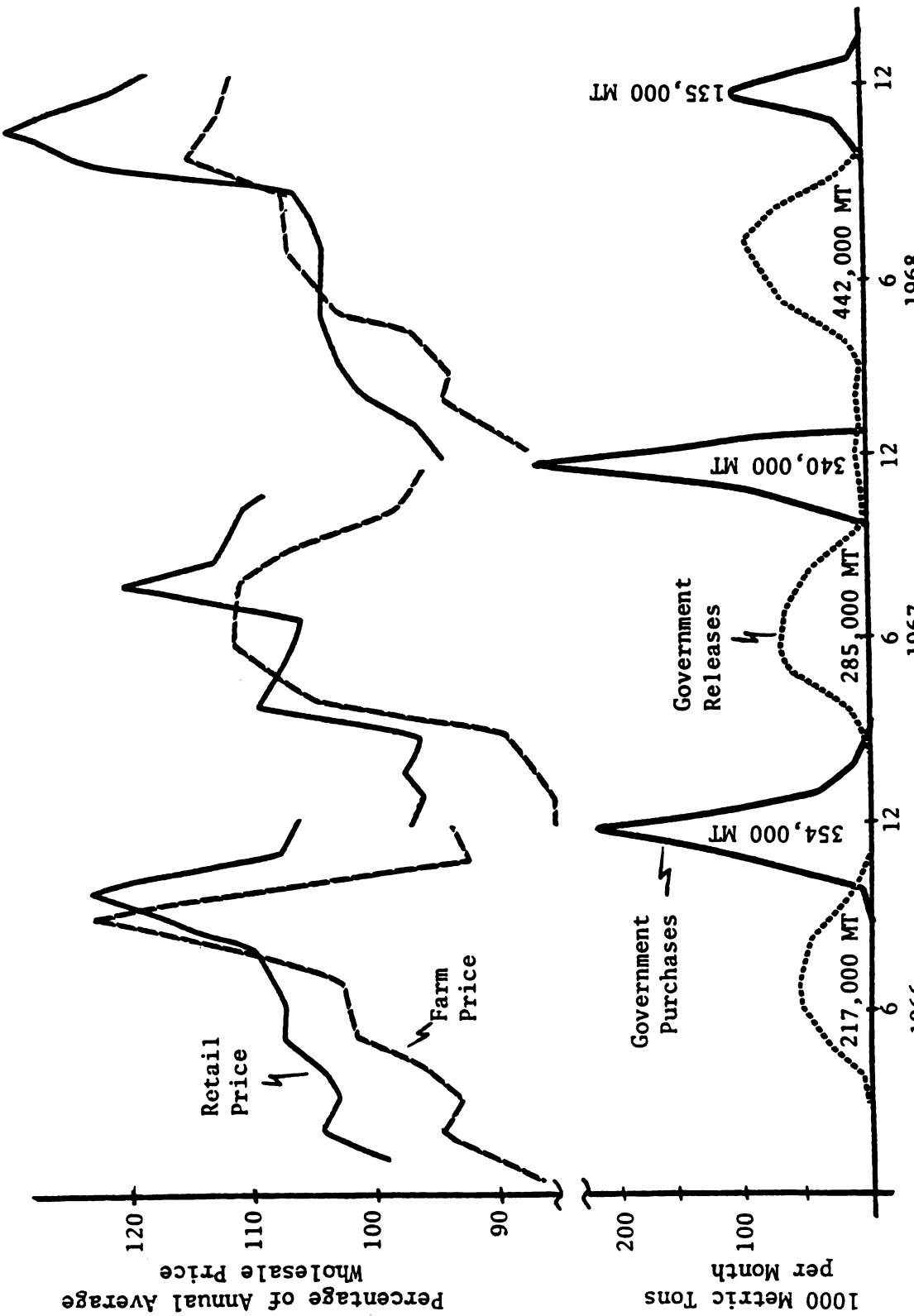


Figure 1.1. Prices and Government Operations (Rice 1966-1968).

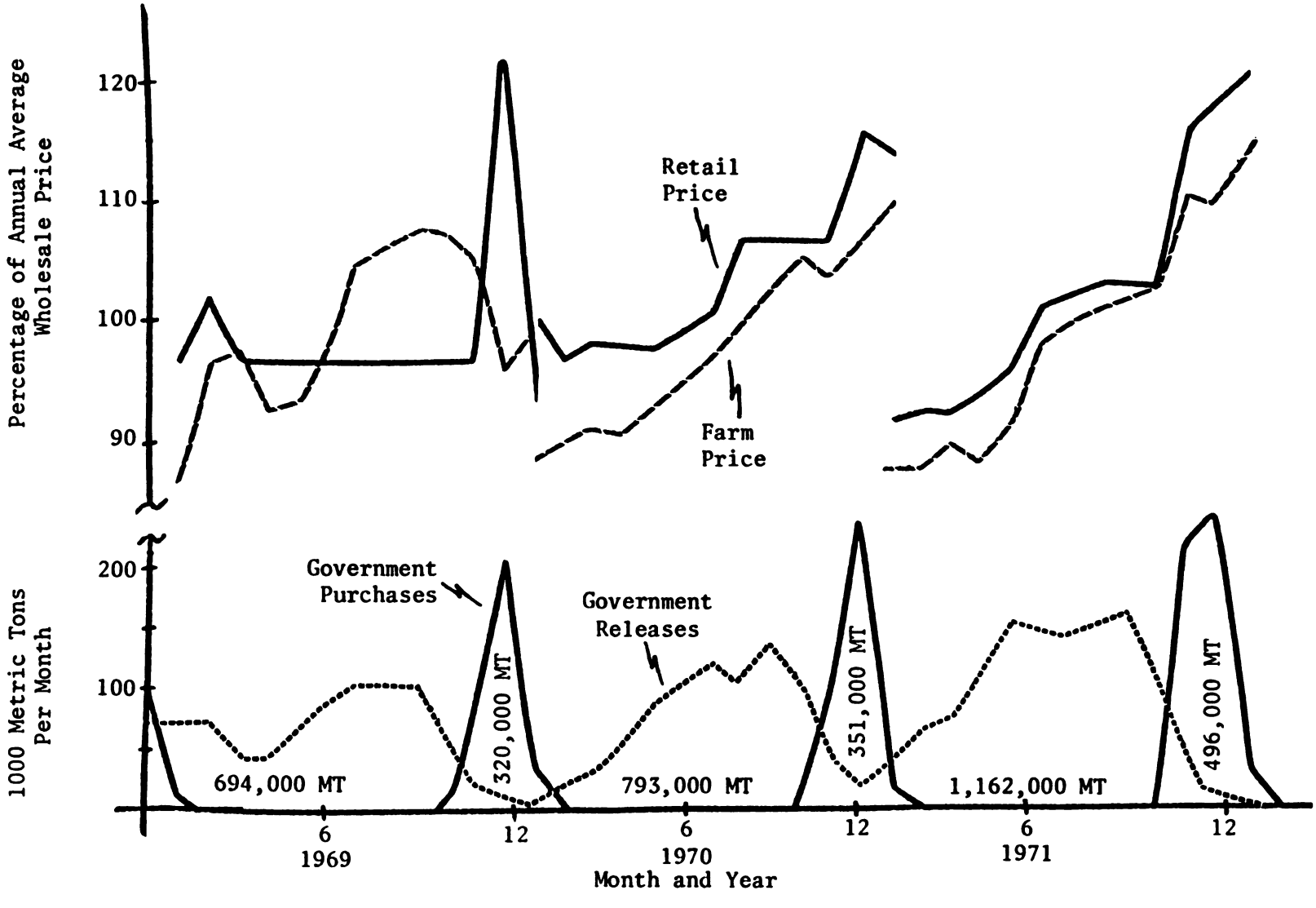


Figure 1.2. Prices and Government Operations (Rice 1969-1971).

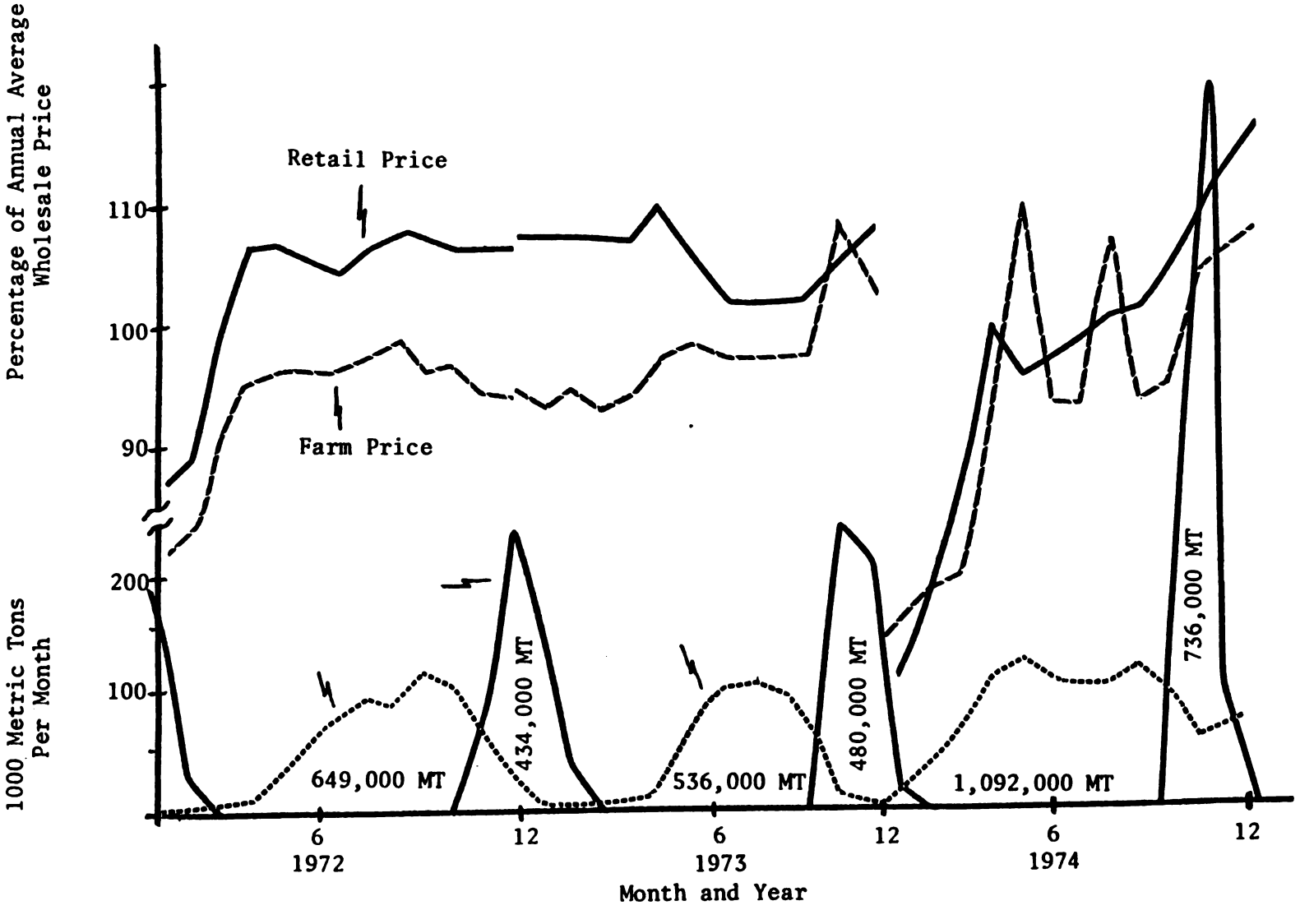


Figure 1.3. Prices and Government Operations (Rice 1972-1974).

type of attitude is self-evident and does not reflect the official position of the government or sensible administrators.

The setting of government release prices is always a major concern throughout the marketing year. Government grains are of inferior quality to grains available through the private subsector. To encourage adoption of new high-yield varieties of rice, the government does not distinguish among types of grains at the time of purchase, paying the same price for new varieties as traditional varieties. New high-yielding (Tongil) rice is considered inferior by consumers and is discounted in value in the private market. The government generally ends up with the lion's share of commercialized Tongil rice. The government also handles imported grains which are often considered inferior because of variety differences and deterioration in quality (very distinguishable by consumers) due to prolonged storage periods. The government attempts to control quality to some extent by mixing traditional and Tongil rice varieties and foreign rice. This mix is also mixed with pressed barley as mentioned previously.

Other grain management problem issues exist: the handling and processing of government-controlled grains, for example. The government traditionally buys all grains from farmers in rough form. Paddy rice, as it is called, has the outer hull intact. Rice in this form is more stable but also occupies twice the volume of hulled rice (brown rice) or polished. Government domestic grains are also always milled in production areas and shipped to consumption areas in polished form. Foreign imported grains arrive in hulled form (as brown rice) and are processed in urban areas. Modifications of these types of standard

practices in managing government grains offer potential benefits, but, because unproven, the government is reluctant to change.

Government grain warehousing is also a problem issue in Korea. Government purchase programs (as they are), gathering huge amounts of grain over short time periods, demand much storage capacity to hold grain reserves and new purchases. New warehouse construction programs, location and type of new warehouse facilities, and use of existing facilities are real problem issues in Korea.

Review

In this first chapter, the grain management problem in Korea has been introduced. The chapter began with some of the preliminaries of introducing the general nature of the problem, pointing out the lack of, and need for more, analytical capacity to study and manage grain programs and policies. The general setting of the grain system in Korea was reviewed, indicating land areas and uses, productivity, and production trends for food grains. The role of food grains in Korea was discussed in terms of farm income, the Korean diet, consumer expenditures, and the national economy. Supply and requirements balance sheets were shown to indicate the increasing dependence on foreign grain imports. Next, a brief historical review of grain policy in Korea since 1939 was presented to give some insight into Korea's chronic grain management problems. And, finally, some of the specific and important problem issues in Korean grain management in recent years were discussed.

The product of this chapter should be an awareness of the Korean grain system and some of the important and real problem issues facing grain management officials. Although the problems of managing the real

world system are diversified and complex, the basic problem is a need for more analytical support to grain management planners and administrators. In short, aside from providing background information, the *need* for a comprehensive grain management program model for Korea, hopefully, has been well established in this chapter.

In the following chapter, the GMP model, designed for satisfying this need and providing a possible solution to this basic problem, will be introduced and described in general terms.

CHAPTER 2

GENERAL DESCRIPTION OF THE MODEL

Introduction

In this chapter, the grain management program (GMP) model will be described in general terms. The objective is to convey general understanding of the overall model concept, before delving into more detailed mathematical descriptions of the various model components in succeeding chapters. Emphasis will be on the "whys" or rationale behind the design aspects of the model, rather than the specific "hows" or mathematical relationships of the model.

To convey the GMP model concept in an orderly manner, the general description of the model will be divided into four major parts. *First,* the reader will be given a brief synopsis of the GMP model. This will include a concise statement of model objectives, methods used for model development, a description of the size and scope of the model, specific program and policy issues which may be addressed by the model, design organization of the model, and a description of the level of system disaggregation used in the model.

The *second* part of the chapter will be devoted to a general description of the grain system operations model which simulates the physical and economic processes, and management decisions over time in the real world Korean food grain system. A brief description of the function of the four major subsector components of the model (farm, urban, private market, and government) will be given, plus a

description of the price and transaction mechanism which acts as the major linkage among these model components. Next will be a general description of the various physical, economic, and decision processes simulated in the model. These include domestic production decisions, production processes, importation, consumption, market supply and demand, grain storage, grain movements, processing of grains, and market price generation.

The *third* part of the chapter will discuss the policy orientation of the model which enables it to address a wide range of grain management problem issues. Orientation of the model toward investigating annual food plans, food grain self-sufficiency, foreign import scheduling, government purchase and release programs, seasonal price stabilization and control, government grain management operating procedures, and government warehousing programs will be described.

Finally, the reader will be given some idea of the kinds and types of model outputs and system performance measurements offered by the GMP model. Forms of model output, grain systems operation performance criteria, fiscal accounting, and special performance criteria will be described. The model also provides measurements of its own performance in tracking (reproducing) historical data, and measurements of success in achieving targeted policy goals, such as seasonal market price patterns. These performance measurements will also be discussed.

Synopsis of the GMP Model

Model Objectives

The design of the GMP model has two main objectives: (1) to approximate, at an acceptable level of detail and accuracy, the real

world (dynamic) food grain system in Korea as it responds to various grain management programs, policies, and decisions; and (2) to design control systems for the model which will enable its use as an on-line grain management tool to be used by government administrators in directing existing grain management programs to achieve prescribed objectives.

The aim of the first objective is to furnish the policy analyst and decision maker an analytical tool by which they can speedily investigate the potential consequences (good and bad) of alternative proposed solutions to a variety of chronic grain management problems existing in Korea today. The detail required from the model is dictated by the kinds and amount of information analysts and decision makers must have about the performance of the food grain system to make sound selections among alternative programs and policies under investigation. The capacity of the model to produce valid comparisons among alternatives being studied is of primary importance, more so than the precise magnitude of the variables being generated.

The second objective is aimed at developing a set of management strategies which can be adopted by government officials in administering existing grain management policies. Seasonal food grain price control is the main concern of this objective, since it remains one of the most perplexing and costly problems facing grain management officials today. Ideally, if the GMP simulation model can be made to approximate the real world dynamic Korean grain system, with supply, demand, and price relationships responding in a realistic manner, then the decision rules developed for controlling market prices generated by the model should imply relevant real world decision rules

required to steer actual market prices toward seasonal price policy objectives.

Method

The general systems simulation approach (GSSA) was utilized in the design of the GMP model [31, 41, 42]. Techniques from various disciplines (including systems design, econometric analysis, economics, operations research, linear and nonlinear systems, and automatic feedback control theory) were used in the model development. The model itself is a nonlinear, dynamic system model with some time-varying parameters.

The model is fully computerized, utilizing FORTRAN computer language. Solutions to model differential equations are gained through numerical integration techniques stepwise through time. Each solution interval of the system model also enables the calculation of all other variables through simple algebraic relationships. Many of the model calculations are internal to the computer and are not output. Solution intervals necessitated by conditions for system stability are not always of interest in generating time series data. For example, solution intervals of one-two days are necessary within the computer, but users may require time series data output at only weekly or monthly intervals. Some variables are used only as intermediate variables for calculation purposes and are not meaningful in the real world. The model produces summary data at prespecified intervals which can be output in table format for the convenience of the model user.

Scope and Size of the Model

The GMP model is a major supplementary component of the Korean Agricultural Sector Simulation (KASS) model [2, 41]. The major Korean food grains--namely, rice, barley, and wheat--are identified explicitly in the KASS model along with fifteen other agricultural commodities. The strength of the KASS model is fairly uniform over all commodities identified, and problems relevant to food grain can be analyzed in as much depth as other commodities. However, the broad design of the KASS model, encompassing the entire agricultural sector with its linkages to the nonagricultural sector and long-term planning horizons of fifteen to twenty-five years, must of necessity limit the depth of investigations into problems relevant to particular agricultural commodities such as food grains.

The GMP model focuses solely on the Korean food grain system and grain management problem issues. With this sharp focus on the food grain portion of the agricultural sector, the model can be used to provide increased insight and analytical capacity into food grain problems not otherwise possible through use of the KASS model alone. Although focused only on the major Korean food grain commodities (rice, barley, and wheat), the size and complexity of the GMP model is not significantly different than the broader KASS model. This is because the reduction in size and complexity gained by narrowing the focus of the model to major food grains only has been reinvested into designing the GMP model to address a wider range of food grain policies, and to increase the depth into which food grain problem issues can be studied and analyzed. This trade-off concept between the two models is depicted in the simple illustration of Figure 2.1.

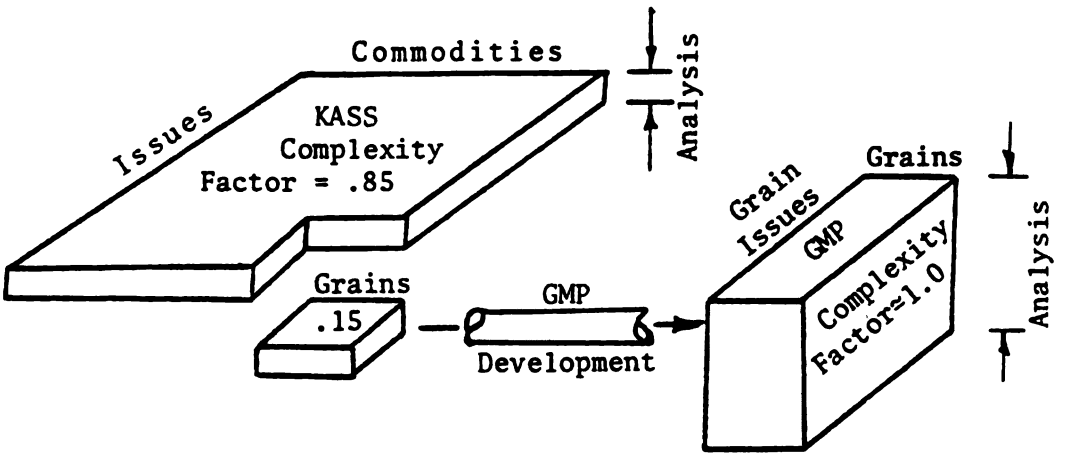


Figure 2.1. Scope and Size of GMP Vs. KASS Model.

As indicated in Figure 2.1, the generalized nature of the GMP model, making it applicable to a broad range of grain management problem issues and capable of analyzing these problems in detail, necessitates it being comparable in size and complexity to the KASS model. The model contains approximately 4300 executable statements and generates more than 2000 variables. Core requirements exceed 120K octal words. Execution time for a full run of the model on a CDC Cyber 70, using a simulation time increment of 1/200 of a year (1.8 days) for a two-year run, is about three minutes CPU time.[1]

Program and Policy Issues

In its current state of development, the model has direct application to the following grain management program and policy issues:

---

[1]Computer costs for a run of the GMP vary considerably, depending on the length of run, size of the simulation increment, amount of analysis and output required, the particular computer used, etc. The model test runs described at the end of Chapter 8 cost approximately $25 on the MSU Control Data 6500 computer. Cost in Korea on a CDC Cyber 70 computer would be somewhat less for the same runs.

1. The timing and quantity of government grain purchases and/or releases in order to control farm and/or urban market prices.
2. Price and, hence, government subsidy requirements of government-regulated wheat flour.
3. Location, quantity, and movement of government-controlled grain stocks.
4. Quantity and scheduling of foreign grain imports.
5. Purchase and release price policies for government grains.
6. Seasonal price pattern policy objectives.
7. Government purchase programs for domestic grains.
8. Food grain self-sufficiency.
9. Planned food grain consumption levels and diet mixes of farm and nonfarm consumers through relative price level control.
10. Foreign grain loan repayment schedules and impact on balance of payments.
11. Grain milling extraction rates.
12. Warehouse construction programs
13. Storage and handling losses.
14. Impacts of grain management policies and programs on domestic food grain production.

More will be said about some of these important policy issues later in the chapter when we describe the Policy Orientation of the Model.

Model Design

The design of the GMP model can be organized into three different categories: (1) grain system operations, (2) policy orientation, and (3) system performance. Model design under the *first* category is used to approximate the dynamic behavior of the real world food grain system in Korea. This portion of the model simulates the production, importation, movement, processing, storage, and disappearance of food

grains in Korea over time. Economic forces--namely, food grain supply, demand, and prices--which govern much of the system operations behavior are also simulated in this portion of the model. The system operations model is designed and parameterized to reflect real world system structure, human behavior, management decisions, and system constraints. The *second* category of model design, policy orientation, has the purpose of orienting the model toward usefulness as an analytical device for studying particular grain management problems. The *third* category of design, system performance, is necessary to provide model users with specific information about the (simulated) performance of the real world system so that well-informed choices can be made among alternative management strategies under study. Self-checks into actual model performance for tuning, testing, and validation purposes, such as how well it tracks past data, are also built into this portion of the model. More will be said later regarding model design under each of these categories.

Disaggregation

To provide the level of detail required by potential users and to represent the state of the food grain system extensively enough to capture the important interrelationships and dynamics required to fulfill model objectives, the GMP model is disaggregated across six dimensions. These dimensions are summarized in Table 2.1.

Subsectors

The GMP model disaggregates the Korean grain system into four subsectors: (1) farm, (2) urban and nonfarm consumer households, (3) private market, and (4) government. Generally, grain management

Table 2.1. GMP Model Disaggregation.

Subsectors	Population	Food Grain Commodities
Farm	Farm	Rice
Urban households	Nonfarm	Barley
Private market		Wheat
Government		
Grain Forms	**Position Points**	**Government Warehouse**
Rough	Production areas	Low temperature
Hulled	Seaports	Class A
Polished (pressed)	Consumption area terminals	Class B
Flour and flour products	Retail sales stores	Class C
		Auxiliary

program objectives are aimed at individuals comprising these components of the overall grain system and may be different for one subsector than for another. Behavior characteristics are also different in each subsector. Farm consumption behavior differs from urban in that farmers must decide whether to consume or market their food grains for needed cash. The private market differs from government marketing channels in that it consists of entrepreneurs motivated by profit incentives to move and store grain, whereas the government is motivated to carry out grain operations in order to achieve grain policy objectives for the entire system.

Food Grain Commodities

Food grain commodities identified by the GMP model are rice, barley, and wheat. These are the major food grains in Korea, accounting for over 95 percent of total human food grain consumption. Rice is by far the most important food grain commodity, accounting for about 51 percent of total human food grain consumption. Barley and wheat

follow rice in importance, with each of these grains accounting for around 22 percent of total food grain consumption.

Grain Forms

The GMP model traces through time all physical operations on food grains from planting to final consumption. All food grains undergo physical characteristic changes through processing before they are consumed by humans. The rice hull remains on the grain after harvest. This hull provides a protective shell around each kernel and enhances the storability of the grain. Common practice is to leave the rice in unhulled (or paddy) form until shortly before it is marketed or consumed. Paddy rice, however, is more bulky than hulled rice and requires twice the storage space. Rice processing can be divided into two stages: hulling and polishing. The hulling process merely knocks the outer hull off the grain, leaving what is commonly called hulled (or brown) rice. Brown rice does not have the storage qualities of hulled rice but still maintains its taste qualities during prolonged storage much better than in the final polished form. Rice is imported in brown rice form and polished in government-licensed mills shortly before release onto the market. Rice hulls have little economic value but are used as fill for pillows and mattresses and also serve as a good absorbent. Rice bran, however, has a high economic value and is used as a high-quality animal feed and in the production of rice bran oil.

Both common and naked barley are produced in Korea. Each of these grains has different physical characteristics after harvest, but after milling, the polished form of the two grains appears similar. Common barley has a fibrous hull firmly attached to the grain. This

hull must be ground off, with the bran by-product going mainly to animal feed. Naked barley appears somewhat similar to wheat after harvest with a skinlike covering over each kernel. This covering is ground off during the milling process with the bran by-product also going mostly to animal feed products. Barley can also undergo further processing into pressed form. At this stage of processing, polished barley is parboiled briefly, dried, and rolled to enhance the cooking qualities of the grain, especially when mixed with rice. Supplemental nutrients are often added to pressed barley.

Since 1971 the Korean government has undertaken a program of mixing rice and pressed barley together. Currently they are providing a 70/30 mix ratio of rice to pressed barley. The program has intensified in recent years and now all government rice is mixed with barley before release. This new commodity, sometimes referred to as "brice," is not handled explicitly by the current version of the model, but represents an area of top priority in future refinements of the model. More will be said about this in Chapter 9.

The major portion of wheat consumption in Korea is in the form of wheat flour and wheat flour products. Over 90 percent of the wheat consumed in Korea comes from wheat imports which are milled into flour by members of the Korean Flour Millers Industrial Association (KOFMIA) and sold to various wheat flour processing industries throughout the country.

As indicated in the preceding discussion, food grains can take on a multitude of forms prior to human consumption. The GMP model disaggregates by grain forms--but only to the extent of absolute necessity, since disaggregation in any dimension means added complexity

to the model. Table 2.2 indicates model disaggregation (and aggregation) of food grains by form.

Table 2.2. Model Disaggregation of Food Grain by Form and Commodity.

Commodity	Unhulled (Whole grain)	Hulled	Polished (Pressed)	Flour (Flour products)
Rice	X	X	X	
Barley	X		X	
Wheat	X			X

Position Points

The GMP model monitors the physical location of food grains until final disappearance. Position is an important dimension of system disaggregation when it comes to parameterizing storage and flow capacities of the model to reflect realistic values. Domestic grains must move from farm positions through commercial marketing channels, undergoing processing and storage over time, before they eventually arrive into urban consumer households for consumption. Imported grains must move into seaport facilities from foreign countries, move into urban areas, undergo processing, and move into retail sales outlets before they arrive into urban households. In general, domestic grains are processed and stored in production areas and move into consumption areas as required to meet urban demand requirements. Imported grains are processed in urban areas.

Government Warehousing Classes

The last dimension of GMP model disaggregation is classification of government-controlled warehousing facilities for food grains.

Although of lesser importance than other disaggregations of the model for immediate use, this dimension enables the use of the GMP in addressing grain management problems related to storage practices on government-controlled grains [20]. The model identifies five classifications of warehouse facilities: (1) low temperature, (2) class A, (3) class B, (4) class C, and (5) auxiliary storage. Each of these classifications of warehouses has different unit construction costs, storage charges, and storage loss characteristics over the four seasons of the year. Table 2.3 indicates the distribution of the five classes of government-controlled warehousing facilities as of June 1974. The distribution of these classes of warehouses changes over time with depreciation, new warehouse construction programs, etc. The GMP model monitors this distribution and simulates expected loss rates from storage over time.

Table 2.3. Capacity and Distribution of Government-Controlled Storage by Class.

Warehouse class	Capacity (1000 MT)	Percent
Low temperature	172	11
Class A	89	6
Class B	473	32
Class C	554	37
Under grade (auxiliary)	217	14
TOTAL	1505	100

Source: Yearbook of Agriculture and Forestry Statistics, Grain Statistics 1974, MAF, 1974.

Grain System Operations Model

A major portion of the GMP model design is devoted to describing the time, space, and form processes of grain operations occurring within the Korean grain system. This includes the simulation of physical grain operations, such as production; importation; market supply and demand; grain transactions; grain movements, processing, and storage; and grain consumption. It also includes the modelling of economic forces, such as farm and urban market prices, which have major effects on the behavior of the grain operations system. Physical processes are parameterized and constrained to real world characteristics to reflect realistic system performance.

The basic structure of the grain system operations model is found in four subsector models representing (1) farm, (2) urban or nonfarm, (3) private market, and (4) government subsectors of the real world grain system. These models are linked and become closely interrelated components of the overall system through a market price generation and transaction mechanism. Once the subsectors are linked, the grain system operations model must not be considered as four separate subsector models, but as a fully integrated system with virtually all (internal) variables being related, directly or indirectly.

In describing the grain system operations model, it is desirable to emphasize the "total" system concept; however, it is difficult to do so when describing the model subsector by subsector. The procedure used will be to describe briefly the individual subsector component models in general terms to give the reader some idea of their individual attributes and functions. From there, further

discussion of the operations model in this chapter will be centered around actual system operations, such as production, importation, grain movements, storage, and consumption.

Subsector Component Descriptions

Farm Subsector

The farm subsector model is structured and parameterized to simulate the production, storage, marketing, and consumption (human and nonhuman) of food grains at the farm level. Farmers respond to past experience, cost factors, prevailing market conditions, and future expectations in their decision processes regarding farm grain management operations. The GMP model attempts to capture some of the important factors and rules going into farm decision processes and reflects the impact of these decisions as they are passed on to other subsectors and are propagated throughout the entire food grain system.

Urban Subsector

The urban demand component model simulates the demand, consumption, and food grain storage characteristics of urban consumer households. Effective market demand for food grains is keyed to both current consumption levels and household grain inventory adjustments. These storage adjustments are responsive to food grain price levels, as well as to future expectation of market prices. Consumption is responsive to food grain prices and also to the level of existing household grain inventories. When inventories become critically low, reflecting inadequate market supplies, consumption is suppressed, reflecting a tightening-of-the-belt phenomenon during times of food grain shortages.

Private Market Subsector

The private market (PM) subsector model reflects the structure, constraints, and decision processes which govern the flow, processing, and storage of food grains through nongovernment marketing channels. Decision and management processes of individual participants (including collectors, assemblers, millers, shippers, commissioners, wholesalers, and retailers) of the private market are modelled. Domestic grains are purchased, stored, and sold according to rational private market demand and supply functions. Grains move into private marketing channels at various position points and are processed where appropriate. They then continue through the private marketing system to retail sales positions, where they move out of the private market subsector and into urban household storage via sales transactions. Imported wheat operations, which are handled by the private market, are also simulated.

Government Subsector

Internal government food grain operations, including domestic purchases, imports, storage, milling, transportation, and releases, are simulated in this subsector model. Decision processes required to administer existing grain management programs and policies, such as farm and/or urban price stabilization, and control of reserve food grain stock level management through importation of foreign grains, are also designed into the model. This aspect of the model, however, does not strive to replicate existing real world government decision processes as the PM subsector model does for the private market. Instead, the model is designed as a tool for prescriptive analysis of government grain operations that would be necessary to achieve

targeted policy objectives. The attempt of the model here is to *improve* on existing government decision processes through providing insight and guidelines for government officials actively engaged in these difficult decisions.

Subsector Linkage

The four subsector components of the GMP model are linked together by a price and transaction (PAT) mechanism. This mechanism is used to interface food grain supply-and-demand relationships in farm and urban markets, generate market prices, and calculate actual grain transactions which occur throughout time.

The grain market transaction mechanism operates both in the farm and urban consumer markets. On the farm market side, government and private market demands for grains are interfaced with farm marketings. Free market decisions of farmers to market into either the private or government sectors are reflected in the mechanism. These choices depend on the relative levels of government and private market demands, the relative buying prices being paid by the government and private market subsectors, and the relative convenience to the farmer in marketing into each of these subsectors. Actual grain transactions then occur so that total farm sales during any period of time are equal to total government and private market domestic grain purchases.

On the urban consumer market side, grain marketings from the private and government subsectors are interfaced with urban consumer demands for grains. Free market decisions of urban consumers to buy from either the private or government subsectors are reflected in the mechanism. These choices depend on the relative levels of

government and private grain marketings, the relative selling prices of government and private market grains, and also on the relative quality of government and private market grains. Actual grain transactions then occur so that total government and private grain sales during any period of time are always equal to total urban consumer purchases.

The transaction mechanism contains parameters which can be altered to reflect government countermeasure policies designed to suppress normal free market decisions of farmers and urban consumers in choosing between private and government markets. More will be said about this while we are discussing the policy orientation design aspects of the model.

Figure 2.2 illustrates the basic conceptualization of the GMP component models and depicts the linkages provided by the PAT mechanism. The figure gives a simple view of the overall system

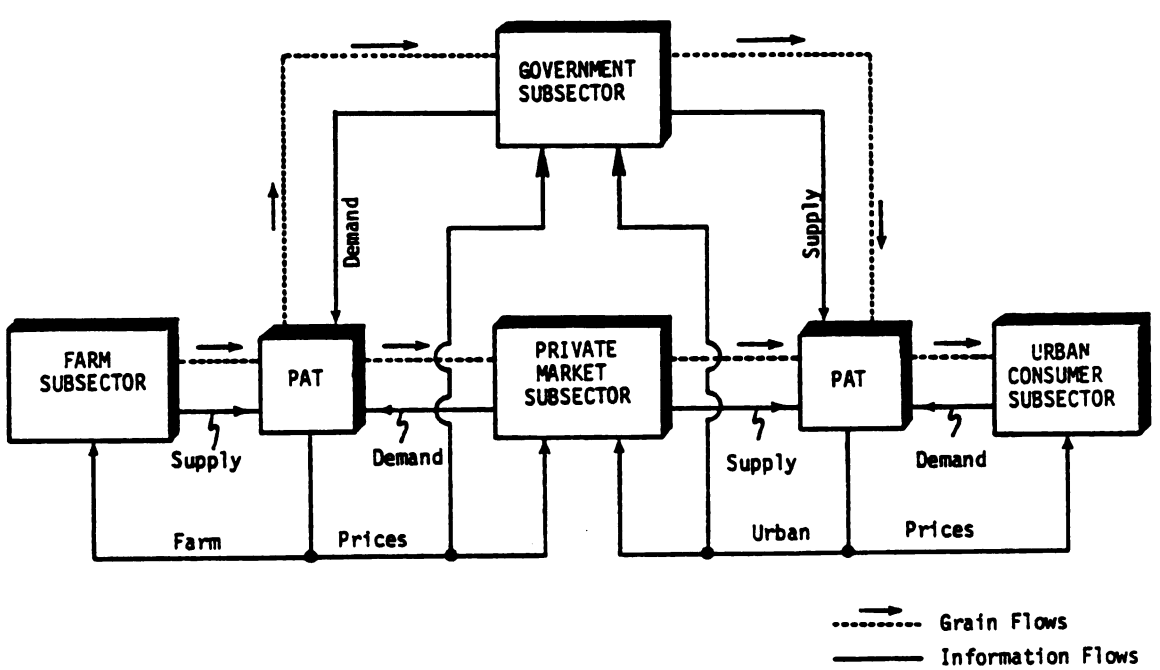


Figure 2.2. Grain Management Program--Model Linkage

concept and shows (domestic) grain flows through the marketing channels. All demands, supplies, and prices are indicated as being endogenous to the system. This is always true, except for government policies--such as demand and supply--which can be either endogenous or exogenous, depending on what use is being made of the model.

Historical tracking experiments, which determine how well the model can reproduce historical time series data, require that government demand and supply correspond with actual purchase and release programs prevailing during the period of the model run. Government imports and purchase and release prices also must correspond to actual historical data on these series for tracking purposes. Other runs of the model may require the investigation into "what if" effects of alternative government purchase prices or alternative government purchase programs (during different times of the year) or alternative release prices. In these run modes of the model, government policies are specified by the user. In the configuration of Figure 2.2, the model also has the capability of calculating some government policies, such as supply and/or demand, endogenously to meet certain policy objectives, such as targeted seasonal price policies.

Many of the causal relationships of the GMP system model are not shown in Figure 2.2. To gain this insight, it is helpful to view the model in terms of the major system processes simulated and their interrelationships. Figure 2.3 is a causal map of the GMP model showing some of these interrelationships. Major grain flows are depicted in the figure. Domestic production moves into farm storage and out again (through time) to various dispositions, i.e., farm household consumption, farm livestock consumption, seed requirements,

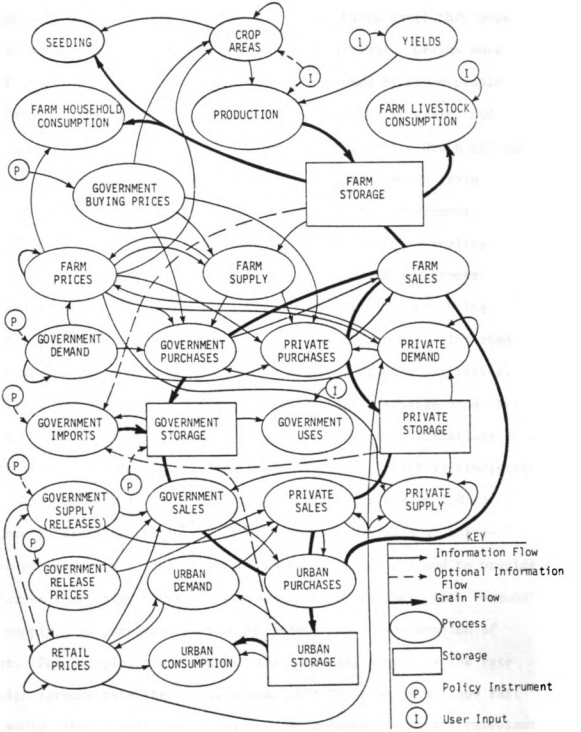


Figure 2.3. Causal Map of GMP Model.

and farm commercial sales. Farm sales are shown divided among private and government marketing channels, with some sales bypassing formal marketing channels altogether. Farm-commercialized grains then move into private and government storage and remain there until they move into urban household storage upon market transactions. Grains move out of urban household storage as they are consumed by urban people. Government imports are shown as an additional source of grain, and government uses as an additional disposition of grain. Grain storage, shown in Figure 2.3 by the four rectangular boxes, depicts grain ownership by farmers, urban (nonfarm) consumers, the government, and the private market. Many activities are occurring in reality, as well as in the model, within each of the grain storage blocks: grains are moving in and out of various storage facilities, being processed, stored, and moved from one position to another. Imported grains are being loaded, shipped, and discharged at port facilities, oftentimes queuing up at ports if arrivals exceed discharge capacity. All these operations require time, space, and form transformations and it is these processes that the grain operations model is simulating.

The demand and supply processes indicated in Figure 2.3 do not come in direct contact with grain flows but are used as information processes to calculate actual market transactions and to provide the forces that cause market prices to change over time. Both "demand" and "supply," as perceived in the GMP model, have a connotation of intent. For example, "farm supply" (or farm marketings) is the rate at which farmers make their grains available for sale--i.e., how fast they would like to sell their grains--and "government demand" represents the rate at which the government intends and is able to purchase grains

from farmers, and so forth. "Supply," as used in the model, does not refer to the amount of grain in storage in the farm, government, or private subsectors, but means the amount each subsector is making available for sale.

To help the reader become acquainted with the causal map of Figure 2.3, let us consider the calculation of, say, private market purchases. Arrows entering the "private purchases" process indicate that private purchases are a function of private demand (i.e., the rate at which the private market wishes to purchase), government demand, farm supply, farm price, and government purchasing price. When the government is active in a purchase program, government demand competes with private demand for farm market supplies. Relative price differences between government purchase price and private market price affect farm choices to market into the respective markets. Also the size of the relative demands implies the accessibility of the alternative markets to farmers, affecting the farm marketings into government or private markets. Finally, farm marketings into the private market are interfaced with private demand and actual transactions (private purchases) are calculated. Other interrelationships depicted in Figure 2.3 can be traced in a similar way. The reader may review Figure 2.3 as a helpful reference in later discussion.

System Operation Processes

The GMP should be viewed in the "system" context and not as a set of isolated subcomponent models connected in a loosely knit fashion. We will now describe in more detail some of the important processes that are simulated in the system operations model.

Domestic Production

The process of domestic production consists of both human decision (by farmers) and physical processes. Farmers decide, based on past experience and future expectations, the land area to be planted to the various food grains. However, the seasonal nature of food grain production dictates closely when each crop will be planted, its maturation time, and when it will be harvested. Barley and wheat are planted in the fall and harvested in May and June of the following year. Rice is transplanted during June and harvested in the fall. Southern regions of the country are capable of producing one crop of rice plus one crop of barley (or wheat) during a single year. Some regions are very well suited for double cropping; others are not suited at all for this practice, with a continuum of suitability in between. In the critical regions during June, one can observe a sequence of barley harvest, paddy preparation, and rice transplanting operations occurring simultaneously on the same land area. New rice varieties, which allow for a shorter growing season, give more farmers the opportunity to double-crop rice with barley or wheat.

Production Decisions

Land area planted to rice, barley, and wheat by farmers can be calculated internally by the GMP model. The user still maintains the option of specifying these land areas before a model run if he so desires, but the internal capability is there to determine the impact of various grain management programs and policies under study on domestic grain production. Several factors are seen to influence farmers' decisions and are included in this decision process. For example, relative returns between new high-yielding rice varieties

and ordinary rice varieties influence the diffusion process of adopting new varieties by farmers. New varieties have a higher expected yield, but also require higher production costs. With more invested, farmers must assume greater risks in raising the new varieties which are also more susceptible to crop damage in bad years. Undesirable results from raising new varieties, such as large yield reductions from those expected due to poor weather or unfavorable economic value of the new varieties, can cause recidivism effects influencing farmers to change back to more reliable traditional varieties.[2] Shorter growing seasons of new rice varieties make it possible for more farmers to double crop more barley or wheat with rice, as was mentioned before. These factors are included in the production decision calculations and used to project land areas planted to rice (Tongil and ordinary varieties), barley, and wheat.

Yields are not modelled endogenously by the GMP model. Users must furnish expected yields, including expected yields of high-yielding rice varieties. This allows for investigating the various impacts of high or low crop yields through the grain system and the resulting impact on the following years' production decisions.

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[2]Production costs for Tongil varieties exceed traditional variety costs by about 20 percent. In 1974 Tongil yield was estimated to be 34 percent greater than traditional varieties, giving a positive influence on the diffusion process with 40 percent more area going into Tongil production in 1975 [43]. In 1972, however, Tongil yield suffered from bad weather conditions and exceeded ordinary yields by only 20 percent. This caused a negative effect on the diffusion process with Tongil area declining 26 percent in 1973.

Production Process

The GMP is a process-oriented model in which domestic food grain production, as well as other processes occurring in the real world system, are simulated through time. Good reasons exist for needing to replicate the actual physical production processes in the model: the seasonal patterns of crop planting, cultivating, harvesting, and sales of food grains say much about the timing of production costs and revenue flows of farmers. Farmers' behavior patterns are strongly linked with their current financial situation and credit obligations. High interest rates, plus the normal terms of credit arrangements, give farmers much incentive to reduce debt obligation soon after harvest, greatly affecting their food grain marketing patterns, which in turn affect seasonal farm market prices. Farm inventory levels also seem to have a marked effect on marketing patterns and, consequently, on farm market prices during the year. Since one of the main objectives of the GMP is to develop the capability of generating valid market price movements during the year, the need for modelling physical production processes should become evident.

Distributed delay functions, which calculate the solutions to higher order differential equations, are used in the model to simulate the various production processes (i.e., planting, cultivating, and harvesting) during the year. Land areas in the form of impulses (with no time dimension) are entered into the production process delays at precise times during the year, corresponding to the beginning of each production activity. The delays then distribute these areas over the normal period of the activity, simulating the

production processes. Unit cost factors are applied to each operation to give production cost flows. Expected yields (input by the user) are applied to the output of the harvest delays to generate harvest rates and the flow of domestic production into farm storage.

Human Consumption

Both farm and urban (nonfarm) food grain consumption are simulated in the GMP model. Consumption patterns vary with own- and substitute-food grain prices, as well as with income. Equation 2.1 indicates the Cobb-Douglas form used in the model to generate farm and urban consumption behavior for commodity i.

$$Q_i(t) = A_i P_1(t)^{\varepsilon_{i1}(t)} P_2(t)^{\varepsilon_{i2}(t)} P_3(t)^{\varepsilon_{i3}(t)} Y(t)^{\varepsilon_{iY}} POP(t) \qquad (2.1)$$

where Q, A, P, Y, ε, and POP are total consumption, a constant, prices, per capita income, price and income elasticities of demand, and population, respectively, for each subsector. The reader will note that the price elasticities of consumption (ε_{i1},ε_{i2},ε_{i3}) are indicated as functions of time. This is necessary to achieve valid seasonal consumption behavior for farm, as well as urban, populations. More will be said about the technique used to generate these time-varying elasticities in later chapters. An additional consumption behavior characteristic is included in the urban subsector model. This is the phenomenon of suppressed consumption due to critically low household food grain stock levels.

Grain Storage, Movements, and Processing

Grain storage, movements, and processing occur within the GMP model in much the same manner as in reality. Harvest season approaches and domestic grains begin to flow into farm storage facilities in rough form. Farm rough grain stocks are depleted (over time) by outflows for purposes of (a) seed for planting new crops, (b) animal feed, (c) sale to the market, and (d) milling into polished form. Most farmers utilize toll milling services of private millers, paying a toll charge of (currently) four percent of the polished product. The remaining polished grains return to farm storage from where they are either consumed on the farm or sold.

The private market subsector purchases grain from farmers in both rough and polished form. Rough grains remain in production areas until they are milled into polished form. They then move out of production area positions by truck or train to consumption area, terminal point positions from where they are distributed to retail stores for sale.

The government (under current purchasing programs) purchases domestic grains in rough form only. These grains are stored in production area positions and milled shortly before they are moved into consumption area positions. Government polished grains in consumption areas are released (according to government policy) and distributed to private market retail stores registered to handle government-controlled grains.

Grain imports arrive at port facilities in unpolished form. These grains enter port storage positions and then move into consumption area positions, where they are stored and then milled

into polished grain form. Oftentimes, imported grains are blended with domestic grains to standardize the quality of government grains before release.

Urban households also maintain grain storage. Although small in comparison to the other subsectors in the system, this storage function has a very important significance on the performance of the overall grain system. Urban household storage is depleted through consumption. As mentioned previously, urban household stock levels, when critically low, may have a dampening effect on consumption. Figure 2.4 depicts the major grain flows and storage functions mentioned above and represented in the GMP system operations model.

Inventory Management

Figure 2.4 identifies fourteen distinct food grain inventories for rice and barley represented in the grain system operations model. Not shown in the figure are the flows, processing, and storage of industrial wheat which is comprised of about 90 percent imports. Industrial wheat flour milling operations are also represented in the model. Wheat inventories are identified at three additional positions not shown in Figure 2.4, namely, port storage facilities (including silos), flour milling warehouses for wheat, and flour miller warehouses for wheat flour. The wheat flour product processing industry, such as noodle and bakery manufacturers, is modelled only in the aggregate. Wheat grain inventories in this subsector are represented with a delay function reflecting the wheat flour product industry's storage and processing operations. Considering also grain inventories in import pipelines, the GMP model identifies food grain inventories at twenty distinct positions. In this section, we describe

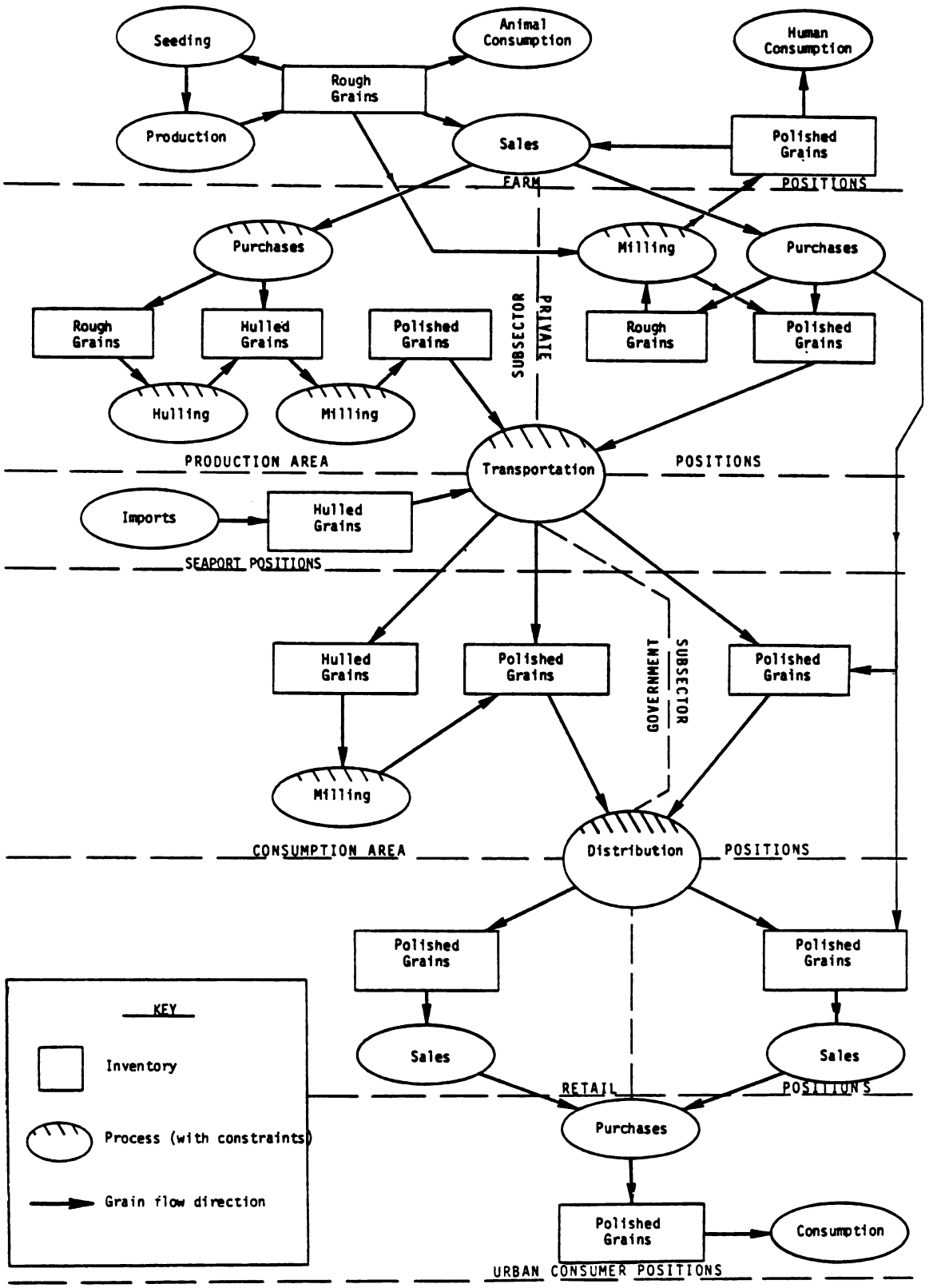


Figure 2.4. GMP Grain Flows and Storage.

some of the modelling techniques used to simulate the processes involved in managing these inventories.

It is not the purpose of this discussion to give full service to all the particulars of the GMP model design. The reader should note that each individual inventory of the GMP model is handled somewhat differently to best replicate what is actually occurring in the real world system. The general discussion given in this section best fits the inventory management processes of the private and government marketing subsectors. Decision processes for farm, urban, and wheat flour industrial sectors are somewhat different but similar enough not to be separately detailed.

Figure 2.5 can be a useful aid in describing the basic concept behind the design of position point inventory management of the private and government subsector models. Note that the figure is general in that not all, nor any particular position point, inventory is depicted. The three inventories, called I, II, and III, represent position point inventories along market channels. A basic assumption of the model is that food grains proceed through the market channels in a non-reversible manner. For example, grains do not flow from consumption area sales store positions back to mills located in production areas. In the figure, this one-way flow of grains is assumed to be in the order of positions I, II, and III, progressively. The management strategy depicted in the figure is for position II. Other position point inventory management strategies would appear similar.

Automatic feedback control techniques are used to represent real world inventory management processes. Managers for inventories at position II in Figure 2.5 are aware of current inventory levels,

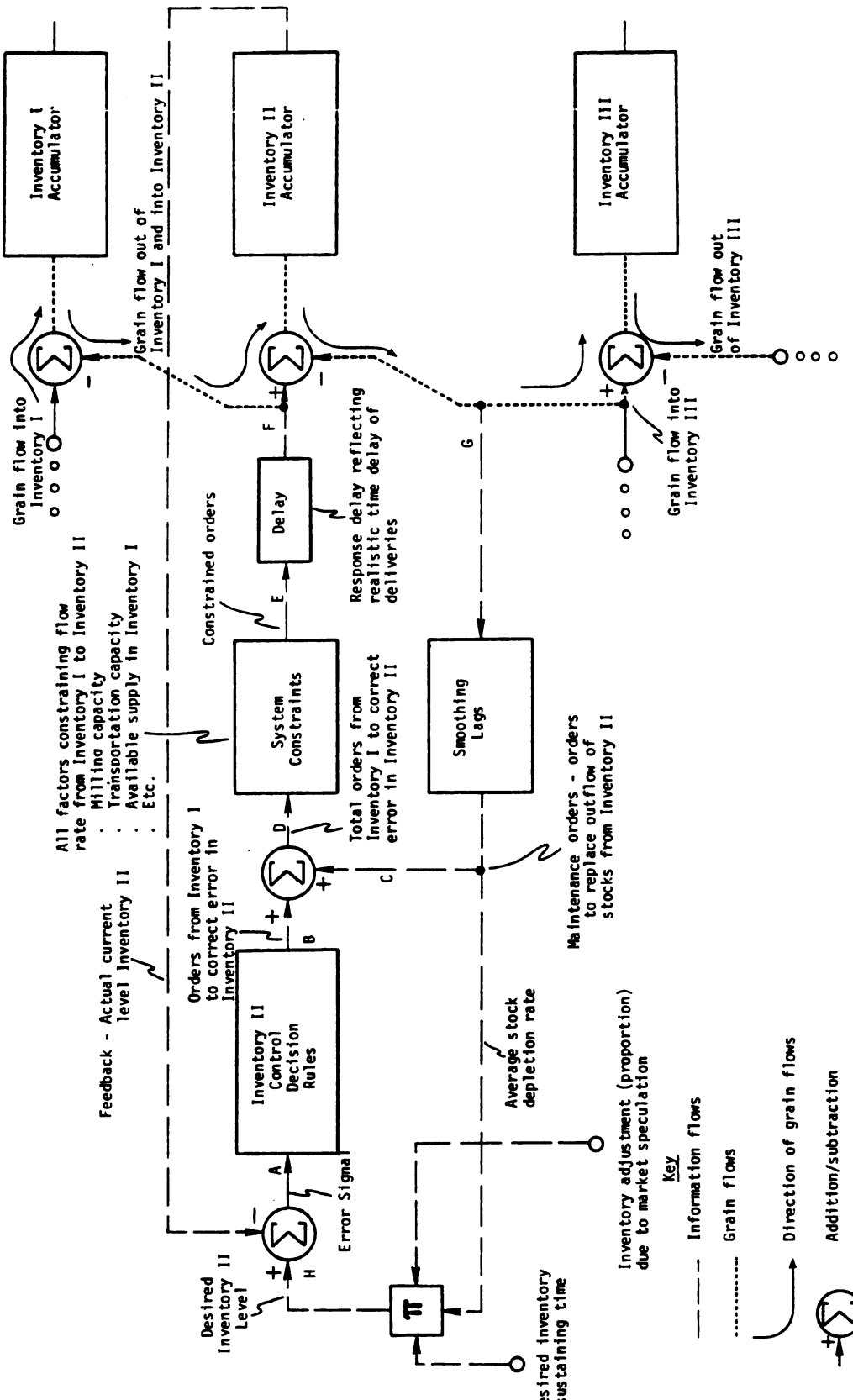


Figure 2.5. Basic Scheme for Inventory Control.

depicted by the feedback information loop. This information on current inventory level is compared with an ideal pattern of inventory level for this position. When a discrepancy is observed between actual and desired inventory levels for this position, corrective action is undertaken. However, many constraints and limitations exist in the real world system which can affect how much and what type of corrective action can be undertaken. A "pull-forward" concept of grain flows seems to best represent real world phenomena. This is to say, inventories at any particular position may be built by placing orders to preceeding position points. However, inventories may not be depleted by shipments to succeeding positions unless orders for shipments exist from those positions. This flow limitation concept is used to propagate urban consumer demand back through private marketing channels to the farm market.

Other constraints also exist. The rate at which orders can be filled for inventory position II depends on the system capacity to move stocks between positions I and II. This may involve milling capacity if position I inventory is in rough form and position II inventory is in polished form. It may also involve transportation capacity if position I is located in production areas and position II is located in consumption areas. Then, of course, stocks must be present at position I before orders can be filled for increasing position II inventories. Time delays are also involved in placing orders, grain handling, milling, transportation, and deliveries of grains to position II.

Market Supply and Demand

We have described in general terms the movements and handling of grains within the GMP model. This degree of modelling effort and design is necessary to represent accurately the physical system constraints of grain movements between farm and urban consumer markets. We will now describe some of the important model functions that determine the supply and demand for grains that meet in the farm and urban marketplaces and are the primary factors in determining market prices.

Farm Supply

The supply of domestically produced grains on the market plays a vital role in market price behavior. Farmers' behavior in marketing their available supplies of food grains depends greatly on their credit situation, available stocks, and also on market prices which they can receive for their products [34]. Government purchase prices and the timing of purchase programs also affect farm marketing behavior. These factors and others are combined in a set of farm marketing equations used in the GMP model. Farm marketing response has proven difficult to model (although acceptable results are being generated). Therefore, at this point it may be proper to mention an important aspect of the GMP model which lends it real strength: that is, the modularity of the model. Nothing in the model prevents the swapping in and out of various functions used to calculate behavioral characteristics, such as production responses, consumption, or marketing behavior. The model is used with the best set of functions available at the time, with continual off-line work researching "better" or more up-to-date functions to use. As "better" functions

become available, they can be inserted into the model and tested. If they test out, they can remain in the model until replaced, with little other effort involved. Therefore, in describing, say, the farm marketing behavioral response of the GMP model, it is preferred that we not discuss any particular function used in the model, for no function can be considered permanent--and no particular behavioral function should be constructed as representing the GMP model, for the model itself provides the structure and dynamic framework for testing behavioral functions which may be developed at a later date.

Urban Demand

Urban household demand in the marketplace is not taken directly from the human consumption function described in an earlier section. The GMP model also simulates the storage function of urban households so that effective urban demand in the marketplace represents urban household decisions to manage their home inventory stock levels. General price levels, price changes, and anticipated price levels all play a part in the urban household inventory management strategy.

Government Demand and Supply

Government demand and supply for food grains are policy variables representing specific grain management programs and objectives. The GMP model gives model users many opportunities to explore the use of these powerful instruments in dealing with several grain management problems. Much more will be said regarding government demand and supply of food grains in a later section of this chapter dealing with the policy orientation of the GMP model.

Private Market Demand and Supply

The private market, acting as a major channel between farm and urban marketplaces, plays a vital role in the overall grain system. Market supply and demand functions generated in this subsector are the critical link between markets and play a critical role in influencing market prices. Unlike the government subsector, whose demand and supply functions are based on grain management program objectives, the private market subsector, as with any free enterprise, is motivated to act through the quest for profit.

The GMP model recognizes two possibilities for generating profits from private market activities. The *first* is by moving grains through the system and realizing a net profit margin between buying and selling price. Assuming that unit costs do not increase with volume, the more grain that can be moved through the system, the higher will be the total profits. The *second* potential means of generating profits available to the private marketing subsector is by purchasing grains on the farm market, holding them over time, and realizing a profit from increases in urban market prices. This second means of realizing profits, naturally has inherent speculative risks with it because of accumulating storage and interest costs over time and the uncertainty of urban market prices in the future.

The GMP model has a speculative behavior mechanism which forecasts future urban prices and demand available to the private marketing subsector. These forecasts are initialized at the beginning of each model run with empirical price and demand data from the past several years. As the simulation run progresses through time, model-generated data (prices and demands) are merged with initial past data, with

the most recent data being weighted heaviest. Seasonal patterns in data are recognized by the forecasting mechanism, with repeating or persistent seasonal patterns acting to reinforce confidence. The speculative response mechanism continually monitors current prices and forecasts and generates desired private market inventory levels through time, which (it thinks) can be held for a profit. Private market demand and supply functions of the GMP model reflect this speculative storage behavioral phenomenon.

Both marketing margin (flow) and market speculation (storage) incentives for generating profits are factors in the demand and supply functions of the private market. The flow component of demand and supply responds to changing margins between farm and urban market prices. As margins increase, the incentive to deal in more grains also increases; both the private market supply and demand increase. The effect of this is to increase farm prices (increased demand) and decrease urban prices (increased supply); thus, reducing the marketing margin. As margins decrease, the incentive to deal in grains also decreases; both private market supply and demand decrease. The effect of this is to decrease farm prices (decreased demand) and increase urban prices (decreased supply); thus, increasing the marketing margin. The net effect of the flow incentive factor is the influence it has upon maintaining normal farm and urban market price margins. The storage component of private market demand and supply does not appreciably affect marketing margins but, rather, has an amplifying effect on the market price changes. As urban price rises exceed the cost of holding grains, the storage incentive component acts to increase private market inventories. Increased demand and decreased supply

act to amplify already rising urban prices (and increase farm prices as well). When storage is no longer foreseen as a feasible profit-making activity (e.g., when urban prices are falling), the storage incentive component acts to decrease excess private market inventories. Decreased demand and increased supply again have an amplifying effect on already decreasing urban prices (and act to decrease farm prices as well).

The relative influences of flow and storage incentives on total private market demand and supply, of course, are not known. The model-tuning process, however, made it possible to test various weighting factors for the two components. It is interesting to note that the model-tuning process for rice indicated that, in the farm market, best results were gained by weighting the marketing margin (flow) responses much more heavily than the storage behavioral responses. However, in the urban market, best results were gained by attaching approximate equal weights of importance to the flow and storage responses. The logic of this phenomenon is reasonable: merchants located in production areas, dealing in farm markets, are risking much more in holding grains on the basis of anticipated urban market price rises than merchants located in urban areas dealing directly with urban markets. This is due to the longer delay time required to market grains stored in production areas, should the urban market suddenly begin to decline, as compared to those held, say, by commissioners or retail sales store merchants.

Market Prices

Farm and urban market prices are generated in the GMP model by bringing market supplies and demands for grains together mathematically.

Basically, the price generation function describes the dynamic changes in market prices in response to disequilibriums of supply and demand over time. On the farm market, private market demand and government demand are combined and compared with the available farm supply. An excess market demand causes prices to rise, while an excess market supply causes prices to decline. On the urban market side, private market supply and government supply (releases) are combined and compared with urban demand. Again, an excess market demand causes prices to rise, while an excess market supply causes prices to fall.

The model recognizes the possibility that supply and demand from government and private subsectors may have different degrees of influence on market prices; that is, private demand may have a greater effect on farm prices than an equal amount of government demand, or vice versa. A similar assumption is made for urban market supplies from the two subsectors. One of the tasks in the model-tuning process was to assign values to the relative importance of these two sources of market supply and demand.

Policy Orientation of the Model

In an earlier section of this chapter, we listed several grain management program and policy issues for which the GMP model can be used to analyze and, hopefully, provide guidance and insight to researchers and decision makers concerned with real world grain management problems. The GMP model (and, for that matter, any simulation model) does not automatically become a useful analytical tool merely by being validated with respect to the real world system it is representing. Much thought and model design must be devoted to surface the important policy instruments and system variables under control

of the eventual model user, making them apparent and readily accessible. Strict attention is necessary to assure that these policy instruments are *connected* in a realistic manner to the overall system.

The GMP model is designed for use by the government sector and is thus oriented toward addressing issues of interest to that sector. The same model conceivably could be oriented toward the interest of other decision makers in the system, such as farm cooperatives, the Private Millers Association, wholesale commissioners, or the Korean Flour Millers Industrial Association (KOFMIA). As such, the model would have a different policy (or use) orientation, with design emphasis on instruments in control of these model users.

It is difficult to clearly classify all types of grain management program and policy issues of interest, or potential interest, to the Korean government. About the best that can be done is to isolate some of the important ones into three categories. *First* are problems in grain management policy and program development for planning and investigative purposes. Analyses in this category may be aimed at investigating the consequences (good and bad) of continuing current policies or changing policies to better meet current conditions. Basically, the model users are interested in asking "what if" types of questions of the model. These questions can be for periods in the past, as well as for periods into the future. For example, "what if" government policy on a particular issue, say, barley purchase price, had been different during the past crop season? What impacts would such a difference have on changing the behavior and performance of the grain system through time and up to its current state? Or "what if" barley purchase price policy were changed now? What would

be the consequences of such an action compared with continuing past policy for, say, two years into the future?

A *second* category of problems which are of interest to government officials is problems in current policy administration. Here model users are interested in asking "how" types of questions. For example, planning studies may indicate a desirable seasonable price pattern for the upcoming year...or the President may set by decree limits on domestic grain prices. "How" should government release programs be administered to best meet these objectives? How much government grain will be needed. What about the timing and amounts of government grain release? What pricing should the government set on these release grains, and what about replenishing government grain stocks?

The *third* category of problems of potential interest can be referred to as crisis situations. Perhaps the world grain situation suddenly changes, world grain prices soar, and/or fuel prices jump. Or a recent drastic change in domestic grain policy is observed to have unanticipated bad effects. Model users who are contending with these situations may be asking "now what" types of questions. For example, world wheat prices begin to soar and the government (as in 1974) raises wheat flour price by some 60 percent. Wheat demand drops; but, subsequently, rice demand increases and domestic rice prices begin to rise, seemingly in an uncontrollable fashion. Now what should the government do? Should they pour huge amounts of government rice or mixed grains on the market to attempt to bring price into control? What combination of release prices should they seek? Should they lower flour prices and pay increased subsidies to flour millers? Should they increase barley releases, lower or

increase barley prices, or should they undertake a combination of the above actions in dealing with the crisis?

A general description is in order of the design orientation of the GMP with respect to some specific policy and program issues of the first two categories mentioned above; namely, problems of grain policy planning (and development) and problems of administering existing grain management operations.

Annual Food Plans

The utility of the GMP model as a grain management tool is greatly enhanced by including the capability of formulating alternative annual food (grain) plans and measuring the consequences of these plans in conjunction with seasonal grain management policies and programs. Basically, a food (grain) plan consists of estimates of food grain requirements and supplies for the upcoming year. Food grain requirements are estimated as the total of expected farm and nonfarm household food requirements; government use requirements for military, government institutions, prisons and relief; livestock feed requirements; seed requirements for the next planting season; and requirements for food processing and industrial use. Expected waste and losses are also included in the total requirement estimate. Food grain supplies are estimated as the total of expected production for the upcoming crop year, plus carry-in, *plus* programmed imports which are given values to equate supplies with expected requirements.

A number of ways can be taken in arriving at estimates of household food grain requirements, depending on the issues at hand. For example, relative world market prices may be such that grain management officials responsible for developing a particular food

(grain) plan may desire to change the diet mix of food grains (rice, barley, and wheat) to economize on foreign exchange expenditures for food grain imports. Self-sufficiency goals for certain food grain commodities may be important issues concerning officials formulating a food plan. In deciding on a zero import requirement for these commodities, officials developing the food plan must be reasonably confident that domestic supplies are adequate to support normal consumption levels over the period of self-sufficiency and/or supplies of substitute grains are planned adequately to preclude drastic price increases in the "self-sufficient" commodities. Socially tolerable limits of consumption pattern shifts to less preferred food grains must also be considered from a political standpoint. Basic food grain price structure may also be of primary concern, since food grains play a dominant role in the consumer price index. In short, formulating a typical food plan requires keen concern over economic, social, and political implications.

Generalized Demand-Price Analyzer

Government officials engaged in formulating a basic annual food (grain) plan are concerned with both quantities and prices of food grains for the upcoming planning period. The generalized demand-price analyzer enables the model user to specify a mix of prices and/or demands for food grains for a particular food plan. The model then uses linear algebraic techniques to solve for the unspecified prices and/or demands, with the result being a full set of annual average food grain prices and demands which are consistent with the Korean food grain demand system specified in the model.

If a specific food (grain) plan requires that domestic supplies be supplemented by imports, the government must import the required amount of grains during the upcoming year and assure that they are available (and in the right amounts) when needed. Such a plan will also require basic (annual) food grain price levels and relationships during the upcoming year to realize the planned consumption levels of rural and urban populations. The government will have to monitor prices throughout the year and administer its domestic grain operations to assure that these annual price levels are met. The GMP model can provide guidelines into these (and other) types of operating and management problems.

Foreign Grain Importation

The annual food plan mechanism described above can be used to approximate the level of foreign grain imports necessary to keep annual price levels in line with price policy objectives. Scheduling of foreign grain imports, however, is an important decision process which can be very costly if not managed properly. Foreign grains which arrive in-country during times of high inventory levels require prolonged storage times or increase the storage time requirements of existing government stocks. For reasons of national security and to assure adequate buffer stocks for seasonal price stabilization, it is also necessary for the government to maintain reserve grain stock levels at some minimum level.

The GMP model can be used to determine import scheduling required to assure that government reserve stock levels do not dwindle below minimum acceptable levels and annual import requirements are attained, regardless of government release (and domestic purchasing)

programs designed for seasonal price control. The mechanism used in the model utilizes automatic feedback control techniques in much the same manner that they are used for controlling domestic position point inventories. Government stock levels are monitored by the model and compared to minimum reserve stock level requirements. When stock levels are observed to be approaching minimum acceptable levels, new import orders are initiated. The intensity and timing of these orders are attuned with current government domestic purchase and release activities, and compensate for lag times between import orders and deliveries.

Grain Price Policies

Establishment of annual food plans and appropriate importation of deficit food grain commodities by government will not assure domestic seasonal price stability. Domestic food grain prices may vary widely during the year, depending on available market supplies. These variations, if too large, can have adverse effects on both farm and urban populations, especially the lower income groups. To assure seasonal price stability in domestic food grain prices, it may become necessary for the government to monitor current market conditions and play an active role in domestic grain dealings (buying and selling).

Seasonal price policy objectives may vary from striving to keep domestic prices within tolerable bounds to targeting prices to follow precise seasonal patterns. Choosing a desirable seasonal price policy (or a *set* of seasonal price policies for the different food grains) is important in influencing the overall grain system to operate in a desirable manner [35, 37, 46, 47]. Various seasonal price patterns can influence farm consumption behavior, farm storage and marketing

behavior, farm income from grains and the amount of domestic grains made available for urban consumption. Price patterns also affect the storage and marketing behavior of the private marketing subsector (complementary to government marketing activities). Given proper price incentives, the private subsector can be motivated to function as an effective grain storage and distribution system for moving and processing large amounts of domestic grains over time from farmers to urban consumers.

The GMP model can be used to investigate impacts of various seasonal grain price policies on the performance of the overall grain system. Just how the GMP model can be used to guide the actions of the government to assure that domestic food grain prices behave in a prescribed manner will be discussed briefly below.

Seasonal Price Control

Given seasonal price objectives, government officials must closely monitor market prices and order appropriate government market activities when prices begin to stray from the desired patterns. Information on current market prices is often delayed in getting to decision makers. This information may have inherent measurement errors, due to imperfect market surveys, human errors in compiling vast amounts of data, etc. Faced with this information, government officials must act in ordering the next day's grain releases or scheduling grain releases over, say, the next week. Normally the analytical tools available to these government officials are few, if they exist at all. Mostly, these decisions are made based on hand calculation, past experience, and human intuition. Some officials may become quite skilled at ordering government grain releases in the

appropriate amounts and in a timely manner to control urban food grain prices. Others may miss early warning signals of impending trouble and delay releases or not release appropriate amounts to head off market price rises. Suddenly, prices may be soaring out of control, requiring huge amounts of government releases to bring them down again.

The seasonal price control mechanism developed for the GMP model simulates the decision processes involved in attempting to control market prices to prespecified targets. Automatic feedback control techniques are used to monitor current market prices, to compare these prices with desired price patterns, and to generate corrective government grain activities (buying and/or selling) to influence market prices to follow desired seasonal patterns. More detail on seasonal price control is discussed in Chapter 5, which describes the government subsector model in mathematical detail.

Government Purchase Programs

In carrying on government price stabilization (and control) programs, it is necessary for the government to play an active role in the domestic grain markets. We have described the important aspects of the seasonal price control mechanism of the GMP for controlling urban food grain prices through government grain releases. The government also has an influence on farm market price behavior through its grain release programs, because urban and farm market prices are *connected* in the real world system as well as in the GMP model. However, no attempt is made in the model (or in the real world) to influence farm prices in any predetermined manner through government releases. A more direct linkage with farm market prices

is gained through government purchase programs. Korea does not have an active program for controlling farm prices, as the government purchasing programs always occur during and immediately following the harvest season.[3] The primary objective of these programs is to replenish government grain stocks from domestic supplies. One of the resulting consequences of the increased demand after harvest due to these purchasing programs is to dampen farm price declines that normally occur after harvest. This is considered a "good" result of purchase programs, but not a primary motive for the programs. The GMP price controller is designed to prescribe both government purchase and release patterns necessary for controlling either or both farm and urban prices to prespecified seasonal targets. Variations to current purchasing programs can also be investigated by the model, without strict farm price control as the primary objective. Programs of extended buying periods, and/or increasing government buying price throughout the buying period to motivate farmers to store their grains longer before marketing, can be investigated [46].

Government Grain Management Procedures

Another group of policy issues for which the GMP model is design oriented are questions of management procedures used on government-controlled grains. The government traditionally purchases paddy rice from farmers since the paddy form increases storability. However, storage space requirements of paddy rice, being approximately twice that of brown rice (hulled rice), oftentimes put a critical

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[3]As mentioned earlier, programs for controlling farm market prices through government purchases during the year can be investigated by the GMP model.

strain on existing storage facilities. Overflows are often piled out-of-doors, or placed in very inadequate storage facilities and are subject to high losses. Solutions to such problems are usually prescribed as construction of additional government warehouse capacity. Alternatives to the construction solution exist, and the design of the GMP model is oriented to allow for the study of several of these alternatives. For example, to take the pressure off of government storage facilities, a portion of government domestic rice purchases could be taken in brown (hulled) form. These grains would require one-half the storage space of paddy form, and could be milled and moved onto the market before government grains stored in rough form, to reduce storage requirements. Another management alternative for government grains may be to hull government rice in production areas in amounts necessary to eliminate inventory overflows and then to re-store it in brown rice form. When needed in consumption areas, it could be milled in production areas or moved into consumption areas in brown rice form and milled there in government-licensed mills normally operating only on imported grains. Additional handling costs are, of course, inherent in such alternatives to grain management procedures. The feasibility of such activities versus construction of additional warehouse facilities, or simply letting overflows occur during peak periods, would require very detailed investigation. The GMP model is designed to aid in such studies.

Government Warehouse Programs

This aspect of the GMP model has less significance when the model is used for short-term policy issues, say, one to two years. However, when using the GMP model for addressing longer term policy

issues or running the model in conjunction with the Korean Agricultural Simulation Model (KASM), government warehousing programs may have major implications in grain management policy formulation. Specific warehousing construction programs may themselves be the central issue in a particular grain management program study. In such instances, this component of the GMP model stands able to provide important information to researchers and decision makers.

Government-owned or -leased warehousing facilities are classified into five major categories: (1) low temperature, (2) class A, (3) class B, (4) class C, and (5) auxiliary storage. These categories are based on construction design and suitability for grain storage, with the low-temperature facilities being most elaborate and class C and auxiliary being least elaborate, usually deteriorated in condition and least suitable for grain storage. Each of these warehouse classifications has inherent different unit construction costs (or storage charges, if not owned by the government) and storage loss characteristics over the four seasons of the year. Government warehouse construction programs can build additional warehouse facilities in the first three categories (low temperature, class A, and class B), but not in the latter two (class C and auxiliary). As the process goes, class A and class B facilities can depreciate to lower categories as time evolves.

The government warehousing component allows for government construction programs in each of the first three categories and a choice of construction location in seaports, production areas, or consumption areas. The model then monitors the amount, distribution, and location of government warehousing facilities through time, based

on new construction programs (if they exist), the normal declassification process of A and B facilities, and the salvage and disappearance of class C and auxiliary facilities.

The government warehousing component is also linked with the government grain operations model. That is, the position point storage capacities and loss rates applied to government grain inventories of the government operations model are consistent with the government warehousing component.

System Performance

The third and final category of the GMP model design is system performance. Model design under this category is perhaps not as difficult as modelling the operational grain system and orienting the model to address real world problems, but it is certainly just as important. Without meaningful measurements of system performance, model users have no means for judging among alternative grain management policies or analyzing the results of model runs. Careful attention must be given to the design of system performance measurements to assure that they are consistent with model user needs. These needs are best defined by potential model users themselves (i.e., policy analysts and decision makers); therefore, much interaction is required between these people and model designers.

Several types of system performance measurements can be generated by the GMP model. Information can be presented in a form and in the units requested by model users.

Forms of Model Output

Regardless of what information is made available from a simulation run, it is always helpful to have an option of viewing the information in several forms. Specially designed summary tables are one option for viewing results of GMP model runs. Although the model simulates the operations (and measures performance) of the grain system through time, model users are often concerned about summary information describing system performance over a period of time. Users of the GMP model have the option of defining the periods for which summary tables are generated. In analyzing model results, however, oftentimes it is helpful (and necessary) to know the time paths actually travelled by particular system variables. The GMP model gives the user the opportunity of viewing any set of model variables (including performance criteria) in time series form. These series can be generated in tabular and/or plot form, depending on the request of the user. The user can also specify which variables appear together on the time series plots and/or tables.

Operations Performance

Table 2.4 summarizes some of the important system operation performance measurements available to model users. Time series of these variables have a one-to-one correspondence with variables generated in the grain system operations model, although the user has an option of specifying the interval at which the time series are output. Summary tables present information about the performance of model time series variables in a number of ways. For example, average values for some variables, such as prices, inventories, and consumption rates, are calculated and presented in summary tables.

Table 2.4. Grain System Performance--Operations.

Variable	Unit	Farm		Urban		Private		Government		Total Systems	
		Time Series	Summary Tables	Time Series	Summary Tables	Time Series	Summary Tables	Time Series	Summary Tables	Time Series	Summary Tables
Production	MT/yr	X									
	MT		X								
Imports	MT/yr					X		X		X	
	MT						X		X		X
Sales	MT/yr	X				X		X			
	MT		X				X		X		
Purchases	MT/yr			X		X		X			
	MT				X		X		X		
Consumption	kg/cap/yr	X	X	X	X						
	MT/yr	X	X	X	X						
	MT		X		X						
Inventories	MT	X	X	X	X	X	X	X	X	X	X
By Form	MT	X				X		X			
By Position	MT	X	X	X	X	X	X	X	X	X	X
Carry-overs	MT		x		x		X		X		X
Stock changes	MT		X		X		X		X		X
Processing	MT/yr					X		X			
	MT						X		X		
Population	people	X	X	X	X						
Prices	won/bag	X	X	X	X						

Maximum and minimum values attained by time series variables are also presented where such information is deemed necessary. Even the calendar dates when maximums and minimums occur are printed in various summary tables which are available to model users. Many other system performance variables not indicated in the table are also available.

Accounting

The GMP model provides detailed cash flow analyses for all subsectors. Such information is a very important performance criterion in analyzing various grain management problems. Table 2.5 summarizes some of the important accounting data provided by the GMP model. The mathematical details of model fiscal accounting will be provided in subsequent chapters.

Special Criteria

Depending on the issues at hand, special performance criteria can be measured and presented to model users to assist them in determining the consequences of particular grain management programs and policies. For example, use of the model in determining the effects of critical food grain shortages (brought about by a hypothetical world crop failure, warfare, or any other reason) and developing plans for dealing with such a crisis situation may raise questions regarding nutrition levels, nutritional deficits, and even death rates from starvation. Other uses of the model, say, to determine the effects of radical changes in grain management policy, may ask for measurement of such things as "discontent." Changes from normal diet levels or diet mixes of food grains are possible measurements which can be made to generate these types of performance indices. Model users working

Table 2.5. Grain System Performance--Accounting.

Variable	Unit	Farm		Urban		Private		Government	
		Cash Flow	Summary Tables	Cash Flow	Summary Tables	Cash Flow	Summary Tables	Cash Flow	Summary Tables
REVENUES									
Grain Sales	won/yr	X				X		X	
	won		X				X		X
--Product Sales	won/yr					X		X	
	won						X		X
--By-Product Sales	won/yr					X		X	
	won						X		X
Value of Grain Consumption	won		X						
EXPENDITURES									
Domestic Production Cost	won/yr	X							
	won		X						
Grain Purchases	won/yr			X		X		X	
	won				X		X		X
	won/HH				X				
Grain Operations	won/yr					X		X	
	won						X		X
--Processing	won/yr	X				X		X	
	won		X				X		X
--Handling	won/yr					X		X	
	won						X		X
--Storage	won/yr					X		X	
	won						X		X
--Credit	won/yr	X				X		X	
	won		X				X		X
Foreign Exchange (Imports)	won/yr							X	
	won								X
Payments to Principle and Interest (Imports)	won/yr					X		X	
	won						X		X
Subsidy Payments	won/yr							X	
	won								X
Warehouse Construction	won/yr							X	
	won								X
Administration	won/yr							X	
	won								X
CASH FLOW ANALYSIS									
Gross Returns	won/yr	X				X		X	
	won		X				X		X
Value of Stock Level Changes	won		X				X		X
Net Returns	won/yr	X				X		X	
	won		X				X		X
	won/HH		X						

with technicians can develop any number of special criteria to be used in analyzing model results. The GMP model has the capability of producing several special performance criteria of the type mentioned above.

Model Performance

To this point, we have described some of the important information furnished by the GMP model regarding the performance of the *simulated* system. The model also monitors its own performance. When using the model to investigate various seasonal price stabilization or control strategies, the user is furnished with summary information on how well these strategies actually work to influence (simulated) market prices to move along targeted seasonal patterns. Many comparisons between targeted and resulting price patterns are made. Some of these comaprisons are shown in Table 2.6 below.

Table 2.6. Price Control Performance Measurements.

Price Measurement	Unit	Target	Results
Average	won/bag	--	--
High	"	--	--
Low	"	--	--
High/low ratio	no units	--	--
Maximum rise	percentage/yr	--	--
Maximum fall	"	--	--
Average trend	"	--	--
Coefficient of variation	no units	--	--

GMP Data Bank

The model also maintains a data bank of important grain statistics from past years. This bank is used for two major purposes: (1) model testing and tuning, and (2) automatic model initialization. If the GMP model is to gain and maintain credibility as a viable grain management analytical tool, it must be under continual scrutiny and testing to improve its performance and keep it attuned to the changing real world [40, 47]. The GMP data bank provides model designers and users with automatic access to important grain statistics needed to determine how accurately the model can reproduce past data. Users can compare time series data from tables or plots on which empirical data are overlayed on model-generated data of the same variable. The model also can provide statistical information on fits between model-generated and statistical data, such as sum of least squares, coefficients of determination (R^2), and B-coefficients (which regress model results on empirical data).

The data bank also serves for automatic model initialization at any time point in the past for which data are present. The GMP data bank currently contains monthly and annual statistical data from 1966 through the later part of 1976. Table 2.7 indicates some of the specific time series present in the GMP data bank. Maintenance of this bank with current and accurate information is crucial if the model is to serve its role as a grain management tool, "ready" to provide timely and valid analyses of current grain management problems.

Table 2.7. GMP Data Bank.

Series Description	Unit	Period of Data (Year.Month)		Data Points
		Start	End	
Monthly Prices Received by Farmers (Polished Equivalent)				
Rice	won/80 kg	66.1	76.8	128
Barley	won/76.5 kg	66.1	76.8	128
Wheat	won/76 kg	66.1	76.8	128
Monthly Consumer Prices (Seoul)				
Rice	won/80 kg	66.1	76.9	129
Barley	won/76.5 kg	66.1	76.9	129
Wheat flour	won/22 kg	66.1	76.9	129
Government Purchase Prices				
Rice	won/80 kg	1965	1976	12
Barley	won/76.5 kg	1965	1976	12
Government Release Prices by Month				
Rice	won/80 kg	66.1	76.9	129
Barley	won/76.5 kg	66.1	76.9	129
Monthly Price Indices				
Consumer Price Index (excluding cereals)	(1970=1)	66.1	76.9	129
Wholesale Price Index (Excluding Grains)	(1970=1)	66.1	76.9	129
Monthly Consumption				
Rice (Farm)	kg/cap/yr	66.1	76.8	128
(Urban)	"	66.1	76.8	128
Barley (Farm)	"	66.1	76.8	128
(Urban)	"	66.1	76.8	128
Wheat (National)	"	66.1	76.7	127
Monthly Inventories				
Rice (Farm)	MT	66.1	76.8	128
(Government)	"	66.1	76.10	130
(Urban)	"	66.1	76.8	128
Barley (Farm)	"	66.1	76.8	128
(Government)	"	66.1	76.10	130
(Urban)	"	66.1	76.8	128
Wheat (National)	"	66.1	76.7	127
Monthly Farm Sales				
Rice	MT/mo.	66.1	75.9	117
Barley	MT/mo.	66.1	75.5	113
Monthly Government Purchases				
Rice	MT/mo.	66.1	76.10	130
Barley	MT/mo.	66.1	76.12	132
Monthly Import Arrivals				
Rice	MT/mo.	66.1	76.9	129
Barley	MT/mo.	66.1	76.9	129
Wheat	MT/mo.	66.1	76.9	129
TOTAL				3,855

Preparation for the Mathematical Description of the Model

The purpose of this chapter has been to describe the basic concept of the GMP model, indicating some of the procedures used in its design and suggesting some of the wide range of potential uses that can be made of the model. To accomplish this overall perspective of the model, it has been necessary (for the most part) to discuss the model in very general terms. With the background information on the grain management problem in Korea given in Chapter 1, and the general description of the GMP model (designed to address many of these problem issues) given in this chapter, the stage is now set for a description of the model in more specific terms.

The following five chapters comprise the main body of this dissertation, describing the current version of the GMP model in specific mathematical terms. A chapter is devoted to the description of each of the four major subsector components of the model and to the model component linkage mechanism (PAT), as depicted in Figure 2.2. Although mathematical in nature, these chapters also carefully document how the real world system operates. The procedure followed is to point out important real world system attributes, behavioral characteristics, and interrelationships in narrative language and present the mathematical relationships used in the model to replicate these important features of the real world system. This represents the systems approach to model design which is documented in full detail in much of the literature [9, 14, 30, 31, 41, 42]. The nontechnical reader can gain much insight into the GMP model design by focussing on the narrative descriptions in the following five chapters and skimming across the mathematical portions which do not raise his interest.

CHAPTER 3

FARM SUBSECTOR MODEL

Introduction

Although small on an individual basis, the Korean farmer holds many of the cards which determine the success (or failure) of many grain management policies and programs. The farm subsector model of the GMP simulates a number of behavioral responses and farm (grain) management decision processes made by the Korean farmer, the impacts of which propagate throughout the entire grain system. The model includes seasonal farm grain storage requirements for food and nonfood uses, food grain production operations, farmer-owned grain inventories (including the management of these inventories), farm household food grain consumption, and farm marketing of domestic food grains. An optional production response mechanism is also included in the farm subsector model, which internalizes rice and barley planting decisions made by farmers in response to economic factors. The model also contains a number of financial accounting equations which are used to generate farm economy summary tables which are (in part) useful performance criteria to measure the impacts of various grain management policies and programs on the Korean farm subsector. This chapter will describe the farm subsector model of the GMP in mathematical detail.

Farm Grain Set-Aside Requirements

Seasonal farm grain requirements are important to the calculation of farm food grain supplies which are available for sale and, thus, farm

marketings of domestic food grains throughout the year. Because of the seasonality of food grain production, farmers must hold adequate stocks of food grains during the year for farm use to last to the next harvest season. These farm-use food grain reserve stock requirements are maximum after harvest and decrease throughout the crop year as the harvest of a new crop approaches. The farm subsector model disaggregates these seasonal farm grain requirements by intended use, since the calculation of each seasonal profile must be done in a slightly different manner to reflect the real situation.

Rough Grain Requirements

Seasonal rough grain requirements for farm use include grain stocks intended for (1) human consumption (later in the year), (2) farm animal feed during the year, and (3) seed requirements for the next planting season. Figure 3.1 is a system diagram depicting the calculation of farm subsector grain inventory requirements during the year. The figure is annotated to indicate the "shape" of several of the signals used for these calculations. It should be a useful reference to the reader in following the mathematical description of the model processes which generate these requirement profiles.

Human Consumption Requirements

In general, Korean farmers set aside an adequate amount of food grains after harvest to take care of family food grain requirements until the next harvest. Since quality is preserved much better when grains are stored in rough form, the bulk of these grains set aside after harvest is unprocessed. During the year, farmers pull from these rough grain stocks, keeping only a few weeks' supply of polished

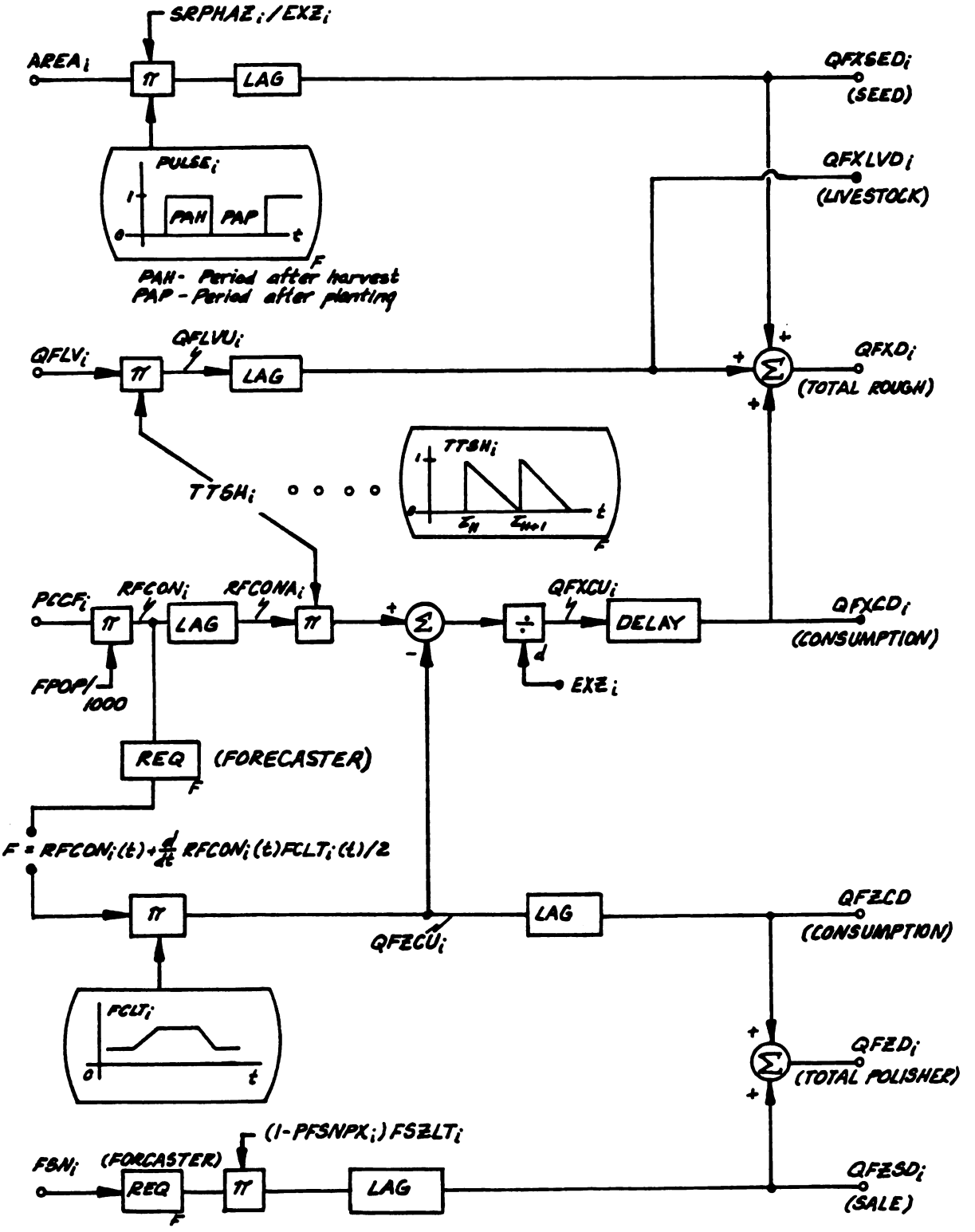


Figure 3.1. Farm Inventory Set-Aside Requirements.

grain on hand for family consumption. Rough grain stock levels needed to sustain farm household consumption until the next harvest season are calculated by the following differential equation.

$$a_k \frac{d^k}{dt^k} QFXCD_i(t) + a_{k-1} \frac{d^{k-1}}{dt^{k-1}} QFXCD_i(t) + \ldots + a_o \, QFXCD_i(t) = [RFCONA_i(t)*TTSH_i(t)-QFZCU_i(t)]EXZ_i \quad (3.1)$$

where:

a_j = coefficients of distributed delay function,

$$a_j = \binom{k}{j}\left(\frac{DELF2}{k}\right)^j \quad , j = 0, \ldots, k$$

DELF2 = delay parameter--yrs

k = order of delay equation

QFXCD = seasonal desired set-aside level of rough grain stocks for farm family consumption--MT

RFCONA = expected annual average farm consumption (see Equation 3.2 below)--MT/yr

TTSH = time remaining before start of next harvest season ($0 \leq TTSH \leq 1$)--yr

QFZCU = quantity of polished grain required on hand to sustain current farm consumption for upcoming (short-run) period of time--MT

EXZ = rough to polished form conversion factor--proportion.

The expected annual average farm consumption $RFCONA_i(t)$ in Equation 3.1 is calculated by the following exponential equation.

$$\frac{d}{dt} RFCONA_i(t) + RFCONA_i(t) = RFCON_i(t) \quad (3.2)$$

$$RFCON_i(t) = PCCF_i(t)*FPOP(t)/1000 \quad (3.3)$$

where:

PCCF = current per capita consumption rate of farm population--kg/capita-yr

FPOP = current farm population--people.[1]

The function $TTSH_i(t)$, time remaining until the beginning of the next harvest season, is a sawtooth function of time. Its value is one (year) at the start of harvest and then decreases linearly to zero over the next year.

The reader should note that the distributed delay feature of Equation 3.1 above produces a more realistic seasonal desired set-aside level of rough grain stocks for farm family consumption over the next year. The rationale for this is as follows: harvest season lasts for a period of roughly one month--starting slowly, rising to a peak, and then tapering off during this time. There is little reason for farmers to set aside the entire next year's food grain requirements at the very beginning of the harvest season. The need for cash to pay off production debts, accumulating interest on farm loans, and other reasons make it reasonable to assume that most of the initial harvest is considered (by the farmer) available for sale outside the farm subsector. Tuning of this delay process on set-aside levels has proved critical in generating valid farm marketing behavior. Both the lagged and unlagged versions of Equation 3.1 are illustrated in Figure 3.2.[2]

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[1] Farm and urban population data and projections are provided to the GMP model exogenously. The urban subsector, however, has an optional feature for estimating urban-to-farm migration due to severe food shortage situations.

[2] Figure 3.2 illustrates a first order delay (exponential) for Equation 3.1. Higher order delays would appear somewhat different with $QFXCD_i(t)$ peaks not necessarily at the intersection of the $QFXCU_i(t)$ and $QFXCD_i(t)$ functions.

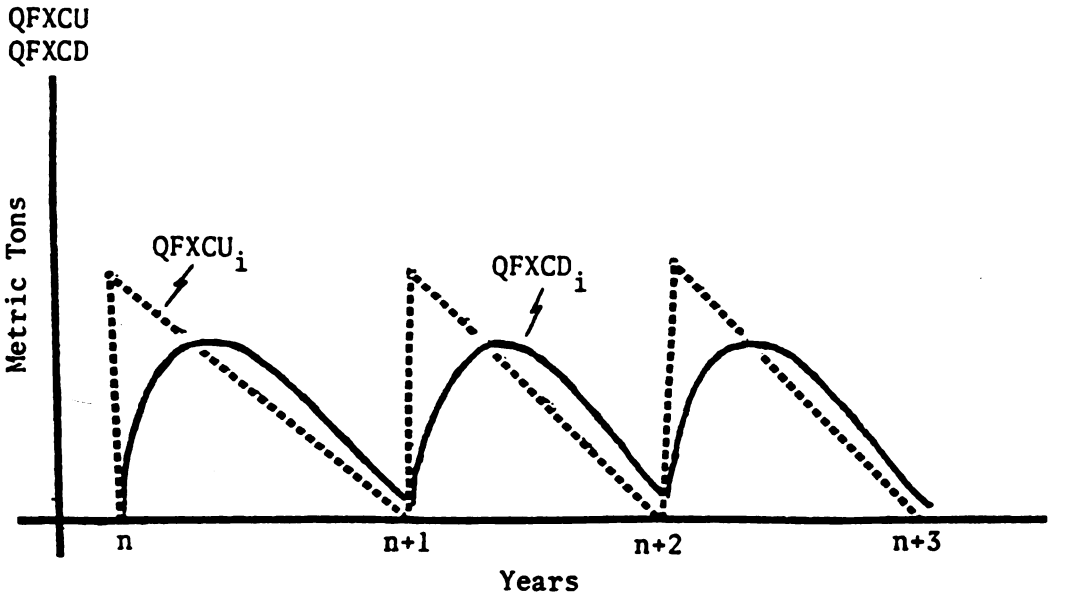


Figure 3.2. Rough Grain Set Asides for Farm Consumption.

Animal Feed Requirements

Set-aside requirements of rough grains for farm animal feed from domestic production are handled similarly to human consumption set asides. The requirements are highest after harvest and then decline throughout the year until the next harvest season. The following equations describe the lagged and unlagged versions of the animal feed requirement calculation done in the model.

$$DELF4*\frac{d}{dt} QFXLVD_i(t) + QFXLVD_i(t) = QFXLVU_i(t) \quad (3.4)$$

$$QFXLVU_i(t) = QFXLV_i(t)TTSH_i(t) \quad (3.5)$$

where:

QFXLVD = seasonal set-aside level at which farmers desire to maintain (rough) grain inventories for animal feed requirements--MT

QFXLVU = estimate of grain required to sustain farm animal feed requirement until next harvest--MT

DELF4 = time constant--yrs

QFXLV = annual animal feed requirements from domestic grain production (exogenous model input)--MT

TTSH = time remaining to start of next harvest season ($0 \leq TTSH \leq 1$)--yr.

Figure 3.2 above can be used to illustrate the basic shape of the two functions $QFXLVU_i(t)$ and $QFXLVD_i(t)$.

Seed Requirements

After harvest, farmers must also set aside the amount of seed needed to produce the next year's crop. During the growing season, there is no need for storing seed grain since it can be taken from the impending harvest. After harvest and before the next planting season, however, farmers must hold grains for seeding purposes. This simple and straightforward fact is modelled through the use of the following binary pulse signal.

$$PULSE_i(t) = 1 \quad , \quad \text{if } t_1 \leq t \leq t_2 \qquad (3.6)$$

$$= 0 \quad , \quad \text{otherwise}$$

where, $t_1 \leq t \leq t_2$ indicates the period after the beginning of harvest and before the beginning of the next planting season.

Total seed requirements are calculated from planting areas projected for the next crop year. These areas can be input to the model exogenously or calculated internally by the production response mechanism which will be described in mathematical detail later in this chapter. Normal seeding rates are multiplied by projected crop areas, resulting in total annual domestic seed requirements.

The seasonal patterns for set-aside levels of domestic grains for seed purposes are then obtained by applying the PULSE signal of Equation 3.6 and lagging the results to obtain a more realistic seasonal pattern. The following exponential equation describes these calculations precisely.

$$DELF5*\frac{d}{dt} QFXSED_i(t) + QFXSED_i(t) = AREA_i(t)\ SRPHAZ_i PULSE_i(t)/EXZ_i \quad (3.7)$$

where:

QFXSED = seasonal set-aside level at which farmers wish to maintain (rough) grain inventories for seed purposes--MT

AREA = projected planting area for next crop year--hectares

SRPHAZ = normal seeding rate used by Korean farmers (polished grain equivalents)--MT/ha

PULSE = binary pulse signal (see Equation 3.6)--no units

EXZ = rough to polished form conversion factor--proportion

DELF5 = time constant--yrs

Figure 3.3 illustrates the shape of both the lagged and unlagged versions of $QFXSED_i(t)$ of Equation 3.7. Note that the mathematical expression for $QFXSEU_i(t)$ in the figure is given by

$$QFXSEU_i(t) = AREA_i(t)\ SPHAZ_i\ PULSE_i(t)/EXZ_i\ . \quad (3.8)$$

Total Rough Grain Set-Aside Requirements

The following summation equation generates the total rough grain set-aside requirements during the year.

$$\underset{QFXD_i(t)}{\text{total}} = \underset{QFXCD_i(t)}{\text{consumption}} + \underset{QFXLVD_i(t)}{\text{feed}} + \underset{QFXSED_i(t)}{\text{seed}}\ . \quad (3.9)$$

(3.1) (3.4) (3.7)

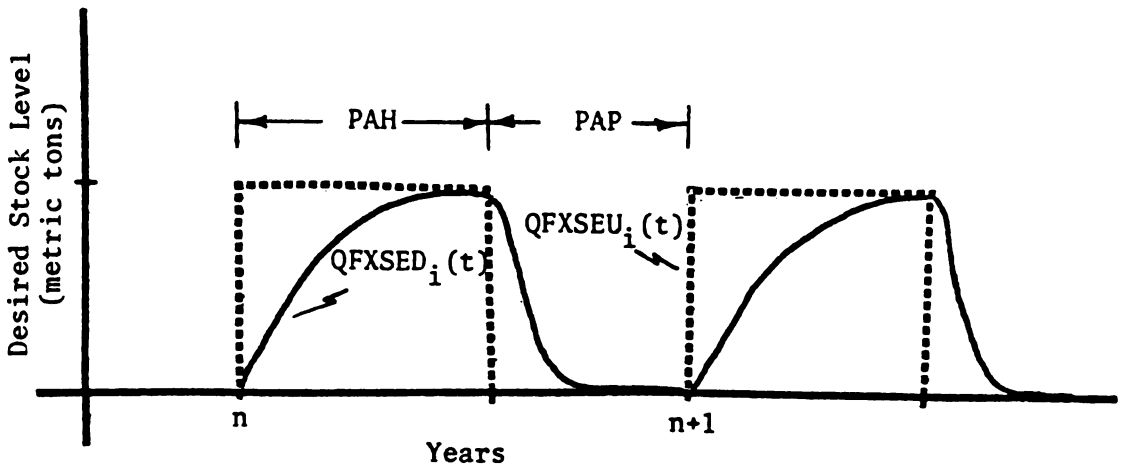


Figure 3.3. Seasonal Farm Stocks for Seed Requirements.

Polished Grain Requirements

Farm stocks of polished grain are intended for either of two purposes: (1) farm household consumption (in the near term, and (2) commercial farm sales of polished grains. The model calculation of these seasonal polished grain set-aside levels will now be described.

Human Consumption Requirements

Most farmers make it a general practice to keep only a few weeks' supply of grain stocks, intended for family consumption, in polished form. The following differential equation is used to calculate the desired stock levels of polished grains for family consumption throughout the year.

$$DELF1*\frac{d}{dt} QFZCD_i(t) + QFZCD_i(t) = QFZCU_i(t) \qquad (3.10)$$

where:

QFZCD = seasonal level at which farmers wish to maintain polished grain inventories for family consumption--MT

QFZCU = estimate of how much grain will be needed to sustain current farm consumption over the next prespecified period of time--MT

DELF1 = time constant--yrs.

Equation 3.10 represents a simple exponential lag function with the driving function $QFZCU_i(t)$ represented by the following relationship.

$$QFZCU_i(t) = FCLT_i(t)[RFCON_i(t)+\frac{d}{dt} RFCON_i(t)\ FCLT_i(t)/2] \qquad (3.11)$$

where:

FCLT = length of time farm polished grain stock levels should sustain current and anticipated consumption rates--yrs

RFCON = current rate of farm food grain consumption (see Equation 3.3)--MT/yr.

If farm consumption were assumed to remain constant throughout the next FCLT (period of time), say, three weeks, the derivative term in Equation 3.11 would not be required. However, with the large variations in farm food grain consumption rates in Korea, much better model results are attained by using the additional information regarding the rate of change of current farm consumption. By lagging the estimate of polished grain consumption requirements obtained from Equation 3.11, a more realistic representation of this farm decision process is simulated.

Farmers may vary the desired sustaining time for polished grain stocks for consumption during the year. During winter months, grains are much more stable in polished form than during the hot humid summer months. The model has the capability of reflecting this phenomenon by allowing FCLT of Equation 3.11 to vary during the year. For example, if farmers normally wish to hold, say, six weeks' supply of polished grain stocks for consumption during winter months and only

two weeks' supply during summer months, this behavioral pattern can be reflected through $FCLT_i(t)$ as illustrated in Figure 3.4.

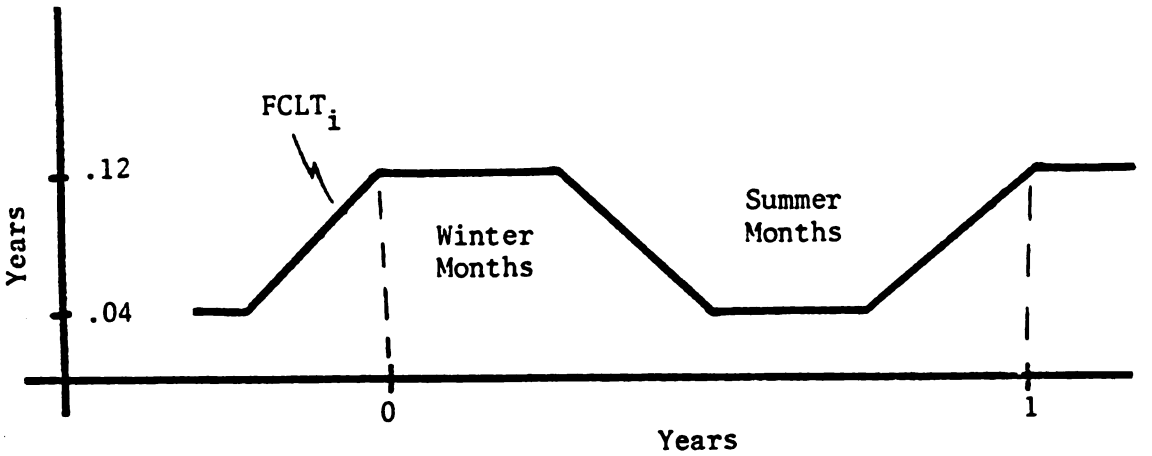


Figure 3.4. Desired Sustaining Time for Polished Grain Stocks for Farm Consumption.

Off-Farm Commercial Sales Requirements

Farmers market grains in both rough and polished forms. The calculation of polished grain requirements for sale follow closely those for polished grain holdings for household consumption. Since higher quantity and quality losses are incurred from prolonged storage of polished grains, farmers prefer to keep polished stocks to a minimum. The following differential equation describes the decision process for determining the desired level of polished grain stocks on hand for commercial sale during the year.

$$DELF2*\frac{d}{dt} QFZSD_i(t) + QFZSD_i(t) = QFZSU_i(t) \qquad (3.12)$$

$$QFZSU_i(t) = (1\text{-}PFSNPX)\ FSZLT_i(t)\ [FSN_i(t) + \frac{d}{dt} FSN_i(t)\ FSZLT_i(t)/2] \qquad (3.13)$$

where:

QFZSD = seasonal level at which farmers wish to maintain polished grain stocks for the purpose of commercial sale--MT

QFZSU = estimate of how much polished grain will be required on hand to sustain sales over the next prespecified period of time--MT

DELF2 = time constant--yrs

PFSNPX = proportion of farm sales to nongovernment sector in rough form--proportion

FSZLT = length of time farm polished grain stock levels should sustain current and anticipated commercial sales--yrs

FSN = farm sales to the nongovernment (private) subsector--MT/yr.

Polished grain inventories for the purpose of commercial sales are replenished from residual rough grain stocks not earmarked by farmers for other on-farm uses. Farmers also may market directly out of these rough grain stocks available for sale. These stocks will be described in more detail later.

Desired Total Polished Grain Stocks

The following summation equation generates the desired seasonal polished grain inventory stock level for the farm subsector.

$$\underset{(3.10)}{QFZD_i(t)} = \underset{(3.10)}{QFZCD_i(t)} + \underset{(3.12)}{QFZSD_i(t)}. \qquad (3.14)$$

total = consumption + sales

Farm Inventory Management

We have described the calculation of food grain set-aside requirements for farm use during the year. This in itself is a facet of farm inventory management. Rough grains are not managed any closer than through these set-aside decisions for on-farm use. Polished

grain inventories, however, are managed closer since these inventories are kept relatively small with a short turnover time.

The farm subsector model uses a hierarchy control scheme (of sort) to simulate the management of polished on-farm grain inventories. *First*, total polished grain inventories are controlled, using automatic feedback control techniques, by comparison of actual total polished grain inventories with desired total polished grain stocks, calculated in Equation 3.14. These polished grain stocks are replenished by performing milling operations on farm rough grain inventories. This milling on farm grains is done by the private subsector on a toll basis. *Secondly*, polished grain stocks for farm household consumption (a component of total polished grain stocks) are also controlled. These stocks are replenished from farm polished grain stocks held for commercial sale. The result of this control scheme is a very quick response time in adjusting polished grain stocks for human consumption to desired seasonal levels. On the other hand, overall polished grain stock levels (those for human consumption plus commercial sale) respond less rapidly to targeted levels because rough grains must be transported to mills, processed, and then transported back to the farm, all of which requires more time than simply reassigning intended purpose as is done in controlling household consumption stocks. This scheme works very well and is consistent with the real world inventory management process used by Korean farmers. The mathematical relationships which are used in the farm subsector model to simulate farm inventory management behavior as described above will now be given.

Farm Inventories

To simulate the farm inventory management behavior, farm grain inventories must be disaggregated as follows.

- total rough grains
- total polished grains
  - polished grains for consumption
  - polished grains for sale
- total grains available for sale

The system diagram of Figure 3.5 will be of assistance in following the mathematical description of farm inventories and inventory management operations.

Rough Grain Inventories

Rough grain inventories on farms are represented by the following differential equation.

$$\frac{d}{dt} QFX_i(t) = RH_i(t)/EXZ_i - FSGX_i(t) - FSNPX_i(t) - RFMXU_i(t) - FXLOSS_i(t)\ QFX_i(t) \tag{3.15}$$

where:

QFX = quantity of farm rough grain inventories--MT

RH = rate at which grains are harvested (polished equivalents)--MT/yr

EXZ = rough to polished form conversion factor--proportion

FSGX = farm sales to government (rough grains)--MT/yr

FSNPX = farm sales to private market (rough grains)--MT/yr

RFMXU = rate at which farm rough grains are moved to mills for processing--MT/yr

FXLOSS = expected storage loss rate of farm rough grains--proportion/yr.

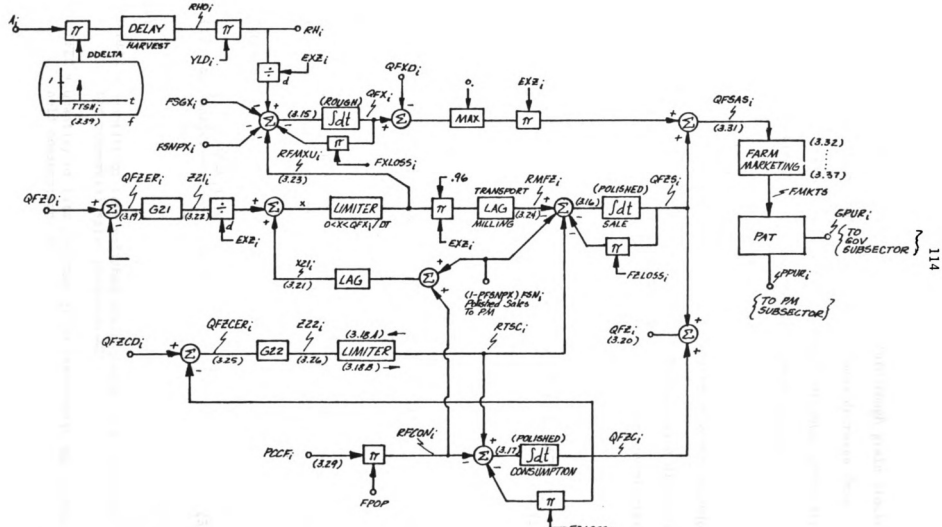


Figure 3.5. System Diagram--Farm Operations.

Equation 3.15 above states that the only way farm rough grain stocks can increase is from farm production. These stocks decrease from sales to government and private sectors, movement of rough grain stocks to mills for processing, and through normal storage losses.

Polished Grain Inventories

Polished grain inventories are disaggregated into two intended use categories: sales and farm consumption. The following differential equations are used to represent these two polished grain inventories.

(Commercial sales)

$$\frac{d}{dt} QFZS_i(t) = RMFZ_i(t) - (1\text{-}PFSNPX)\ FSN_i(t) - FZLOSS_i(t)\ QFZS_i(t) - RTSC_i(t) \tag{3.16}$$

(Household consumption)

$$\frac{d}{dt} QFZC_i(t) = RTSC_i(t) - RFCON_i(t) - FZLOSS_i(t)\ QFZC_i(t) \tag{3.17}$$

(If $QFZCER_i(t)>0$)

$$RTSC_i(t) = \min\left\{\max\left[0, \frac{QFZS_i(t)}{DT}\right],\ G22A*QFZCER_i(t)\right\} \tag{3.18A}$$

(If $QFZCER<0$)

$$RTSC_i(t) = \min\left\{\max\left[0, \frac{QFZC_i(t)}{DT}\right],\ -G22A*QFZCER_i(t)\right\} \tag{3.18B}$$

where:

QFZS = quantity of farm polished grain inventories available for commercial sales purposes--MT

QFZC = quantity of farm polished grain inventories for household consumption--MT

RMFZ = rate at which farm-owned grains are polished and returned to farm storage--MT

PFSNPX = proportion of farm sales to nongovernment sector in rough form--proportion

FSN = farm sales to nongovernment subsector--MT/yr

FZLOSS = expected storage loss rate of farm polished grains--proportion/yr

RFCON = rate of farm sector household consumption--MT/yr

RTSC = rate of reassignment of polished grain stocks to alternative purpose (i.e., sales or consumption)--MT/yr

G22A = control gain parameter--$\frac{MT/yr}{MT}$

QFZCER = error signal describing difference between desired and actual consumption inventory level--MT

i.e., $QFZCER_i(t) = QFZCD_i(t) - QFZC_i(t)$

min = minimum function

max = maximum function.

Equation 3.16 indicates that farm polished grain stocks intended for commercial sale increase through milling of farm rough grain stocks. These polished grain stocks decrease through commercial sales and normal storage losses. The $RTSC_i(t)$ term of the equation indicates that these stocks are also used as buffer stocks for farm decisions controlling the level of polished grains held for household consumption purposes.

Equation 3.17 indicates that farm polished grain stocks intended for household consumption decrease through farm household consumption and normal storage losses. These stocks are replenished and adjusted from polished stocks intended for commercial sale through the $RTSC_i(t)$ term of the equation. RTSC may be either positive or negative and is logically limited by the size of the source inventory from which transfers are made.

Control of Farm Polished Grain Inventories

In this section the control equations used in the farm subsector model to simulate management of polished grain stock levels will be described.

Control of Total Polished Grain Inventories

The following equations are used to generate control signals designed to simulate the movement of rough grains out of farm storage for milling in order to maintain farm polished grain stock levels at desired seasonal levels. Each equation below is preceded with a brief annotation to indicate its basic function.

(Error signal)

$$QFZER_i(t) = QFZD_i(t) - QFZ_i(t) \tag{3.19}$$

(Total polished stocks)

$$QFZ_i(t) = QFZS_i(t) + QFZC_i(t) \tag{3.20}$$

(Average attrition)

$$DELF8 \frac{d}{dt} X21_i(t) + X21_i(t) = (1\text{-}PFSNPX_i)\ FSN_i(t) + RFCON_i(t) \tag{3.21}$$

(Control signal)

$$Z21_i(t) = G21A*QFZER_i(t) + G21B \frac{d}{dt} QFZER_i(t) + G21C \int_{t_o}^{t} QFZER_i(\tau)\tau \tag{3.22}$$

(Rough grains out)

$$RFMXU_i(t) = \max[0,\ Z21_i(t)/EXZ_i + X21_i(t)] \tag{3.23}$$

(Polished grains in)

$$DELF4 \frac{d}{dt} RMFZ_i(t) + RMFZ_i(t) = .96*EXZ_i\ RFMXU_i(t) \tag{3.24}$$

where:

QFZER = error signal measuring difference between desired polished stock levels and actual polished stock levels--MT

QFZD = desired polished grain stock level (see Equation 3.14)--MT

QFZ = actual polished grain stock level--MT

QFZS = quantity of farm polished grain inventories for commercial sales purposes--MT

QFZC = quantity of farm polished grain inventories for household consumption--MT

X21 = average attrition rate of farm polished grain inventories--MT/yr

PFSNPX = proportion of farm sales to nongovernment sector in rough form--proportion

FSN = farm sales to nongovernment sector--MT/yr

RFCON = rate of farm sector household consumption--MT/yr

DELF4,8 = time constant parameters--yrs

Z21 = control signal representing *adjustments* to farm milling operations to manage polished grain inventories to desired levels--MT/yr

G21A,B,C = feedback control gain parameters--appropriate units

RFMXU = rate at which rough grains are moved out of farm storage to mills for processing--MT/yr

RMFZ = rate at which polished grains return to farm storage after toll milling by private millers--MT/yr

EXZ = rough to polished conversion factor--proportion

max = maximum function.

The function of the above set of equations is to generate an error signal reflecting the difference between desired and actual farm polished grain stock levels. This error signal is then operated on by the inventory controller G21, using proportional-plus-derivative-plus-integral control design as shown in Equation 3.22. An average polished farm inventory attrition rate is calculated by the distributed lag

function indicated by Equation 3.21. Results of Equations 3.21 and 3.22, the average attrition rate and inventory control signal, are then summed to form the signal $RFMXU_i(t)$, representing the rate at which farm rough grains are moved out of storage to be milled in order to replenish polished grain stocks at a rate which will manage these stock levels to desired levels throughout the year. Since milling operations are non-reversible, $RFMXU_i(t)$ is constrained to take on nonzero values only.

Milling Operations on Farm-Owned Grains

Equation 3.24 simulates the transportation and toll milling processes on farm-owned grains. The model assumption is made that farm-owned grains take priority in milling operations of the private market subsector so that it is unlikely that a milling rate capacity constraint would have to be placed on the output of Equation 3.24. The reader should note, however, that the total throughput of private milling operations, consisting of toll milling requirements for farmers *and* private market milling requirements, is constrained by maximum private market milling rate capacity. The reader can refer to Equations 4.42 and 4.43 of the private marketing subsector for verification of this. The current toll milling charge to farmers is 4 percent of the polished product. This is reflected in the driving function $.96EXZ_iRFMXU_i(t)$ of Equation 3.24 above.

Control of Farm Consumption Polished Inventories

Polished grain inventories for farm consumption are controlled simply by using polished grain inventories on hand for sale at farm locations as buffer stocks for adjustments to these inventories. Since no movement or processing of grains is involved, the response time for

such adjustments is quick, representing simply the reassignment of intended purposes for polished grains on hand by farmers. The adjustments are limited by the quantity of grain existing in the source inventory. The following equations are used to represent the management of farm polished inventories for consumption.

(Error signal)

$$QFZCER_i(t) = QFZCD_i(t) - QFZC_i(t) \tag{3.25}$$

(Control signal)

$$Z22_i(t) = G22A*QFZER_i(t) + G22B \frac{d}{dt} QFZER_i(t) \tag{3.26}$$

(Limiter)

$$RTSC_i(t) = \min[Z22_i(t), QFZS_i(t)/DT], \quad \text{(alt. 3.18A)} \tag{3.27}$$

$$\text{if } Z22_i \geq 0$$

$$RTSC_i(t) = \max[Z22_i(t), -QFZC_i(t)/DT], \quad \text{(alt. 3.18B)} \tag{3.28}$$

$$\text{if } Z22_i \leq 0$$

where:

QFZCER = error signal representing difference between desired and actual polished grain inventories held for consumption purposes--MT

QFZCD = seasonal level at which farmers wish to maintain polished grain inventories for family consumption--MT

Z22 = control signal representing rate of reassignment of polished grain stocks to alternative purpose (sales or consumption) to control stock levels of polished grains for household consumption--MT/yr

RTSC = constrained version of Z22 above precluding transfers from depleted inventory sources--MT/yr

DT = time increment of simulation model--yrs

min = minimum function

max = maximum function.

Farm Household Consumption

Farm household grain consumption patterns vary with own and substitute food grain prices as well as with the season of the year. A Cobb-Douglas function is used to model farm food grain consumption patterns throughout the year.

$$PCCF_i(t) = AFO_i \prod_{j=1}^{3} PF_j(t)^{EFCP_{ij}(t)} \tag{3.29}$$

where:

PCCF = seasonal rate of farm food grain consumption--kg/capita-yr

AFO = constant term for Cobb-Douglas function

PF = farm market price--won/bag

EFCP = price elasticity of farm consumption (i.e., the percentage change in farm consumption of commodity i due to a percentage change in the farm price of commodity j)--proportion

Π = product symbol.

The constant term AFO_i of the Cobb-Douglas function given in Equation 3.29 is calculated during the initialization phase of a model run. Base period farm prices and consumption levels are used in this calculation to force the seasonal demand curves, represented by Equation 3.29, through the expected prices and consumption levels for the period of the run. The following equation is used to generate values for AFO_i at model initialization.

$$AFO_i = PCCFA_i(t_o) \Big/ \prod_{j=1}^{3} PFA_j(t_o)^{EFCP_{ij}(t_o)} \tag{3.30}$$

where:

PCCFA = expected annual average farm consumption for period of model run--kg/capita-yr

PFA = expected annual average farm price for period of model run--won/bag.

The values of PCCFA and PFA of Equation 3.30 above may be user assigned or calculated by the generalized demand-price analyzer of the GMP front-end mechanism as described in Chapter 5.

The reader will note that the price elasticities of farm consumption are indicated as functions of time. Three sets of price elasticities are used in the farm consumption function to represent the seasonal nature of farm consumption behavior in Korea. The values of these parameters were estimated off-line for three seasons during the year. During a model run, the values of the parameters move linearly toward the succeeding set of estimated values as time evolves, so that the Cobb-Douglas functions used in the model have continuous time-varying parameters. This was necessary to achieve valid seasonal consumption behavior for farm, as well as urban, populations.

The three seasons of the year for which the consumption parameters were estimated are (1) October through January, (2) February through May, and (3) June through September. This choice of three distinct seasons is quite reasonable for the Korean situation [37]. Rice harvest occurs during October and November; thus, the first seasonal period corresponds to the rice harvest and post-harvest period when farm stocks are the highest and a glut of new rice appears on the market. The second period, February through May, can be called the off season, when no harvesting is occurring and farm stock levels of all grains are depleting. The third seasonal period, June through September,

corresponds to the barley (and wheat) harvest and post-harvest season, when barley stocks are highest. Rice transplanting and cultivation also occurs during this period. These three distinct periods during the year seem to influence the consumption behavior patterns of farm (and urban) households to the extent that constant values for price elasticities of consumption do not yield valid model results.

Figure 3.6 illustrates one group of parameter values used in the farm consumption function and how these parameters continually change throughout the year.[3] Rows of the matrices correspond to per capita consumption quantities (per unit time) and columns of the matrices correspond to prices received by farmers. The third column (wheat) corresponds to wheat flour price rather than wheat price received by farmers. For example, looking at the first row of the 15 November matrix, the first column element states that a 1-percent rise (fall) in rice price will produce a .74-percent fall (rise) in rice consumption on 15 November. After 15 November this response parameter decreases linearly with time to -.06 by 15 March, then increases to -.62 by 15 July, and finally returns to -.72 by 15 November. The first row, second column element of the 15 November matrix states that a 1-percent rise (fall) in barley price will produce a .96 rise (fall) in rice consumption on 15 November. After 15 November this parameter decreases to .15 by 15 March, increases to .70 by 15 July, and returns to .96

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[3]Negative values of certain "cross-elasticity" elements shown in Figure 3.6 cannot be rationalized in economic terms. The difficulty obviously stems from the fact that many more factors, other than market prices alone must influence consumption rates. Nevertheless, the values shown in Figure 3.6 yield valid results for farm demand. The aesthetic difficulty with signs is circumvented by referring to the elements of the matrices as demand system "parameters" rather than "elasticities."

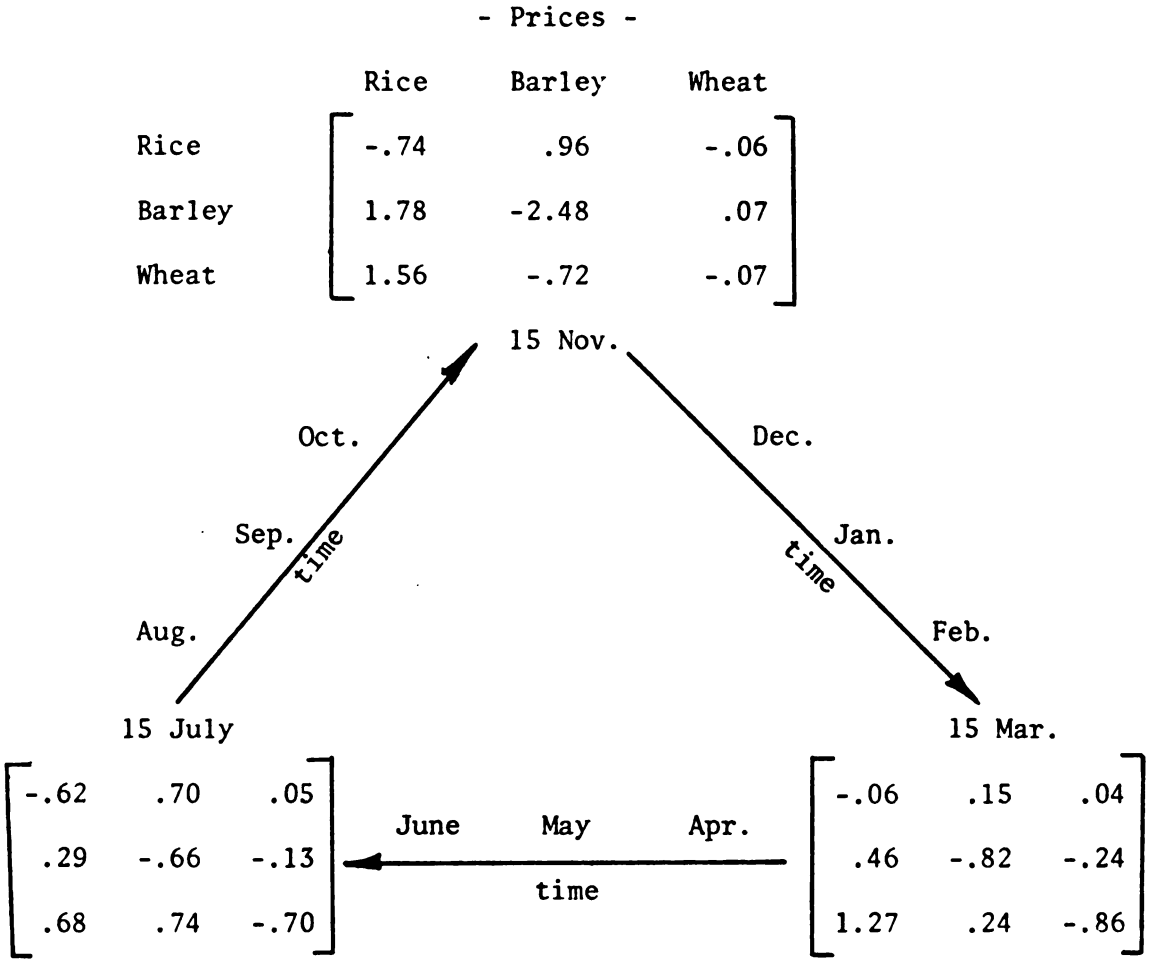


Figure 3.6. Time-Varying Parameters of Farm Consumption Model.

by 15 November. The reader can observe from the figure the time-varying nature of other parameters of the farm consumption function.

Farm Marketings

Farm marketing decisions can be influenced by several factors. A primary consideration to put into any farm marketing behavioral equation is that Korean farmers are very unlikely to sell themselves short during the marketing year. Farm grain set-aside requirements (discussed earlier) should, therefore, be an integral part of all farm marketing decisions. The quantity of farm grain storage that is available for sale at any time during the marketing year is given by the following equation.

$$QFSAS_i(t) = EXZ_i * \max[0, QFX_i(t) - QFXD_i(t)] + QFZS_i(t) \qquad (3.31)$$

where:

QFSAS = quantity of farm grain inventories available for sale--MT

QFX = total rough grain inventory (see Equation 3.15)--MT

QFXD = total rough grain set-aside requirements (see Equation 3.9)--MT

QFZS = quantity of farm polished grain inventories available for sale (see Equation 3.16)--MT.

Several functional forms for farm marketing behavior have been devised and tested throughout the GMP model development process. These forms vary widely in complexity and, although many appear to suffice, none is free from problems or can be hailed as being best for all purposes of the model. The underlying difficulty is the diversity in farm marketing behavior according to income classification. Until the model is so disaggregated, these difficulties will most likely persist. The

additional model complexity required for this level of disaggregation did not appear warranted for initial versions of the GMP model.

Farm marketing patterns (in the aggregate) demonstrate a very consistent skewed shape year after year, with the bulk of commercialized grain going onto the market directly after harvest. A simple functional form which picks up this behavior, can be tuned fairly accurately, and "guarantees" that farm stocks will not attain levels short of on-farm requirements during the year is given below.

$$FMKTSU_i(t) = A_i * QFSAS_i(t) \tag{3.32}$$

where:

FMKTSU = unsmoothed version of farm marketings--MT/yr

QFSAS = quantity of farm inventory available for sale--MT

A = tuning parameter--$\frac{MT/yr}{MT}$.

The simplicity of Equation 3.32 above is its main difficulty. Although this functional form can be tuned to do an acceptable job for historical tracking runs, its use is limited because it does not connect farm marketings directly with seasonal market prices. There *is* a connection with market prices in the calculation of annual farm requirements and thus, QFSAS; but this is very loose due to large smoothing factors used in calculating annual requirements. (See Equations 3.1, 3.2, and 3.3, for example.) The following equation represents a modification to Equation 3.32 reflecting seasonal market prices directly.

$$FMKTU_i(t) = QFSAS_i\{A_i[1 + EAP_i\ DPF_i(t)]\} \tag{3.33}$$

where:

A = constant term--$\frac{MT/yr}{MT}$

EAP = elasticity parameter describing how the parameter A of Equation 3.32 varies with respect to market price--no units
i.e.,

$$EAP = \frac{\Delta A}{A} \Big/ \frac{\Delta PF}{PF} \text{ (a constant)}$$

DPF = proportional change in farm price from base period (or average)--no units
i.e.,

$$DPF_i(t) = \frac{PFO_i(t) - PF_i(t)}{PFO_i} \tag{3.34}$$

PF = farm market price--won/bag

PFO = average farm market price--won/bag
i.e.,

$$\frac{d}{dt} PFO_i(t) + PFO_i(t) = PF_i(t). \tag{3.35}$$

Equation 3.33 above maintains the same restriction on farm marketings as does Equation 3.32. Many times, experimental design may involve use of the GMP model to investigate the effects of additional factors besides market prices on farm marketings--and in turn--total system response. The following equation contains such factors as (1) farm market prices, (2) government buying price, (3) relative difference between farm market price and government buying price, (4) quantity available for sale in farm storage, and (5) whether or not a government purchase program is currently in effect.

$$FMKTSU_i(t) = B1_i + B2_i\ PF_i(t) + B3\ QFSAS_i(t) + D1_i \left[B4_i + B5_i PF_i(t) + B6_i PB + B7_i \frac{PF_i(t) - PB_i(t)}{PF_i(t)} \right] \tag{3.36}$$

where:

PF = farm market price--won/bag

PB = government buying price--won/bag

QFSAS = quantity of farm inventory available for sale--MT

D1 = dummy variable--no units

D1 = 1, when government purchase program is in progress

D1 = 0, otherwise

B1, . . . , B7 = coefficients of regression--various units.

The reader will note that the "oversell" restriction of Equations 3.32 and 3.33 is not present in Equation 3.36 above.

It is desirable to smooth farm marketing responses generated in the model, regardless of the mathematical equation used in their generation. This is done as follows.

$$DELF6 \frac{d}{dt} FMKTS_i(t) + FMKTS_i(t) = FMKTSU_i(t) \qquad (3.37)$$

where:

FMKTS, FMKTSU = smoothed and unsmoothed versions of farm marketings--MT/yr

DELF6 = smoothing parameter--yrs.

Food Grain Production Operations

Food grain production operations consist of three distinct activities during the year: (1) planting operations, (2) crop cultivation, and (3) harvest operations. The farm subsector model simulates each of these activities for each crop throughout the year. The model utilizes a series of distributed delay functions to distribute these activities properly over time. Each delay equation is stimulated

making use of a unit impulse function, $\delta(t)$, having the following (theoretical) properties.[4]

$$\delta(t-t_o) = \begin{cases} 0, & t \neq t_o \\ \infty, & t = t_o \end{cases} \tag{3.38}$$

$$\int_o^1 \delta(t-t_o) = 1$$

where, t is defined as the "time of year," $0 \leq t \leq 1$, and t_o is some point in time within the year.

Since it is impossible to generate the δ function described above, a "psuedo" unit impulse function with the following properties is used by the model.

$$\text{DDELTA}(t-t_o) = \begin{cases} 0 & , t \notin (t_o, t_o+DT) \\ 1/DT, & t \in (t_o, t_o+DT) \end{cases} \tag{3.39}$$

$$\int_o^1 \text{DDELTA}(\tau-t_o)d\tau = 1$$

where, t is again defined as the "time of year," $0 \leq t \leq 1$, t_o is the time of year to begin psuedo impulse, and DT is the time increment used in the simulation model.

Crop areas for each production activity are multiplied by an appropriate DDELTA function to generate properly timed impulses to drive

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[4]More specifically, $\delta(t)$ is often called the Dirac Delta function, after the theoretical physicist P. A. M. Dirac.

differential equations designed to distribute each activity over time. The output of each delay function then consists of the rate (hectares per year) at which each production activity is being performed. From these production profiles, other significant information such as labor profiles, production cost flows, and the rate of harvest (MT/yr), can be generated over time. The mathematical details of these model processes will now be described.

Production Profiles

In this section the model equations used to produce production activity profiles, and the amount of area undergoing production activities will be given. Figure 3.7 is a system diagram depicting these mathematical relationships. The figure also shows the general shape of production activity profiles produced by the model.

Planting Operations

Planting operations consist of seed bed preparation, seedling generation (for rice), paddy irrigation management, planting or transplanting (for rice), and other activities related to getting a crop in the ground. The following differential equation is used to generate production profiles for planting activities.

$$a_k \frac{d^k}{dt^k} RPO1_i(t) + a_{k-1} \frac{d^{k-1}}{dt^{k-1}} RPO1_i(t) + \ldots + a_o RPO1_i(t) = DDELTA(toy-TSP1_i)*AREA_i \qquad (3.40)$$

where:

a_j = coefficients of distributed delay function

$$a_j = \binom{k}{j}\left(\frac{DELP1}{k}\right)^j \quad , j = 0, \ldots, k$$

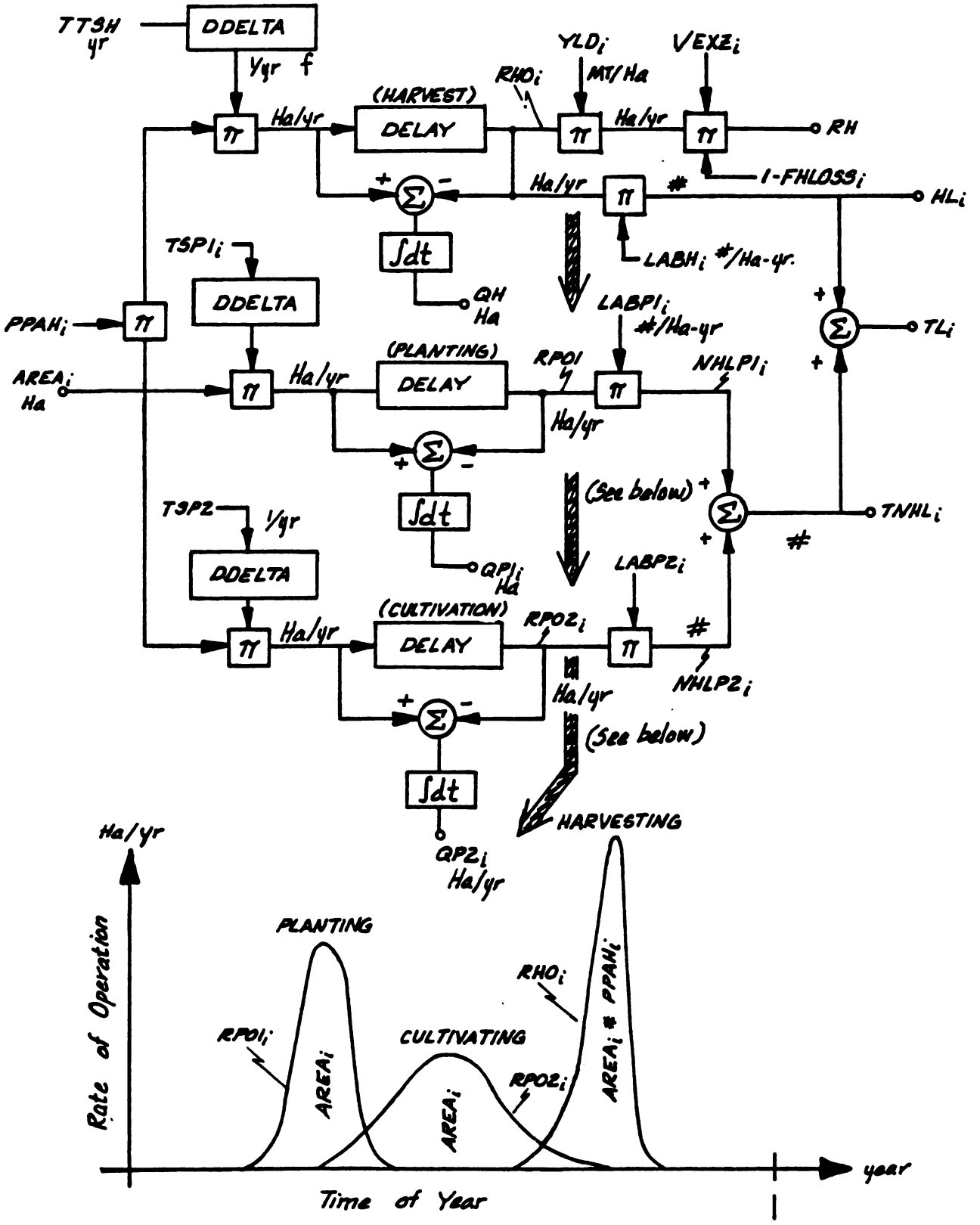


Figure 3.7. System Diagram--Production Operations.

DELP1 = mean time of delay function--yrs

k = order of particular delay function

RPO1 = rate at which planting operations are completed--ha/yr

DDELTA = psuedo unit impulse function (see Equation 3.39)--no units

AREA = total area being planted--ha

toy = time of year clock, $0 \leq toy \leq 1$--yr

t = simulation time clock--yrs

TSP1 = time of year planting operations begin--yr.

The current amount of land undergoing planting operations is given by the following integral equation.

$$QP1_i(t) = AREA_i * \int_0^{toy} DDELTA(\tau - TSP1_i)d\tau - \int_0^t RPO1_i(\tau)d\tau \qquad (3.41)$$

Cultivating Operations

Cultivating operations consist of weeding; paddy irrigation management (for rice); application of pesticides, herbicides, and other chemicals; fertilization; and other activities performed during the crop growing season. The following differential equation is used to generate seasonal production profiles for cultivation activities.

$$a_k \frac{d^k}{dt^k} RPO2_i(t) + a_{k-1} \frac{d^{k-1}}{dt^{k-1}} RPO2_i(t) + \ldots + a_o RPO2_i(t) = DDELTA(toy - TSP2_i) * AREA_i \qquad (3.42)$$

where:

RPO2 = rate at which cultivation operations are completed--ha/yr

TTSP2 = time of year cultivation operations begin--yr

and, where other variable definitions can be found under Equation 3.40.

The current amount of land undergoing cultivation operations is given by the following integral equation.

$$QP2_i(t) = AREA_i \int_o^{toy} DDELTA(\tau - TSP2_i)d\tau - \int_o^t RPO2_i(\tau)d\tau . \qquad (3.43)$$

Harvesting Operations

Harvest operations consist of cutting, gathering, drying, threshing, bagging, hauling, and other activities performed at harvest time. The following differential equation is used to generate seasonal production profiles for harvest activities.

$$a_k \frac{d^k}{dt^k} RHO_i(t) + a_{k-1} \frac{d^{k-1}}{dt^{k-1}} RHO_i(t) + \ldots + a_o RHO_i(t) = DDELTA(toy - TSH_i) * AREA_i * PPAH_i \qquad (3.44)$$

where:

RHO = rate at which harvest operations are completed--ha/yr

TSH = time of year harvest operations begin--yr

PPAH = expected proportion of area planted actually harvested--proportion

and, where other variable definitions can be found under Equation 3.40.

The amount of land currently undergoing harvest operations is given by the following integral equation.

$$QH_i(t) = PPAH_i * AREA_i \int_o^{toy} DDELTA(\tau - TSH_i)d\tau - \int_o^t RHO_i(t)d\tau . \qquad (3.45)$$

The rate at which food grain is being harvested throughout the year is generated by the following equation.

$$RH_i(t) = YLD_i * RHO_i(t) * [1-FHLOSS_i] \quad (3.46)$$

where:

RH = rate at which grain is harvested (polished equivalent)--MT/yr

YLD = yield--MT/ha

RHO = rate at which harvest operations are completed--ha/yr

FHLOSS = expected loss at harvest (not accounted for in yield parameter)--proportion.

Labor Profiles

The farm subsector model also generates seasonal labor profiles for production operations. These profiles indicate the size of the farm labor force required to carry on production operations at the seasonal rates generated by the model. The profiles are used to calculate farm labor cost flows over the year. The farm accounting equations of the model will be described later in this chapter. The equations below are used to generate seasonal labor profiles.

$$NHLP1_i(t) = LABP1_i * RPO1_i(t) \quad (3.47)$$

$$NHLP2_i(t) = LABP2_i * RPO2_i(t) \quad (3.48)$$

$$TNHL_i(t) = NHLP1_i + NHLP2_i(t) \quad (3.49)$$

$$HL_i(t) = LABH_i * RHO_i(t) \quad (3.50)$$

where:

NHLP1 = labor force required to carry out planting operations--labor units

NHLP2 = labor force required to carry out cultivating operations--labor units

TNHL2 = labor force required to carry out planting and cultivating operations--labor units

HL = labor force required to carry out harvest operations--labor units

LABP1, LABP2, LABH = unit labor requirement parameters for planting, cultivating, and harvesting operations, respectively--labor units/ha-yr.

The total farm labor force engaged in production operations is calculated as follows.

$$TL(t) = \sum_{i=1}^{3} [TNHL_i(t)+HL_i(t)]. \qquad (3.51)$$

Optional Production Response Mechanism

One of the questions consistently asked by government grain management policy makers is what effects various grain management policies and programs will have on future domestic grain production. In most cases, this question is very difficult and often goes unanswered or results in a special study.

The farm subsector model contains an *optional* production response mechanism which can be called upon to internalize farm production decisions made by farmers regarding areas planted to rice (ordinary and high-yielding varieties) and barley. The model does not internalize wheat area decisions since domestic wheat production accounts for less than two percent of total food grain production. No attempt is made to predict yields in the model other than average rice yield, which is

merely a weighted average of the expected yields of ordinary and high-yielding varieties based on the relative areas of each predicted by the model. The user, however, still maintains the option of specifying food grain production land areas exogenously if he so desires.

In this section the GMP optional production response mechanism will be described in detail. The reader will find that the actual equations used to project planting area decisions made by farmers appear quite simple and might tend to question the credibility of the mechanism if not given a full background of the rationale underlying the response equations. Therefore, preceding the presentation of the production response equations used in the model, an appropriate foundation for the model structure will be developed by discussing in detail what seems to be the important factors influencing farm production decisions in Korea. Results of testing the response mechanism's ability to reproduce past production decisions made by farmers in Korea will also be given in this section.[5]

Rice Production Response

Rice production decisions made by farmers in Korea are by far the most important of any domestic production decisions, having the greatest impact on the overall Korean grain system. Introduction of new high-yielding rice varieties in recent years has resulted in a drastic increase in rice production. Nevertheless, both economic and noneconomic factors must be considered by farmers deciding whether

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[5]Although there is a chapter devoted to model testing and validation, it seems more appropriate for the case of production response to present test results along with the development of the equations.

to plant new or old varieties of rice. New varieties adaptable to slightly different growing seasons allow for changes in farming practices which make double cropping rice and barley more feasible, especially in marginal double-cropping areas. Therefore, rice production decisions can also have an effect on barley (and wheat) production decisions. In this section, the rice production response mechanism will be described both in narrative and mathematical detail.

Background and Model Rationale

Production statistics for rice over a recent ten-year period are presented in Table 3.1. Some of these data are also plotted in Figure 3.8 in order to lend support to the following discussion.

As depicted in Figure 3.8, total rice area in Korea has remained very steady over the past several years, varying less than 1 percent since 1971. Since the GMP model is designed to address current grain management problems and project consequences over a relatively short time horizon of one to three years, it seems reasonable to assume total rice area will remain stable. Rice production, however, has been on an increase over the past several years. The reason for this increase is the introduction and diffusion of the new high-yielding Tongil variety (IR667) in 1971. Ordinary rice yields have averaged 3.33 metric tons per hectare over the past five years, while Tongil rice yields have averaged 4.61 metric tons per hectare (or 38 percent above ordinary varieties) over the same period. The diffusion process of the new varieties has been very rapid with an estimated 450,000 hectares, or 39 percent of total rice area, being planted to Tongil in 1975. Potential area for Tongil production is estimated to be around 490,000

Table 3.1. Rice Production--1966-1975.

Crop Year	Area			Yield			Production			100 B/A
	Total	Tongil	Other	Average	Tongil	Other	Total(A)	Tongil(B)	Other	
	- 1000 hectares -			- metric tons per hectare -			- 1000 metric tons -			percent
1966	1231	--	1231	3.23	--	3.23	3976	--	3976	--
1967	1235	--	1235	2.97	--	2.97	3668	--	3668	--
1968	1151	--	1151	2.81	--	2.81	3234	--	3234	--
1969	1220	--	1220	3.39	--	3.39	4136	--	4136	--
1970	1203	--	1203	3.30	--	3.30	3970	--	3970	--
1971	1190	3	1187	3.36	5.01	3.35	3998	25	3973	0.6
1972	1191	187	1004	3.32	3.86	3.22	3954	722	3232	18.3
1973	1182	139	1043	3.56	4.81	3.39	4208	669	3539	15.9
1974	1204	307	897	3.69	4.73	3.33	4443	1452	2991	32.7
1975	1206	450	756	3.82	4.64	3.33	4607	2088	2519	45.3

Source: Ministry of Agriculture and Fisheries.

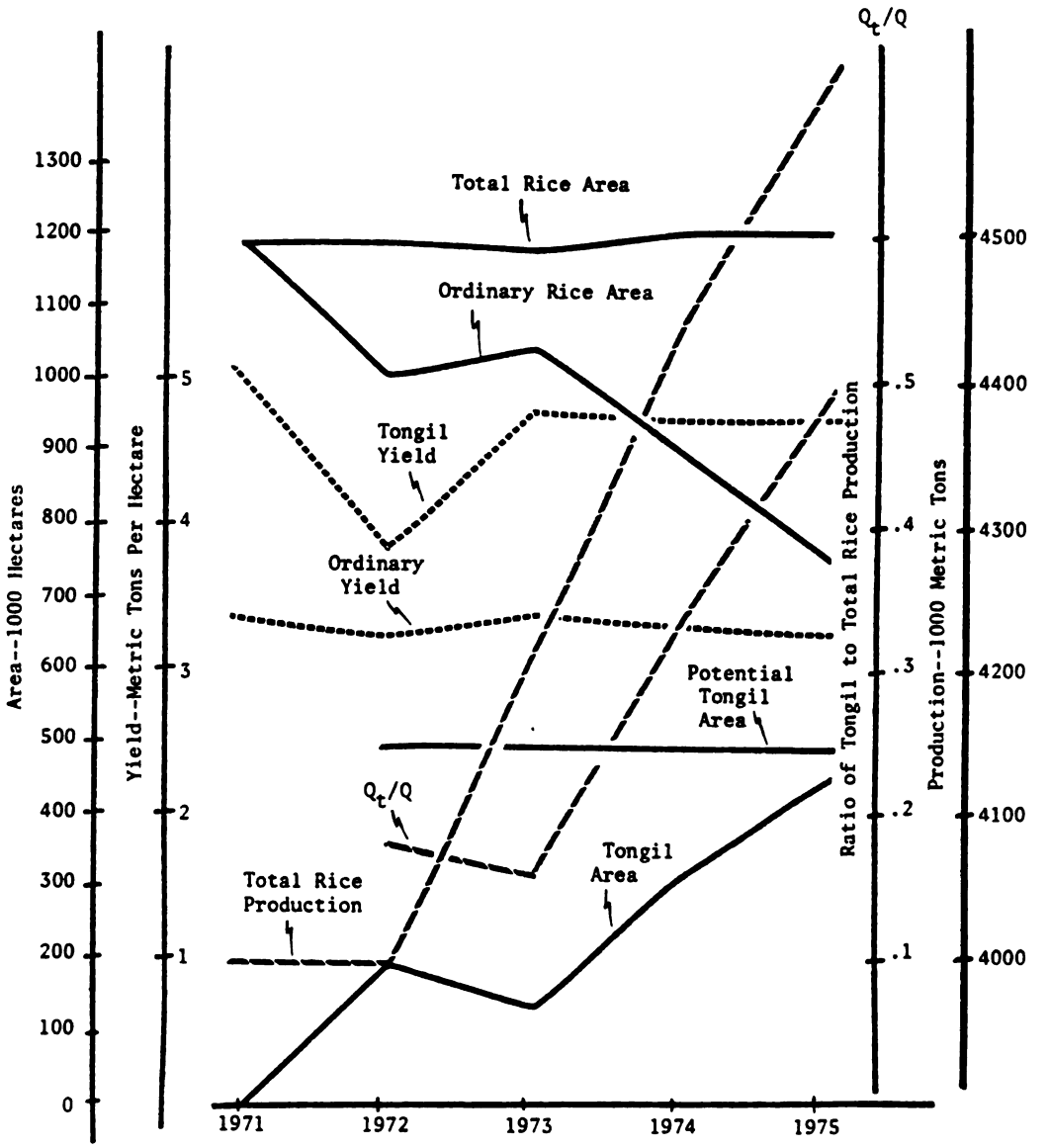


Figure 3.8. Rice Production, 1971-1975.

hectares; therefore, by 1975, nearly 92 percent of potential area had already gone into Tongil production.

Although Tongil yields are higher than ordinary varieties, several other factors influence farmers' decisions regarding planting of the new rice variety. Korean consumers prefer the traditional short-grain native varieties for their taste and quality characteristics; therefore, Tongil rice sells at an approximate 21-percent discount on the private market.[6] The Korean government, in order to encourage the production of the new high-yielding variety, makes no distinction among rice varieties purchased. Table 3.2 summarizes some of the price differentiations between Tongil and ordinary varieties at the farm level.

As indicated in the table, the Korean government has consistently offered a sizable premium (over private market price) to the farmers for raising Tongil varieties, yet more is involved in the farmer's decision to raise Tongil. Production costs for Tongil rice are higher than ordinary varieties by about 20 percent. And, although average Tongil yields are higher than ordinary yields, Tongil yields are much more varient than ordinary yields, as evidenced in 1972 (see Figure 3.8) when August rains (and other unfavorable conditions throughout the growing season) caused a 23-percent drop in Tongil yields. During the same year, however, ordinary rice yields dropped only 4 percent below average. Tongil yield still remained above ordinary variety yield, yet the following year, 1973, witnessed a 26-percent decline in the area of Tongil rice planted. In 1973 rice yields were above average. Since Tongil area was relatively small in 1972, the 26-percent cutback

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[6]Based on master's thesis research by Ju, Chul Ho, NAERI, MAF, Seoul, Korea, 1973.

Table 3.2. Average Prices Received by Farmers from November Through January for Tongil and Ordinary Rice Varieties.

Crop Year	Government Purchase Price (A)	Private Market Purchase Price (B)		$\frac{A-B}{B} \times 100$	
	Ordinary and Tongil	Ordinary	Tongil	Ordinary	Tongil
	- won/80 kilograms (polished equivalent) -			- percent -	
1970	7000	6557	--	6.8	--
1971	8750	8476	--	1.0	--
1972	9888	9742	7696	1.5	28.5
1973	11,377	10,948	8649	3.9	31.5
1974	15,760	16,673	13,172	-5.5	19.6
1975	19,300	20,009	15,807	-3.5	26.6

Sources: Ministry of Agriculture and Fisheries; National Agricultural Economics Research Institute.

in Tongil area in 1973 did *not* show up as a reduction in overall rice production, clouding what had really happened. The recidivism effect is most likely strongest in the initial years while farmers' confidence in a new variety is being established. Yet, should the same thing repeat itself and 26 percent of current Tongil areas were to be converted back into ordinary rice varieties production, due to weather or unfavorable economic conditions for Tongil production, Korea might expect total rice production to drop as much as 200,000 metric tons, even if yields remained at their 1975 levels.

The rice production response mechanism operates on the above principles and forecasts the changes in Tongil area planted. Relative values of Tongil and ordinary rice production are compared for the November-January period each year. The value of ordinary rice is yield

times private market price received by farmers, while the value of Tongil rice production is calculated as yield times government purchase price for rice. Since unit input charges (labor, fertilizer, etc.) for Tongil and ordinary varieties are essentially the same from year to year, calculation of relative returns is not necessary. These relative values of Tongil and ordinary rice production are set up in a response equation which calculates the change in Tongil rice area from the previous year. Total rice area planted is assumed constant at 1,206,000 hectares so that ordinary rice area is the residual between total rice area and Tongil area. Expected yields are used for forecasting production so that average total rice yield is calculated as a weighted average of Tongil and ordinary rice yield. We will now look more precisely at how these principles are applied in the model.

Model Structure

Consider the following difference equation.

$$Y(t) - Y(t-1) = \alpha Y(t-1) + \gamma \left(\frac{X_1 X_3 - \beta X_2 X_4}{\beta X_2 X_4} \right) \qquad (3.52)$$

where:

Y = Tongil rice area--hectares (ha)

X_1 = Tongil yield in preceding year--MT/ha

X_2 = ordinary rice yield in previous year--MT/ha

X_3 = government buying price in previous year--won/MT

X_4 = average price received by farmers from private market during November-January period of the previous year--won/MT.

Equation 3.52 is a linear difference equation describing the diffusion process of Tongil rice area. The excitation term of the

equation states that the value of Tongil rice production must remain higher than the value of ordinary rice production by at least a factor of β to realize no decreases in Tongil area planted.

The parameters α, γ, and β of Equation 3.52 were estimated by transforming the equation into a linear statistical form as follows.

$$Y(t)-Y(t-1) = \alpha Y(t-1) + \gamma\left(\frac{X_1X_3-\beta X_2X_4}{\beta X_2X_4}\right) \qquad \text{(3.52) repeated}$$

$$= \alpha\, Y(t-1) + \frac{\gamma}{\beta}\,\frac{X_1X_3}{X_2X_4} - \gamma\,.$$

Letting $\beta_1' = -\gamma$ and $\beta_2' = \gamma/\beta$, we have

$$Y(t)-Y(t-1) = \alpha\, Y(t-1) + \beta_1' + \beta_2'\,\frac{X_1X_3}{X_2X_4}\,. \qquad (3.53)$$

After estimating Equation 3.53 the parameters γ and β of Equation 3.52 can be calculated from the following relationships.

$$\gamma = -\beta_1'$$

$$\beta = -\beta_1'/\beta_2'$$

Results of the estimation are given below.

$$Y(t) - Y(t-1) = \underset{(-18.44)}{0.4082}\, Y(t-1) - \underset{(27.90)}{1{,}197{,}099} + \underset{(20.97)}{889{,}264}\,\frac{X_1X_3}{X_2X_4} \qquad (3.54)$$

$$R^2 = .99$$

Parameters in Equation 3.54 were estimated based on actual Tongil area responses from crop years 1972 through 1975.

Converting Equation 3.54 will give more insight into the meaning of the estimated parameters.

$$Y(t) - Y(t-1) = 0.4082\ Y(t-1) + 889264.\left(\frac{X_1X_3 - 1.346\ X_2X_4}{X_2X_4}\right) \qquad (3.55)$$

or

$$Y(t) - Y(t-1) = 0.4082\ Y(t-1) + 889264.\left(\frac{X_1X_3}{X_2X_4} - 1.346\right). \qquad (3.56)$$

Equation 3.56 states that if the value of Tongil production remained 35 percent above the value of ordinary rice production, it would take approximately four years for Tongil area to reach a level of 450,000 hectares after introduction. Of course, Equation 3.56 must be limited to operate only in the range of potential Tongil area, i.e., between zero and 490,000 hectares.

Once Tongil rice area is estimated for the upcoming rice year, ordinary rice area is calculated as the residual between total rice area (assumed constant at 1,206,000 hectares) and Tongil rice area. Expected yields for Tongil and ordinary rice are then used to estimate total rice production. For example, the model estimated Tongil area in 1974 to be 308,751 hectares. The following equation describes how total rice production is then calculated.

308,751	x	4.61	+	(1,206,000 - 308,751)	x	3.33	=	4,411,181
Estimated Tongil area	x	Expected Tongil yield	+	Estimated ordinary rice area	x	Expected ordinary yield	=	Estimated total rice production

Test Results and Implications

Test results in Table 3.3 indicate both the strengths and weaknesses of the rice production response model. The high coefficient of determination (COD) for the years 1972 through 1975 for estimated Tongil rice area indicates that the model does a good job in this respect. Furthermore, the high COD for the years 1973 through 1975 for estimating total rice production indicates that the model does a good job when yields are close to average. However, the 1972 production estimate is off by 302,000 metric tons due to poor yields in both Tongil and ordinary rice varieties during that year. This failure of the model is not surprising since it is not designed to estimate yield responses. Encouraging (or not so discouraging) also is the fact that no model could have predicted the inclement weather conditions of 1972 which brought about the drastic declines in rice yields (23 percent in Tongil and 4 percent in ordinary rice).

Although yields are not projected by the rice production response mechanism, the model user is able to investigate the impacts of poor (Tongil) rice yields on the following year's rice production. Since the GMP model is used on relatively short (one- or two-year) time horizons, information regarding actual Tongil yields, ordinary variety yields, and private market price can be used to assist the government in establishing a purchase price for rice insofar as production impacts are concerned. For example, in 1972 the government purchase price for rice (Tongil included) was 9,888 won per 80-kilogram bag (see Table 3.2). Private market price for ordinary rice was 9,742 won. Even though government purchase price was approximately 1.5 percent above private market price, Tongil rice area declined some 26 percent in 1973 due to

Table 3.3. Test Results of the Rice Production Response Model.

Crop Year	Tongil Rice Area		Total Rice Production	
	Model	Actual	Model	Actual
	- hectares -		- 1000 metric tons -	
1972	187,471*	187,471	4,256	3,954
1973	137,962	139,028	4,193	4,208
1974	308,751	306,897	4,411	4,443
1975	441,181	450,000†	4,571	4,607
Coefficient of Determination	R^2 = .95		R^2 = .92§	

* Model initialization.
† Preliminary estimate from MAF.
§ Does not include 1972 response due to crop failure.

poor Tongil yields the previous year. The model indicates, however, that if government purchase price for rice in 1972 (Tongil included) had been approximately 5 percent higher than private market price, i.e., 10,239 won per bag; then the value of Tongil production, even with the depressed yields, would have been sufficient relative to ordinary rice production to preclude a reduction in Tongil area in 1973. This could have meant an increase in 1973 rice production of over 100,000 metric tons. At prevailing domestic prices this would have meant approximately thirty-one million dollars worth of rice for an additional cost to the government of about five million dollars.

Barley Production Response

Although second only to rice in importance, barley production in Korea does not compete with rice production. Even at subsidized

farm prices under the dual barley price program, farm barley price would have to increase some 250 percent before net returns for barley production would equal those for rice. Farmers' decisions regarding changes in barley planting areas seem hinged to technical factors determining the feasibility of double cropping barley on rice land, especially in the marginal double-cropping regions of the country.

Background and Model Rationale

Just as in the case for rice production response, the model makes no attempt to forecast barley yields, because this variable depends on too many factors outside the model such as weather, fertilizer application rates, government subsidies on input costs, etc. Production statistics for barley (common and naked barley combined) are given in Table 3.4. The table indicates that the variation for barley yields over a recent ten-year period has been only 3.5 percent, giving support to a model assumption using average yield as a predictor. The variation of barley area over the same period was a more significant 6.5 percent. It seems these variations in barley area can be explained quite well by a combination of economic and technical factors which are available to the GMP model.

The barley production data of Table 3.4 are also plotted in Figure 3.9 along with other data in order to lend support to the present discussion. As is shown in the figure, barley production area has varied some ±80,000 hectares about a mean. Using average yield for the period shown of 2.16 metric tons per hectare, this range in variation in production area accounts for a variation in barley production of roughly ±175,000 metric tons, about a mean production of 1,944,000 metric tons.

Table 3.4. Barley Production, 1966-1975.

Crop Year	Area	Yield	Production
	1000 hectares	MT/ha*	1000 metric tons
1966	961	2.10	2018
1967	971	1.97	1913
1968	978	2.13	2083
1969	942	2.19	2063
1970	904	2.18	1971
1971	833	2.23	1858
1972	868	2.26	1962
1973	816	2.18	1779
1974	859	1.99	1709
1975	885	2.35	2080
Mean	902	2.16	1944
Coefficient of variation	6.5%	3.5%	6.6%

* MT/ha - metric tons per hectare.

The steady decline in barley area between 1968 and 1971 correlates closely with a downward trend in the price ratio of barley price to rice price, $\frac{P_B}{P_R}$, over this same time period. Data for this price ratio are plotted in Figure 3.9. Although the price ratio factor seems also to correlate well with the increase in barley area planted after 1971, this positive barley area response is also related to changes in farming practices brought about by the introduction and diffusion of high-yielding Tongil rice after 1970, making barley production on marginal double-cropping areas more feasible.

Speaking in relation to marginal double-cropping areas, both rice and barley production (yields) can be adversely affected due to the changes in farm practices (mainly the timing of planting) required

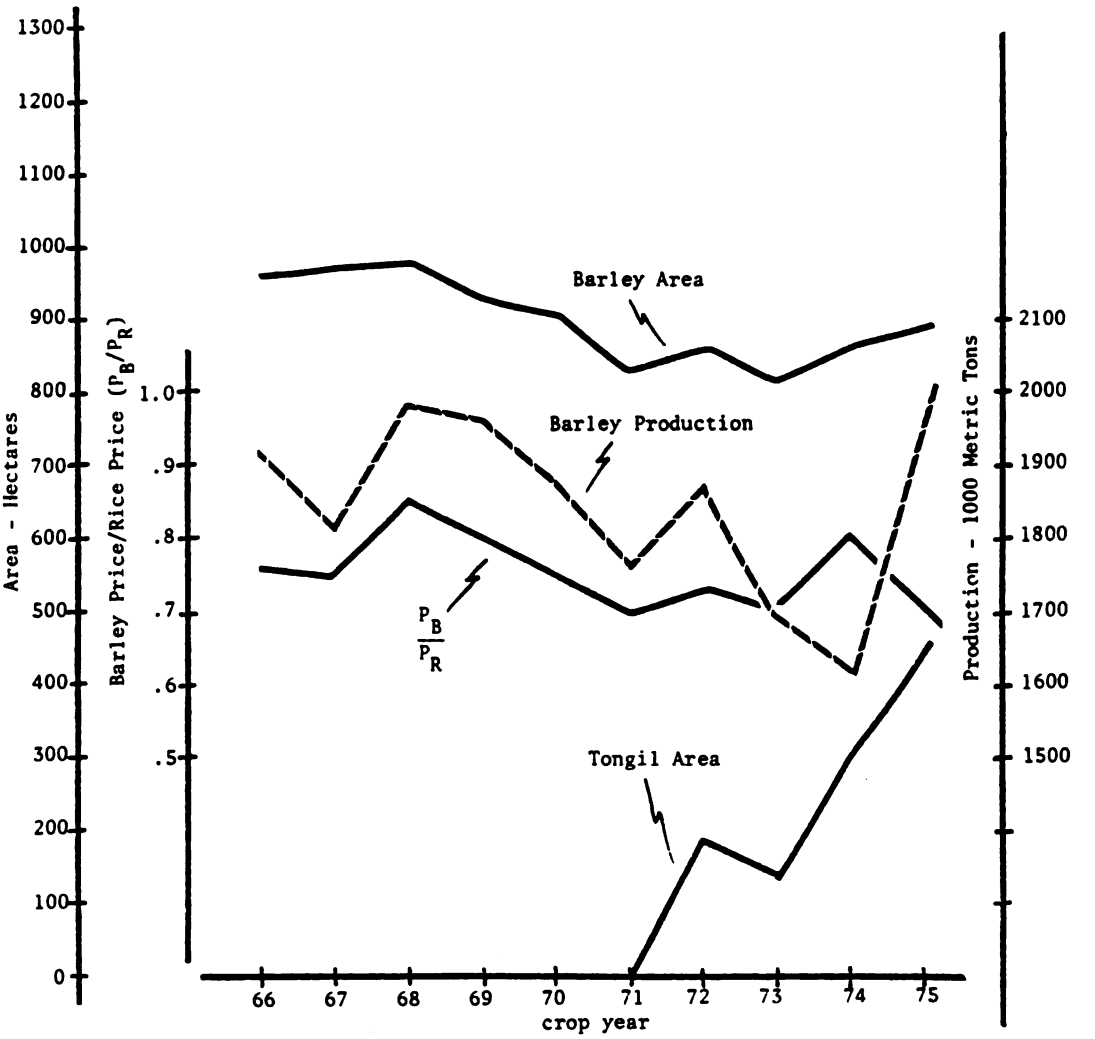


Figure 3.9. Barley Production, 1966-1975.

for double cropping. Barley yield can be adversely affected by delayed planting dates in the fall. In marginal areas these delays are caused by late maturing and harvesting of rice crops which necessarily push the barley planting time considerably beyond the optimal planting date. Rice yield can also be adversely affected for the same reason: delayed rice transplanting dates caused by late maturing and harvesting of barley crops in the late spring and early summer. Farmers' decisions regarding the economic feasibility of double cropping must include the expected suppressed yields of both crops due to changes in farm practices required.

Since the introduction and diffusion of the Tongil rice variety since 1971, new early-maturing barley varieties such as Olbory, Milyang 6, and Radiation 6 have also been rapidly diffused. The combination of this, plus the fact that Tongil rice can be transplanted approximately one week earlier than ordinary rice varieties without adverse yield effects, has resulted in increasing the size of potentially feasible double-cropping area [43]. Although the growing period for Tongil rice is not appreciably shorter than ordinary varieties, the shift forward of the planting time results in an earlier rice harvest. This earlier rice harvest makes possible more timely planting of the winter barley crop. Thus, it can be seen that a good predictor of barley planting area should somehow consider the amount of Tongil rice area in combination with purely economic factors. Figure 3.9 shows Tongil rice area from 1971 through 1975. The correlation between changes in barley area and Tongil rice area can be seen clearly. We will now describe how these rationales are applied in the model.

Model Structure

The following equation does a good job at predicting the barley area planted over the 1966-1975 period.

$$Y(t) = 385.9 + 0.8106X_1 - .04463X_2 + 91.72X_3 \quad (3.57)$$

where:

Y = total barley area (common + naked)--ha

X_1 = total barley area in previous year--ha

X_2 = exponential average of farm *rice* price over the previous year--won/bag

X_3 = ratio of the value of Tongil rice production to ordinary rice production in previous year.

Barley price does not appear in the above equation. The correlation coefficient between previous years' government buying price for barley and barley area over the past four years is calculated to be only 0.137. On the other hand, the correlation coefficient between X_3 (a good indicator of Tongil rice area) and barley production is calculated at 0.646.

Equation 3.57 could undoubtedly be improved by replacing the X_2 term (rice price alone) with the ratio of government buying price for barley to government buying price for rice.

Test Results

Table 3.5 displays the performance of the current barley response model in predicting barley area and barley production for the years 1972 through 1975.

Table 3.5. Test Results of Barley Production Response Model.

Crop Year	Barley Area		Barley Production	
	Model	Actual	Model	Actual
	- 1000 hectares -		- 1000 metric tons -	
1972	890	868	1935	1962
1973	831	816	1795	1779
1974	843	859	1820	1709
1975	861	885	1859	2080
Coefficient of Determination	$R^2 = .67$		$R^2 = .63$	

New Production Response Equations

One of the advantages of the GMP model is that it is modular at a number of levels below the four major subsectors being described here. The production response mechanism is a good example of this modular nature of the model in that new and improved production functions can be inserted into the model with ease when they become available.

Farm Subsector Accounting

When utilizing the GMP to study various grain management programs and policies, it is important to measure their impact on the farm economy. The farm subsector model contains an accounting mechanism which calculates cash flows and accounts for farm food grain operations. In this section the mathematical details of these equations will be described.

Gross Farm Income

Gross farm income from food grain production operations consists of revenue generated from the commercial sale of food grains, plus the

value of food grains produced and used for on-farm purposes (i.e., seed, livestock feed, and farm household consumption). Another meaningful measurement of gross farm income over a particular accounting period (mainly annual) is the change in the value of farm-owned food grain inventory levels.

Revenues

Farm revenues (from food grains) are generated from the commercial sale of domestic food grains. Farmers (normally) operate in a free market and enjoy the choice of marketing their grains to the government, private market, or directly to urban consumers.[7] Furthermore, farmers may market these grains at any point along private market channels. Prices received for farm marketings can therefore vary, depending into which market and market position they are sold. As the GMP model operates, total farm marketings (farm market supplies) are generated in the farm subsector model. Farmers' choices as to how these marketings are divided between government and nongovernment subsectors and the eventual final market transactions are calculated in the price and transaction mechanism, described in detail in Chapter 7. Given the rate of farm sales to the government and nongovernment subsectors, the following accounting equations are used to distribute these sales to the various market position points where farm sales may be made, assign proper market (position) prices, and generate revenue flows to farmers resulting from these transactions.

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[7]Under emergency conditions, the Grain Management Law provides authority to the Minister of Agriculture to order producers or owners of grain to sell their grains to the government or persons designated by the government [22]. These special countermeasure provisions are reflected in the price and transaction mechanism of the GMP model, described in Chapter 7.

(Rough grains to government)

$$RVFSG_i(t) = FSGX_i(t)*EXZ_i*BPMTZ_i*[PB_i(t)-C204_i(t)] \quad (3.58)$$

(Rough grains to production area positions)

$$RVFSPX_i(t) = FSNPX_i(t)*EXZ_i*BPMTZ_i[PF_i(t)-TOLL1_i(t)*PF_i(t)-C205_i(t)] \quad (3.59)$$

(Polished grains to production area positions)

$$RVFSPZ_i(t) = FSNPZ_i(t)*BPMTZ_i*\{PF_i(t)*P201_i + PU_i(t)*[1-P201_i] - C205_i(t)\} \quad (3.60)$$

(Polished grains to wholesale positions)

$$RVFSCZ_i(t) = FSNCZ_i(t)*BPMTZ_i*\{PF_i(t)*P202_i + PU_i(t)*[1-P202_i] - C206_i(t)\} \quad (3.61)$$

(Polished grains to retail stores)

$$RVFSRZ_i(t) = FSNRZ_i(t)*BPMTZ_i\{PF_i(t)*P204_i + PU_i(t)*[1-P204_i] - C208_i(t)\} \quad (3.62)$$

(Polished grains directly to urban consumers)

$$RVFSUZ_i(t) = FSNUZ_i(t)*BPMTZ_i\{PF_i(t)*P205_i + PU_i(t)*[1-P205_i] - C209_i(t)\} \quad (3.63)$$

(Total grains to nongovernment subsectors)

$$RVFSN_i(t) = RVFSPX_i(t) + RVFSPZ_i(t) + RVFSCZ_i(t) + RVFSRZ_i(t) + RVFSUZ_i(t) \quad (3.64)$$

(Total revenue from farm sales)

$$RVFSLS_i(t) = RVFSG_i(t) + RVFSN_i(t). \quad (3.65)$$

Variable definitions for Equations 3.58 through 3.65 above will now be given.

- Revenue flows -

RVFSG = revenue flow from farm sales to government--won/yr

RVFSN = revenue flow from farm sales to nongovernment subsectors--won/yr

RVFSPX = revenue flow from farm sales of rough grains to private market (PM) production area positions--won/yr

RVFSPZ = revenue flow from farm sales of polished grains to PM production area positions--won/yr

RVFSCZ = revenue flow from farm sales of polished grains to PM wholesale positions--won/yr

RVFSRZ = revenue flow from farm sales of polished grains to PM retail positions--won/yr

RVFSUZ = revenue flow from farm sales of polished grains directly to urban consumers--won/yr

- Farm sales -

FSGX = rate of farm sales of rough grains to government sector--MT/yr

FXNPX = rate of farm sales of rough grains to PM production area positions--MT/yr

FSNPZ = rate of farm sales of polished grains to PM production area positions--MT/yr

FSNCZ = rate of farm sales of polished grains to PM wholesale positions--MT/yr

FSNRZ = rate of farm sales of polished grains to PM retail positions--MT/yr

FSNUZ = rate of farm sales of polished grains directly to urban consumers--MT/yr

- Prices -

PB = government purchasing price--won/bag

PF = farm market price--won/bag

PU = urban consumer market price--won/bag

- Parameters -

EXZ = rough to polished conversion factor--proportion

BPMTZ = bags per metric ton (polished grain)--bag/MT

C20X = marketing costs to farmers realized by selling grain at various market positions--won/bag

P20X = weighting factor used to determine current price at various market positions--proportion

TOLL1 = toll milling charge paid by farmers--proportion.

It should be evident in Equations 3.58 through 3.65 that a constant marketing margin is not assumed in the GMP model. Therefore, in calculating a price for a particular market position, a weighted average is calculated from current farm and urban prices. Each sale position is also assumed to have its own expected marketing cost to farmers. The rate of sales to various positions along marketing channels is calculated by the following apportioning equations.

$$FSGX_i(t) = GPUR_i(t)/EXZ_i \tag{3.66}$$

$$FSNPX_i(t) = PFSNPX_i * FSN_i(t)/EXZ_i \tag{3.67}$$

$$FSNPZ_i(t) = PFSNPZ_i * FSN_i(t) \tag{3.68}$$

$$FSNCZ_i(t) = PFSNCZ * FSN_i(t) \tag{3.69}$$

$$FSNRZ_i(t) = PFSNRZ_i * FSN_i(t) \tag{3.70}$$

$$FSNUZ_i(t) = PFSNUZ_i * FSN_i(t) \tag{3.71}$$

where:

GPUR = government purchases (i.e., farm sales to government subsector)--MT/yr

FSN = farm sales to nongovernment subsectors (i.e., private market and urban consumer purchases from farmers)--MT/yr

PFSNXX = proportion of farm sales to nongovernment subsectors to particular position points ($\Sigma PFSNXX_i = 1$)--proportion. $\forall XX$

Value of Food Grain Consumption

The value of food grain consumed on the farm (from domestic production) is also important in farm economy accounting. The following equations are used in the model to generate this category of farm income flow.

(Value of animal feed)

$$VAF_i(t) = QFLV_i(t)*PF_i(t)*BPMTZ_i \quad (3.72)$$

(Value of seed)

$$VSEED_i(t) = QFSE_i(t)*PF_i(t)*BPMTZ_i \quad (3.73)$$

(Value of household consumption)

$$VFCON_i(t) = RFCON_i(t)*PF_i(t)*BPMTZ_i \quad (3.74)$$

where:

VAF = value of domestic food grain used for on-farm animal feed--won/yr

VSEED = value of domestic food grain used for seed--won/yr

VFCON = value of domestic food grain used for farm household consumption--won/yr

QFLV = annual domestic food grain requirement for livestock feed (polished equivalent)--MT/yr

PF = farm market price--won/bag

BPMTZ = bags per metric ton of polished grain--bags/MT

QFSE = annual domestic food grain requirement for seed purposes--MT/yr

RFCON = rate of farm household food grain consumption--MT/yr.

The total value of domestic food grains used for on-farm purposes is given by the following summation.

$$TVFC_i(t) = VAF_i(t) + VSEED_i(t) + VFCON_i(t). \quad (3.75)$$

Value of Food Grain Inventories

A meaningful consideration in calculating farm income over a particular accounting period is to account for the net change in farm inventory levels taking place over the period. Period-end prices are used to calculate the value of the changes in carry-over inventories.

$$VFINVC_i(t) = PF_i(t)*BPMTZ_i[QF_i(t)-QF_i(t-1)] \quad (3.76)$$

where:

VFINVC = value of difference between opening and ending inventories (valued at period-end prices)--won/yr

PF = farm market price--won/bag

BPMTZ = bags per metric ton polished grain--bags/MT

QF = farm-owned food grain inventories--MT.

Expenditures

Farm expenditures (for food grain operations) are broken down into fixed and variable costs of food grain production, value of on-farm food grain consumption, and expenditures for processing food grains for farm household consumption or commercial sale. Marketing costs and milling charges for sale of rough grains are included in the net price computations, indicated in the revenue generation equations already discussed.

Fixed Costs

Fixed costs include those farm expenditures which do not vary with the amount of food grain production (land areas, yields, or production). Payments to principal and interest on farm personal

property, capital investments, depreciation, land payments, rents, taxes, etc., all fall into the category of fixed costs. The model attempts to apportion appropriate amounts of total fixed costs associated with farming operations to food grain production and to each food grain commodity. To do this, the model is provided with estimates of total annual fixed costs for farm operations. The proportion of these fixed costs attributable to food grain production is calculated by dividing total annual food grain production area by total cropland area. Multiple-cropping areas are accounted for in the calculation of this quotient. Next the amount attributable to specific food grain commodities is calculated by dividing total land area of crop by total land area for food grain production, again accounting for double-cropping areas. These fixed cost computations are made through the following equation.

$$CFXD_i(t) = [TFIX(t)] * \frac{\Sigma AREA_i(t)}{[TAREA(t)]} * \frac{AREA_i(t)}{\Sigma AREA_i(t)}$$

(model input)

$$= \left[\frac{TFIX(t)}{TAREA(t)}\right] * AREA_i(t) \qquad (3.77)$$

where:

CFXD = annual fixed cost associated with the production of food grains (by commodity)--won/yr

TFIX = total annual fixed cost associated with farming operations (model input)--won/yr

TAREA = total annual production area, accounting for multiple-cropping areas--hectares

AREA = area planted to specific food grain commodity--hectares.

Equation 3.77 above does not appear very elegant; however, it does provide the user the opportunity to input projections of total annual fixed costs for farming and projections of the total production area. Given these projections, the model can then automatically calculate net profits from food grain production, which include both fixed and variable cost expenditures. These results can be more meaningful in judging the impacts of various grain management programs than calculating gross margins which include variable costs only.

Variable Costs

Variable costs include those farm expenditures associated directly with food grain production. These costs include expenditures for material inputs (seed, fertilizer, chemicals, fuel, or animal feed, etc.), labor, and the cost of production investment capital. In the case of fixed costs, rates of expenditures during the year are assumed constant, equal to the annual average rate. Variable cost expenditures, on the other hand, vary seasonally during the year depending on the farming operation under way.

To simulate the seasonality of variable production costs, use is made of the planting, cultivation, and harvesting profiles generated during the year. Unit material input costs are specified for each production process, and the result is a seasonal cost flow for material inputs. Labor profiles associated with these production processes are utilized to simulate expenditures for farm labor throughout the year. Net revenue flows, which include revenue flows from sales of food grains less variable production cost flows, are accumulated throughout the year, resulting in what is referred to as a food grain production debt pool. This debt pool is used to calculate interest costs during

the year for production investment capital. The equations which generate these variable costs for food grain production will now be described.

(Material input costs)

$$CVMI_i(t) = C201_i(t)\ RPO1_i(t) + C202_i(t)\ RPO2_i(t) + C203_i(t)\ RHO_i(t) \tag{3.78}$$

(Labor costs)

$$CVLAB_i(t) = C211_i(t)\ NHLP1_i(t) + C212_i(t)\ NHLP2_i(t) + C213_i(t)\ HL_i(t) \tag{3.79}$$

(Production investment cost)

$$CVPI_i(t) = AIP_i(t)*DEPTPL_i(t) \tag{3.80}$$

where:

CVMI = variable cost flow associated with material inputs for food grain production--won/yr

C201, C202, C203 = unit material cost parameters associated with particular production operation--won/ha

RPO1 = rate at which planting operations are completed--ha/yr

RPO2 = rate at which cultivation operations are completed--ha/yr

RHO = rate at which harvest operations are completed--ha/yr

CVLAB = variable cost flow associated with hired labor for food grain production--won/yr

C211, C212, C213 = unit labor cost parameters associated with particular production operation--won/man-yr

NHLP1 = labor force required to carry out planting operations at current rate--labor units

NHLP2 = labor force required to carry out cultivating operations at current rate--labor units

HL = labor force required to carry out harvest operations at current rate--labor units

CVPI = variable cost flow associated with interest payments on production debt--won/yr

AIP = annual interest rate paid by farmer for production operating loans--proportion/yr

DEBTPL = production debt pool (see Equation 3.82 below)--won.

Total variable production cost flows are then calculated by the following summation.

$$CFVAR_i(t) = CVMI_i(t) + CVLAB_i(t) + CVPI_i(t). \tag{3.81}$$

Production Debt Pool

The amount of the production debt pool is calculated by accumulating the net revenue flow from food grain operations throughout the year.

$$DEPTPL_i(t) = DEPTPL(t_o) + \int_{t_o}^{t} [RVFSLS_i(\tau)-CFVAR_i(\tau)]d\tau. \tag{3.82}$$

The total food grain production debt pool is calculated by summing the debt pools for individual commodities.

$$TDEBTP(t) = \sum_i DEPTP_i(t). \tag{3.83}$$

As discussed in the section on farm marketings, this total food grain production debt pool can be an important factor influencing the rate of farm marketings throughout the year.

Profits

The farm accounting mechanism calculates several measurements of farm profits from grain operations such as gross margins, disposable

farm income, and net farm income. These are described by the following equations.[8]

Gross Margin

Gross margin is defined as the accumulated net revenue flow over the period of one crop year.

$$QRFGM_i(t) = \int_{t_A}^{t} [RVFSLS_i(\tau) - CFVAR_i(\tau)]d\tau \qquad (3.84)$$

where:

QRFGM = gross margin from farm food grain production--won/yr

RVFSLS = revenue flow from farm commercial sales (see Equation 3.65)--won/yr

CFVAR = variable production costs (see Equation 3.81)--won/yr

t_A = time at which accounting period is initiated--yr.

The accounting period for calculating gross margin, as well as for other measurements of farm profits from grain operations, can be on a calendar year basis, crop year basis, or any other period designated by the model user.

Disposable Farm Income

The farm subsector accounting mechanism defines disposable farm income from food grain operations as follows.

$$\frac{d}{dt} DFINC_i = RVFSLS_i(t) - CFVAR_i(t) - CFXD_i(t) \qquad (3.85)$$

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[8]Probably no terms escape precise definition as completely as business *income* or *profit* [53]. The reader is asked to tolerate the nomenclature used to title the various measurements of farm income and profits, especially if they are inconsistent with his concept of the same measurement.

where:

DFINC = disposable farm income from food grain operations--won

RVFSLS = revenue from off-farm sales--won/yr

CFVAR = variable production costs--won/yr

CFXD = fixed cost associated with food grain production--won/yr.

Again, the accounting period for measuring disposable farm income can be chosen by integrating over the appropriate time interval.

Net Farm Income

The following equation describes net farm income as defined in the farm subsector accounting mechanism.

$$\frac{d}{dt} NFINC_i(t) = RVFSLS_i(t) + TVFC_i(t) - CFVAR_i(t) - CFXD_i(t) \qquad (3.86)$$

where:

NFINC = net farm income from food grain production--won

TVFC = total value of domestic food grains used for farm purposes--won/yr.

Other Measurements of Farm Profits

The farm account mechanism also has the capability of scaling profit measurements to units, perhaps more meaningful to model users. Food grain returns (profits) per farm household, per hectare of cropland, or per farm capita, are common units used.

This concludes the detailed description of the farm subsector component of the GMP model. The private marketing component will be described in the following chapter.

CHAPTER 4

PRIVATE MARKET SUBSECTOR MODEL

Introduction

All nongovernment market grain flows and activities are handled by the private market (PM) subsector component of the GMP model. In order to deal with the real world private market situation for all rice, barley, and wheat, it is necessary to separate the private market component into two submodels--one dealing with domestic food grains, and the other dealing with industrialized wheat and wheat flour. Both of these submodels of the private marketing component will be described in mathematical detail in this chapter.

Domestic Food Grains Submodel

The major function of the private market domestic food grain model is the generation of realistic (nongovernment) farm market demand and urban market supply of domestic food grains. These demand and supply functions reflect profit motives, management decisions, and system constraints of the real world private market subsector. In this section, we will first describe the unconstrained private market demand and supply functions. Next, we will describe the system structure of the private market representing position-point inventories, processing, grain movements, and management decisions which constrain the behavior of the PM model to respond in a realistic manner.

Private Market Supply and Demand

Market supply and demand functions generated in this subsector are the critical link between markets and play a critical role in influencing market prices. Unlike the government subsector, whose demand and supply functions are based on grain management program objectives, the private market subsector--as with any free enterprise--is motivated to act through the quest for profit.

The GMP model recognizes two possibilities for generating profits from private market activities. The *first* is by moving grains through the system and realizing a net profit margin between buying and selling price. Assuming that unit costs do not increase with volume, the more grain that can be moved through the system, the higher will be the total profits. The *second* potential means of generating profits available to the private marketing subsector is by purchasing grains on the farm market, holding them over time, and realizing a profit from increases in urban market prices. This second means of realizing profits naturally has inherent speculative risks with it because of accumulating storage and interest costs over time and the uncertainty of urban market prices in the future.

Both marketing margin (flow) and market speculation (storage) incentives are factors in the demand and supply functions of the PM model. Equations 4.1 and 4.2, although not very revealing in themselves, describe how these factors are combined to represent overall (net) PM demand and supply in the marketplaces.

$$PDEMU_i(t) = FSUPPM_i(t)[1+F35_i(t)] + Z35_i(t) + Z31_i(t) \qquad (4.1)$$

(flow) (storage) (milling operations)

$$PMKTSU_i(t) = UDEMPM_i(t)[1+F35_i(t) - Z35_i(t) \quad (4.2)$$

(flow) (storage)

where:

PDEMU = unlagged version of private market demand--MT/yr

PMKTSU = unlagged version of private market supply--MT/yr

FSUPPM = exponential average of farm marketings available to private market (see Equation 4.5)--MT/yr

UDEMPM = exponential average of urban demand available to private market (see Equation 4.6)--MT/yr

F35 = factor used to represent the margin (flow) effect of PM supply and demand (see Equations 4.7 and 4.8)--no units

Z35 = speculative (storage) incentive component of PM supply and demand (see Equation 4.26)--MT/yr

Z31 = component of the PM demand function designed to represent demand for rough grains by private market millers throughout the year to sustain milling operations (see Equation 4.37)--MT/yr.

Since total PM demand and supply are represented in Equations 4.1 and 4.2, it is more realistic to assume that these demands and supplies will exhibit some momentum and not respond instantaneously to changes in inputs. This is accomplished through the following smoothing equations for private demand and supply.

$$\frac{d}{dt} PDEM_i(t) = -\frac{1}{DEL4} PDEM_i(t) + \frac{1}{DEL4} PDEMU_i(t) \quad (4.3)$$

$$\frac{d}{dt} PMKTS_i(t) = -\frac{1}{DEL4} PMKTS_i(t) + \frac{1}{DEL4} PMKTSU_i(t). \quad (4.4)$$

The functions of the individual terms of Equations 4.1 and 4.2 above will require a substantial amount of explanation and mathematical description. Each of these terms will be described under a separate heading below.

Marketing Margin (Flow Component)

The first terms of Equations 4.1 and 4.2 represent the flow component of PM demand and supply. The base variables about which PM flow demand and supply are varied (depending on marketing margin) are $FSUPPM_i(t)$ and $UDEMPM_i(t)$, defined briefly under the above equations. The equations for these variables are indicated below.

$$\frac{d}{dt} FSUPPM_i(t) = - \frac{1}{DEL35} FSUPPM_i(t) + \frac{1}{DEL35} [FMKTS_i(t)-GPUR_i(t)] \quad (4.5)$$

$$\frac{d}{dt} UDEMPM_i(t) = - \frac{1}{DEL35} UDEMPM_i(t) + \frac{1}{DEL35} [UDEM_i(t)-GSLS_i(t)] \quad (4.6)$$

where:

FMKTS = farm marketings--MT/yr

GPUR = government domestic purchases--MT/yr

UDEM = urban demand--MT/yr

GSLS = government sales--MT/yr

DEL35 = time delay used in smoothing equations--yrs.

The solutions to Equations 4.5 and 4.6 represent the exponential averages of the excess of farm marketings over government purchase and the excess of urban demand over government sales, respectively.

The model assumes that when marketing margins are *normal*, the flow component of PM demand and supply is represented by $FSUPPM_i(t)$ and $UDEMPM_i(t)$, respectively. However, when the margin deviates from *normal*, adjustments are made to these two functions by the factor $[1+F35_i(t)]$ in Equations 4.1 and 4.2. Consider the following equation for the unsmoothed value of $F35_i(t)$.

$$F35U_i(t) = ELAS35_i \frac{PU_i(t)-PF_i(t)}{PFO_i(t)} - C35_i \quad (4.7)$$

where:

F35U = unsmoothed version of F35 which represents the proportionate change in *normal* PM flow demand and supply (FSUPPM and UDEMPM) due to prevailing marketing margins--proportion

ELAS35 = parameter (elasticity) which describes the proportionate change in normal PM flow demand and supply due to a proportionate change in the net profit margin between farm and urban market prices--no units

PU = urban retail price--won/bag

PF = farm market price--won/bag

PFO = smoothed value of farm market price--won/bag

C35 = normal profit margin--proportion.

The smoothed versions of $F35U_i(t)$ and $PF_i(t)$ in the above equation are the solutions to the following differential equations.

$$\frac{d}{dt} F35_i(t) = - \frac{1}{DEL35} F35_i(t) + \frac{1}{DEL35} F35U_i(t) \qquad (4.8)$$

$$\frac{d}{dt} PFO_i(t) = - PFO_i(t) + PF_i(t). \qquad (4.9)$$

Equation 4.9 implies a time constant (delay) of one year, used to smooth farm market price for this purpose.

Suppose the model assumed a normal profit margin between farm and urban price of, say, 10 percent (i.e., $C35_i = 1.10$). When this profit margin is actually being realized, $F35_i(t)$ of Equations 4.1 and 4.2 will move toward zero, and the flow component of PM demand and supply will move toward the current prevailing values of FSUPPM and UDEMPM, respectively. Viewing Equation 4.7, it can be seen that as the profit margin between farm and urban price becomes less than normal (less than $C35_i$), F35 will move toward a negative number, and the flow demand and supply terms of Equations 4.1 and 4.2 will move

to values less than the prevailing values of FSUPPM and UDEMPM, respectively.

We have described how the flow component of PM demand and supply responds to changing margins between farm and urban market prices. As margins increase, the incentive to deal in more grains also increases; both PM supply and demand increase. The effect of this (as we will see later) is to increase farm prices (increased demand) and decrease urban prices (increased supply), thus reducing the marketing margin. The opposite is true in the case of depressed marketing margins. As margins decrease, the incentive to deal in grains also decreases, and both PM demand and supply decrease. The effect of this is to decrease farm prices (decreased demand) and to increase urban prices (increased supply, thus increasing the marketing margin. The net effect of the flow incentive factor is the influence it has upon maintaining normal farm and urban market price margins.

Market Speculation (Storage Component)

The second term, $Z35_i(t)$, of Equations 4.1 and 4.2, represents the speculative storage component of PM demand and supply. The GMP does not attempt to model optimal storage behavior, but does attempt to reflect rational storage behavior when obvious profitable storage situations exist [29]. Some storage is necessary in the private market subsector to sustain normal operations. Buffer stocks are necessary along private marketing channels to enable timely response to sudden increases in urban demand, to sustain milling operations, and to replenish operating stocks as they are depleted. The storage described in this section is that amount over and above the normal storage

requirements and held for the sole purpose of profit. Normal PM storage requirements will be discussed later in this chapter.

Before getting into the detailed description of the speculative storage component of PM demand and supply, it will be beneficial to briefly outline the kinds of information sought by the model in its attempt to replicate rational private market speculative behavior.

1. The model must be capable of recognizing a feasible storage situation when it is present.
2. The model must have a means of anticipating the duration of a feasible storage situation.
3. The model must have a means of anticipating the amount of demand available to the PM subsector during the feasible storage period determined in 2 above.

The first item listed above is the only information the model can determine with certainty. The second and third items require forecasts of urban market prices and demand. Once a feasible storage situation is recognized by the model, forecasts are made to determine the information in items 2 and 3 above. This information is then used to adjust the desired PM inventory levels in an attempt to realize full benefits of holding grains through the feasible storage period. Model processes than take over to simulate real world system responses and consequences of this attempt of the PM subsector to adjust its stock levels to these desired levels.

Feasible Storage Periods

In this section we will describe the interpretations and assumptions used by the GMP model in determining the presence of feasible storage periods, i.e., those periods of time during which indications are that grain can be held over time for increased profits.

Although the GMP model itself does not assume constant marketing margins in generating market prices, the added complexity of dealing with varying margins in modelling storage behavior is not warranted. Assuming constant margins when modelling speculative storage behavior does not yield truly optimal results, but still reflects a rational attempt by private market entrepreneurs to react to *obvious* market opportunities for increased profits. Such an assumption may also be more in line with the real world situation in which it is quite doubtful that private grain storers exhibit optimal behavior.

Using the assumption of a constant marketing margin (or at least the assumption of a marketing margin which tends to re-establish itself, as in the GMP model), the following condition is interpreted by the model to represent a feasible storage situation.

$$\frac{d}{dt} PU_i(t) > PINT1[PF_i(t)+C301A_i] + C303_i \qquad (4.10)$$

where:

PU = urban retail price--won/bag

PF = farm market price--won/bag

PINT = prevailing interest rate for private entrepreneurs--proportion/yr

C301A = cost associated with buying--won/bag

C303 = average storage cost--won/bag-yr.

The expression on the right-hand side of Equation 4.10 defines the rate at which costs associated with holding grains accumulate over time. Interest rates operate on the original value of grain investments, and storage and handling costs accumulate over time on grain inventories. For later notational convenience, the following

variable will be used to represent the expression on the right-hand side of Equation 4.10.

$$AVCHP_i(t) = PINT1[PF_i(t)+C301A_i] + C303_i \qquad (4.11)$$

where:

AVCHP = average variable cost of holding private purchases--won/MT-yr.

Assuming that holding costs accumulate at a constant rate, these costs are represented in Figure 4.1 by the slope of the straight lines emanating from the buying price curve. The value along any particular line represents the accumulated unit cost associated with grain purchased at a previous point in time. These lines will be called the "investment cost lines." Notice that the *slope* of the investment cost lines depends on the value of the original grain investment as well as storage costs.

Figure 4.1 depicts the assumption of a constant marketing margin. Therefore, the feasible storage periods illustrated in the figure correspond to all time points at which the slope of the investment cost line, emanating from the buying price curve, is less than the slope of the selling (or buying) price curve. Time point t_a in the figure corresponds to a feasible storage situation, since the investment cost line emanating from the buying price at that time is initially under the buying price curve. Time point t_b in the figure does not correspond to a feasible storage situation. The time period (t_o,t_c) in the figure corresponds to a feasible storage period as defined in Equation 4.10 above.

Considering the feasible time period illustrated in Figure 4.1, at time t_o the model first recognizes the feasible storage situation.

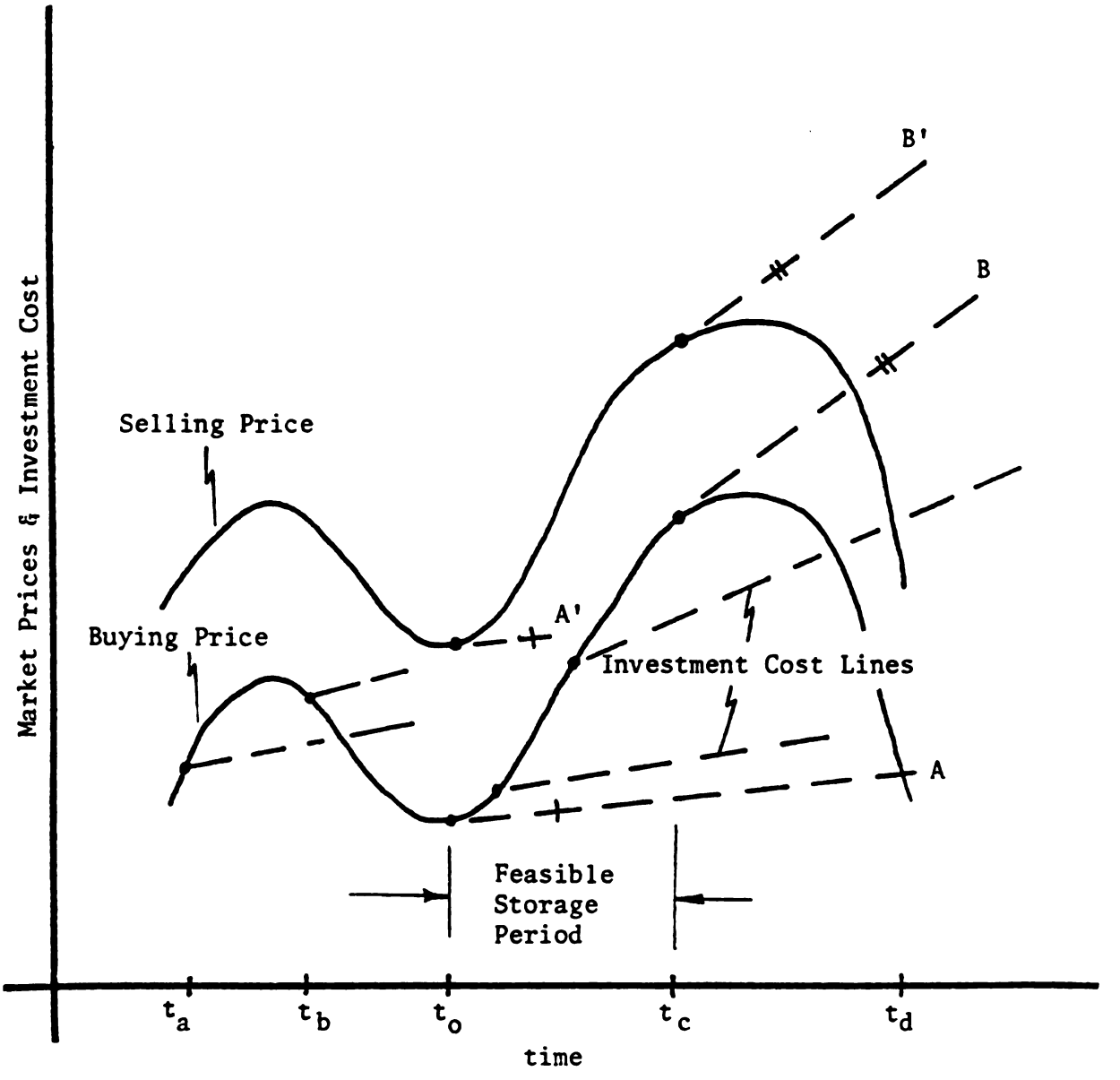


Figure 4.1. Feasible Storage Period With Constant Marketing Margin.

Suppose the prices beyond t_o represent forecasted prices. Following the investment cost line (labelled A), we see that, although holding costs are increasing over time, the marketing margin between the investment cost line for grains purchased at t_o and (forecasted) selling price increases over time. Ideally, it would be most profitable at t_o for the PM subsector to build its stock levels (above normal operating levels) to an amount adequate to cover the cumulative demand for PM grains for the period (t_o,t_d). Of course, this cannot be done instantaneously at time t_o, so the ideal stock level upon which purchases are based decreases over time. At t_c the ideal stock level upon which purchases are based is zero, since the margin between the investment cost line B, for purchases made at t_c, and selling price only decrease beyond t_c.

To simplify the calculations needed, the amount of desired PM (speculative) stock levels during a feasible storage period is set equal to the cumulative demand for PM grains remaining during the particular feasible storage period. In the situation illustrated in Figure 4.1, the desired PM stock levels at t_o are set equal to the anticipated cumulative demand for PM grains during the period (t_o,t_c). As time progresses, the desired PM stock levels decrease to reflect the amount of anticipated cumulative demand for PM grains remaining until time t_c. At time t_c the amount of desired PM speculative stock level is zero.

Figure 4.2 illustrates the desired PM inventory levels throughout the feasible storage period represented in Figure 4.1 above. To add numerical clarity to the illustration, the following assumptions are made: (1) forecasted demand throughout the feasible storage

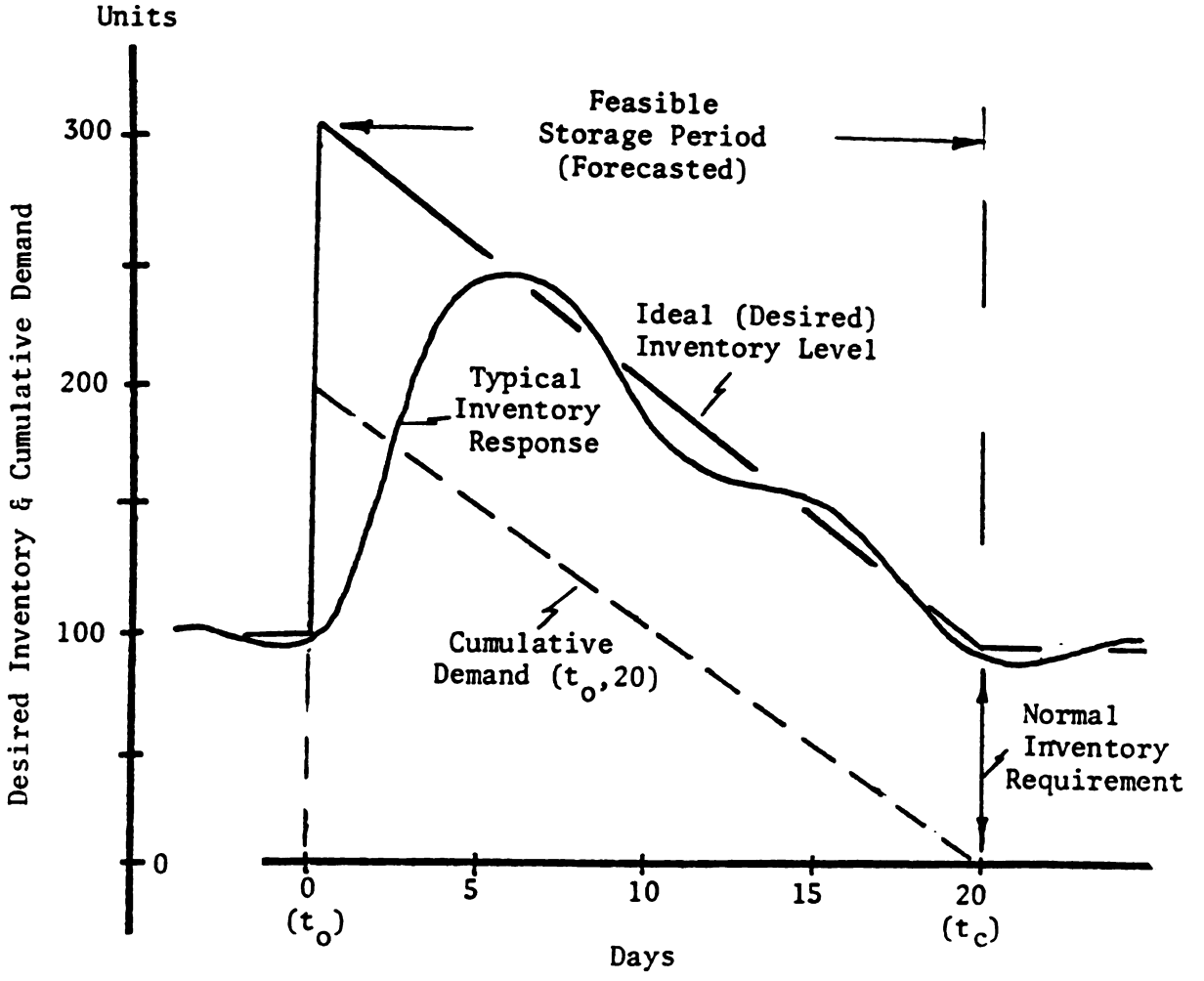


Figure 4.2. Desired Inventory During Feasible Storage Period.

period remains constant at ten units per day, (2) the feasible storage period is projected to last twenty days, and (3) the PM subsector operates on a normal inventory level of 100 units. Figure 4.2 also depicts a typical response in PM inventory levels that might be expected during the speculative storage period.

A detailed description of the method used to forecast market conditions during feasible storage situations will now be given.

Market Forecasting

Of primary importance to private market entrepreneurs engaged in storing food grains for the purpose of profiting from market fluctuations is some notion regarding the future of the market. Price and demand forecasts are the key elements to be considered in these grain storage decisions. Price observation and forecasting is, of course, important because successful grain storers build stocks during periods of low prices and decrease stocks during periods of relative high prices. Decisions regarding the timing of *when* to begin increasing stock levels, and (some notion about) *how long* a period of profitable grain storage may persist, come about through market price observation and forecasting. Forecasting of demand for food grains over periods of profitable storage is also important because it gives an indication of *how much* grain can be held profitably during these periods.

Individuals engaged in price and demand forecasting use a multitude of factors for their future speculations. Government-announced activities such as imports, exports, support prices, crop conditions, and experiences of past patterns of market prices and demands are some of the factors influencing these forecasts. The forecasting mechanism developed for the GMP model does not attempt to consider all the

above factors in generating price and demand forecasts that mimic what might be in the minds of those individuals of the private market engaged in grain storage activities. Such an attempt would necessitate too much attention to this single aspect of the GMP model with the benefit of the added sophistication being questionable in meeting the needs of the overall model. What is felt to be one of the more important factors influencing the forecasting of food grain prices and demand also happens to be one that easily lends itself to mathematical modelling. This factor is simply the observation of actual market prices and demands (available to the PM subsector) over time, remembering these observations clearly for the most recent past, but then slowly forgetting these observations as they get deeper and deeper into the past. Such a process closely resembles the human learning and forgetting processes. If little or no consistency can be discerned in price and/or demand patterns from year to year, a relatively unclear notion or forecast of the future will result, implying, in the human context, a lack of confidence in the forecasts generated and less willingness to risk speculative market activities. As consistent patterns begin to develop in price and demand observations, and as these patterns begin to persist from year to year (or season to season), forecasts of the future of the grain market are reinforced by past experience and become clearer. This implies, again in human context, the building of confidence in the future of the market and more willingness to risk speculative market storage activities.

The mechanism used in the GMP model to simulate price and demand forecasting stores what is called a one-year "impression curve" of past years' prices and demands related to the private marketing

subsector. This impression curve is formed at the beginning of the simulation run from actual monthly data from several years prior to the starting time of the run. These data are pulled from the GMP data bank and undergo a series of exponential averaging of like-month data, weighting most recent years more heavily, and time series smoothing to arrive at the one-year impression curve. This curve is then loaded into a specially designed cyclic boxcar delay function [28]. The above process is illustrated in Figure 4.3 below, using four years' (48 months) period data to form the impression curve with forty data points being loaded into the cyclic boxcar delay.

Now, as the model run proceeds through time and new values are generated for prices and demands, these new values are merged with corresponding time-point values of the impression curve. Using the boxcar delay with forty cells illustrated in Figure 4.3, after the model run has proceeded 1/40 year, the new value of, say, price generated by the model corresponds to the exact time of year represented by the last (40th) cell of the boxcar. The impression curve is reformed by shifting the information in the boxcar back one cell (1/40 year). The information in the 40th cell is not lost but is merged exponentially with the new value of price at t_o+1/40 and loaded into the first cell of the impression curve boxcar. The process occurs (intermittently) throughout the model run so that a new impression curve, reflecting both past data and model-generated data, is available whenever forecasts are made.[1] Forecasting is done by projecting the impression

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[1]Since the impression curve is used only for forecasting, it is updated only when it is needed. New values of model-generated data are held in buffer arrays until an update is required. Boxcar shifts and merging of old impression curve data occur only at these times, greatly reducing the amount of data manipulation required of the computer.

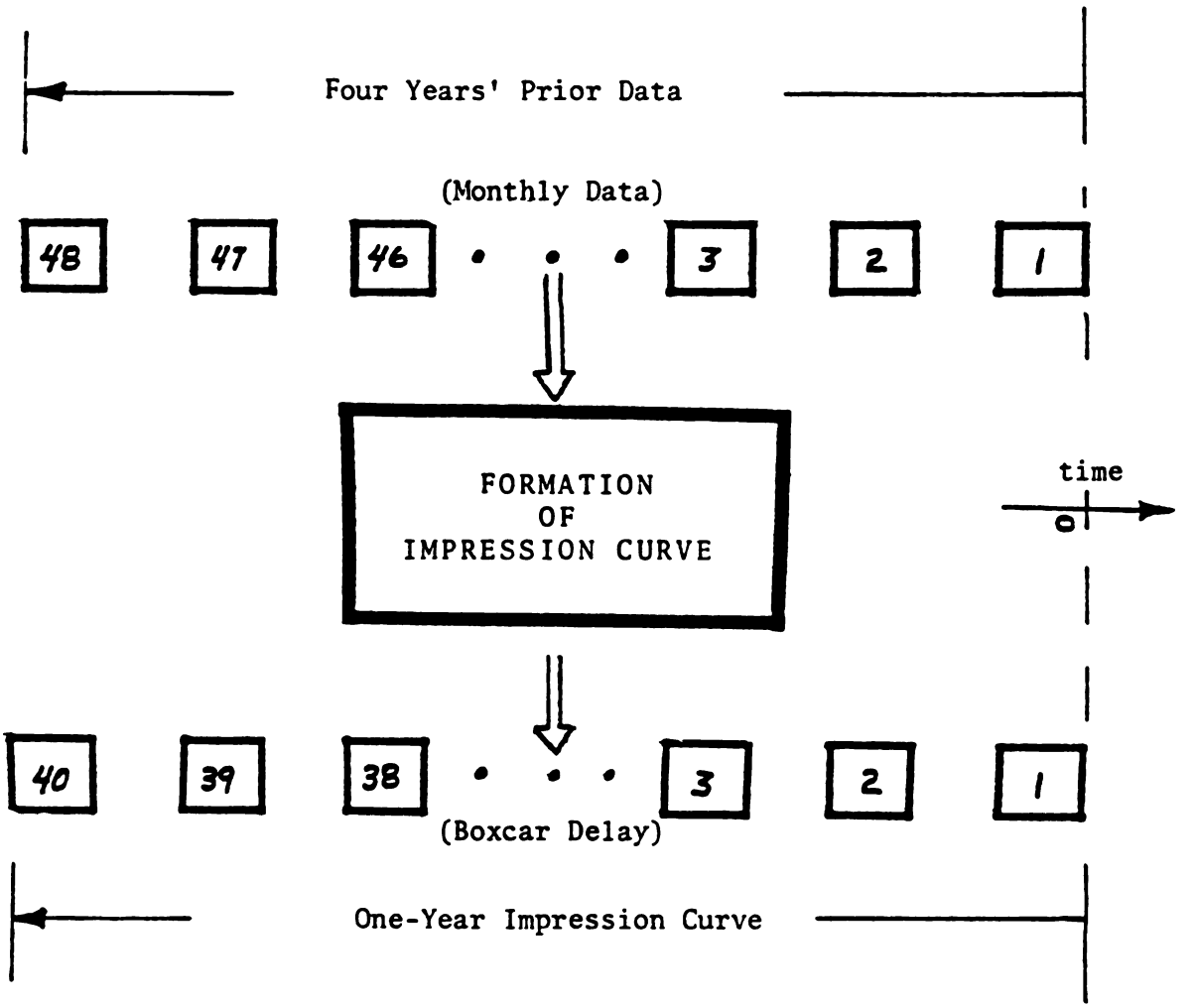


Figure 4.3. Formation of Impression Curve.

curve into the future. Figure 4.4 illustrates an impression curve, such as described above, along with the resulting forecast. We will now describe precisely how a feasible storage situation is determined by the GMP model, how market forecasts are made, and how the information gained from forecasts is transformed into adjustments to PM demand and supply.

Whenever a forecast is required (i.e., when the model detects the condition represented in Equation 4.10 as being present), a regression equation is estimated for the data held in the boxcar delay, representing the past year impression curve. The linear statistical form of a Fourier Series with a constant and trend term is used to estimate the impression curve function. The Fourier Series equation used includes frequencies up to the third harmonic, giving it the capability of fitting cycles of the impression curve with durations down to two months.

$$YP_i(t) = b_{i1} + b_{i2}t + \sum_{n=1}^{3} (b_{i,2n+1} \sin n\omega ot + b_{i,2n+2} \cos n\omega ot) \qquad (4.12)$$

where:

YP = expected value of the projected price (or demand) at time t--won/bag (or MT/yr)

b = coefficients of the regression equation

ωo = fundamental frequency ($2\pi/T$) of the Fourier Series--radians/yr
(T = the period of the Fourier Series--1 year)

i = commodity index

t = time, with t=0 at time of estimation--yrs.

The general matrix form of Equation 4.12 is given by the following equation.

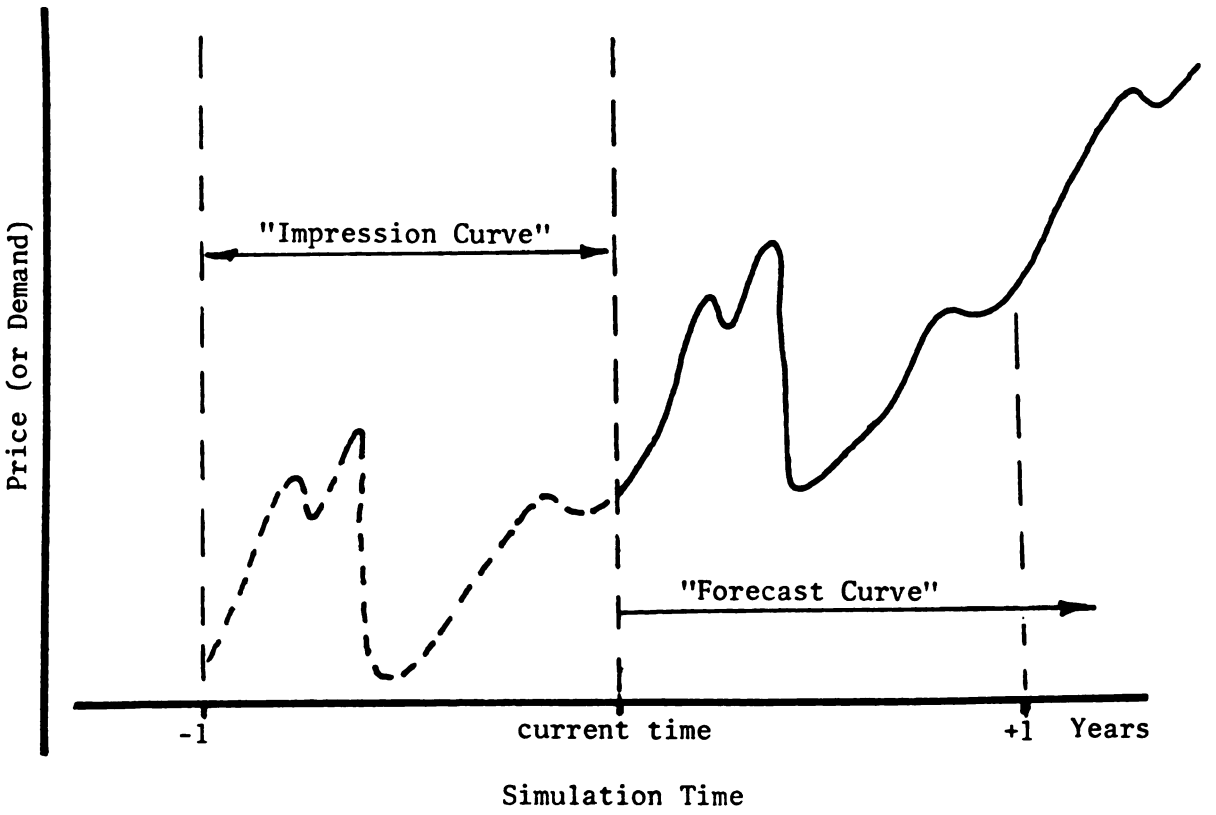


Figure 4.4. Illustration of Forecasting Technique.

$$E[P] = TB \tag{4.13}$$

where:

E = expected value operator

P = 40 x NC (number of commodities) matrix with each column representing the random vector time series (for each commodity) of values of the impression curve at corresponding values of time. (t = -.025, -.05, -.075, . . . , -1.0)--won/bag (or MT/yr)

B = 8 x NC matrix of the random value coefficients of Equation 4.12

T = 40 x 8 matrix of the regressors (functions of time of Equation 4.12 taken for t = -.025, -.05, -.075, . . . , -1.0, i.e.,

$$T = \begin{bmatrix} 1 & 1 & & 1 \\ -.025 & -.05 & \cdots & -1. \\ \sin 2\pi(-.025) & \sin 2\pi(-.05) & \cdots & \sin 2\pi(-1.) \\ \cos 2\pi(-.025) & \cos 2\pi(-.05) & \cdots & \cos 2\pi(-1.) \\ \vdots & \vdots & \vdots & \vdots \\ \sin 6\pi(-.025) & \sin 6\pi(-.05) & \cdots & \sin 6\pi(-1.) \\ \cos 6\pi(-.025) & \cos 6\pi(-.05) & \cdots & \cos 6\pi(-1.) \end{bmatrix}.$$

The problem, of course, is the estimation of the matrix of coefficients B of Equation 4.13. The formula for least squares estimation of these coefficients is given by

$$\hat{B}\ (T'T)^{-1}T'P \tag{4.14}$$

where, $\hat{B}$ is an 8 x NC matrix with each column vector representing the estimated value (for each commodity) of the coefficients of Equation 4.12. T and P are defined above.

$(T'T)^{-1}T'$ in Equation 4.14 is an 8 x 40 matrix calculated off-line (on a one-time basis) and contained in the model as data array. The forecasting model of Equation 4.12 can therefore be estimated for any

commodity at any time during the simulation run by post-multiplying this matrix by the appropriate time-series contained in the impression curve boxcar delay.

Let us suppose the above matrix multiplication has just been performed by the model to estimate the coefficients of the impression curve function. We can write Equation 4.12 as follows.

$$YP_i(t) = \hat{b}_{i1} + \hat{b}_{i2}t + \hat{b}_{i3} \sin 2\pi t + \hat{b}_{i4} \cos 2\pi t + \hat{b}_{i5} \sin 4\pi t + \hat{b}_{i6} \cos 4\pi t + \hat{b}_{i7} \sin 6\pi t + \hat{b}_{i8} \cos 6\pi t \quad (4.15)$$

where:

YP = expected value of projected price (or demand)--won/bag (or MT/yr)

$\hat{b}$ = estimated coefficients of impression curve function.

The first thing the model must do when arriving at a feasible storage situation is to estimate how long the present feasible storage period will persist. This is done by running t forward and checking for when the following condition first occurs.

$$\frac{d}{dt} YPU_i(t) \leq PINT1[YPF_i(t)+C301A_i] + C303_i \quad (4.16)$$

where:

YPU = forecasted value of urban price, expressed in the form of Equation 4.15--won/bag

YPF = forecasted value of farm market price--won/bag

PINT1 = prevailing interest rate for private market entrepreneurs--proportion/yr

C301A = cost associated with buying--won/bag

C303 = average storage cost--won/bag-yr.

Since constant (normal) marketing margins are assumed for forecasting purposes,

$$YPF_i(t) = YPU_i(t)/C35_i \tag{4.17}$$

where, C35 is the normal profit margin between farm price and urban price, expressed in proportion (see Equation 4.7).

The expression on the right-hand side of Equation 4.16 is the *forecasted* average cost of holding private purchases, i.e.,

$$FAUCHP_i(t) = PINT1[YPF_i(t)+C301A_i] + C303_i \, . \tag{4.18}$$

The expression for the derivative $\frac{d}{dt} YPU_i(t)$ in Equation 4.16 is, of course,

$$\begin{aligned}\frac{d}{dt} YP_i(t) = \hat{b}_2 &+ 2\pi \hat{b}_{i3} \cos 2\pi t - 2\pi \hat{b}_{i4} \sin 2\pi t \\ &+ 4\pi \hat{b}_{i5} \cos 4\pi t - 4\pi \hat{b}_{i6} \sin 4\pi t \\ &+ 6\pi \hat{b}_{i7} \cos 6\pi t - 6 \hat{b}_{i8} \sin 6\pi t \, .\end{aligned} \tag{4.19}$$

A simple "IF" check loop in the program enables the model to quickly identify the value of t (say, t=t*) when the condition of Equation 4.16 first occurs. This time is the anticipated length of the present feasible storage period, or also called 'the time remaining in the feasible storage period' (i.e., $TRFSP_i(t_o)=t^*$).

Next, the model must estimate how much urban demand will be available to the PM subsector throughout the feasible storage period. Letting $YD_i(t)$ represent the expected value of projected demand, and $\hat{c}$ represent the estimated coefficients of the demand estimating

equation, we have upon integrating,

$$\int_0^{t^*} YD_i(\tau)d\tau = \hat{c}_{i1}t + \frac{\hat{c}_{i2}t^2}{2} - \frac{\hat{c}_{i3}}{2\pi}\cos 2\pi t + \frac{\hat{c}_{i4}}{2\pi}\sin 2\pi t - \frac{\hat{c}_{i5}}{4\pi}\cos 4\pi t + \frac{\hat{c}_{i6}}{4\pi}\sin 4\pi t - \frac{\hat{c}_{i7}}{6\pi}\cos 6\pi t + \frac{\hat{c}_{i8}}{6\pi}\sin 6\pi t \Bigg|_0^{t^*} \qquad (4.20)$$

$$\int_0^{t^*} YD_i(\tau)dt = \hat{c}_{i1}t^* + \frac{\hat{c}_{i2}t^{*2}}{2} - \frac{\hat{c}_{i3}}{2\pi}\cos 2\pi t^* + \frac{\hat{c}_{i4}}{2\pi}\sin 2\pi t^* - \frac{\hat{c}_{i5}}{4\pi}\cos 4\pi t^* + \frac{\hat{c}_{i6}}{4\pi}\sin 4\pi t^* - \frac{\hat{c}_{i7}}{6\pi}\cos 6\pi t^* + \frac{\hat{c}_{i8}}{6\pi}\sin 6\pi t^* + \frac{\hat{c}_{i3}}{2\pi} + \frac{\hat{c}_{i5}}{4\pi} + \frac{\hat{c}_{i7}}{6\pi}. \qquad (4.21)$$

We have described how the GMP model generates the information outlined as needed to replicate a valid attempt by private market entrepreneurs to engage in successful storage activities. We will now describe how this information is used to generate appropriate changes in the storage component of the PM demand and supply functions.

Desired Inventories Based on Market Forecasting

To repeat ourselves, upon first recognition of a feasible storage situation defined in Equation 4.10, the GMP model updates the impression curve of past data and model output observations and

forecasts future market prices and demand for PM grains. The time remaining in the new feasible storage period is determined as per the conditions of Equation 4.17 and is represented by the variable $TRFSP(t_o)$.

The value of cumulative urban demand for PM grains remaining in the feasible storage period $[DRFSP_i(t_o)]$ is calculated by Equation 4.21, letting $t^* = TRFSP(t_o)$.

As the simulation model progresses through time, the values of the time and demand remaining during the feasible storage period are

$$TRFSP_i(t) = TRFSP_i(t_o) - r(t-t_o) \tag{4.22}$$

and

$$DRFSP_i(t) = DRFSP_i(t_o) - \int_{t_o}^{t} UDEMPM_i(\tau)d\tau \tag{4.23}$$

where, $r(t-t_o)$ is the translated unit ramp function and UDEMPM is the amount of urban demand available to the PM subsector as defined in Equation 4.6.

As can be seen from the above, forecasts and lengthy computations need not be made every simulation cycle during a feasible storage period. Long storage periods may require updating forecasts intermittently during the period to improve results. However, the GMP is continually monitoring the feasible storage situation expressed in Equation 4.10, and, if the condition ends prematurely, appropriate adjustments are made to the desired PM inventory levels.

Now, the desired overall PM inventory level is continually calculated as follows.

$$QPMDS_i(t) = QPMD_i(t) + \max[0, DRFSP_i(t)] \tag{4.24}$$

where:

QPMDS = total desired inventory level for the PM subsector--MT

QPMD = desired normal inventory level for the PM subsector--MT

max = maximum function

DRFSP = demand remaining in the present feasible storage period--MT.

Using automatic feedback control theory, the amount of PM demand and supply reflecting the storage component of the model is given by the following equations.

$$QPMER_i(t) = QPMDS_i(t) - QPM_i(t) \tag{4.25}$$

$$Z35_i(t) = G35A*QPMER_i(t) + G35B \frac{d}{dt} QPMER_i(t) \tag{4.26}$$

where:

QPMER = observed error in total PM inventory level--MT

QPM = actual total PM inventory level--MT

Z35 = storage component of PM demand and supply (see Equations 4.1 and 4.2)--MT/yr

G35A, B = gains applied to the PM inventory control function representing the intensity of demand and supply responses to detected inventory errors--appropriate units.

This completes the detailed discussion of the private market demand and supply functions displayed in Equations 4.1 and 4.2. The $Z31_i(t)$ term in Equation 4.1 represents the demand for rough grains by private market millers throughout the year to sustain (or attempt to sustain) milling operations. This term will be described in detail later in this chapter.

We are now ready to discuss some of the important internal operations of the PM subsector model in mathematical detail.

Private Market Domestic Grain Operations

In this section we will describe the mathematical structure of the PM subsector model which enables it to replicate real world grain storage, grain movements, and processing activities occurring within the private market subsector. This aspect of the GMP model is very important because it is through this mechanism that the efficiencies, inefficiencies, capacities, constraints, and general operating behavior of the private marketing system are reflected.

A detailed system diagram of the PM subsector operations model is presented in Figure 4.5. Most of the mathematical relationships described in this section, as well as the important PM demand and supply relationships described earlier, are depicted in the diagram in symbolic form. The reader should find the diagram to be a very useful reference throughout this discussion.

Domestic Grain Inventories

Private market domestic grain inventories are disaggregated across three dimensions: (1) commodity groups, (2) physical grain forms, and (3) position points. The commodity groups identified are rice and barley, with "barley" being an aggregate of common barley, naked barley, and domestic wheat. Physical forms explicitly identified are rough (or paddy) and polished grains. Position points identified are production areas, consumption area terminal points, and retail sales stores. Table 4.1 below gives a clear picture of the disaggregation of PM domestic inventories.

Rough grain inventories at production area positions are represented by the following differential equation.

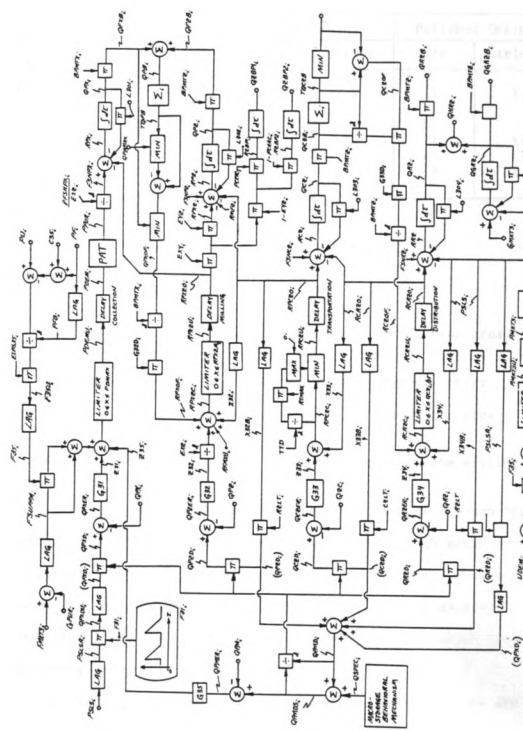


Figure 4.5. System Diagram--Private Market Grain Operations.

Table 4.1. Disaggregation of PM Domestic Grain Inventories.

Position Points	Rough Grains		Polished Grains	
	Rice	Barley	Rice	Barley
Production areas	X	X	X	X
Consumption area terminal points			X	X
Retail sales stores			X	X

$$\frac{d}{dt} QPX_i(t) = - L301_i \; QPX_i(t) + FSNPX_i(t) - RPXZO_i(t) \qquad (4.27)$$

where:

QPX = quantity of rough grains located at production area position points--MT

L301 = expected loss rate during storage--proportion/yr

FSNPX = farm sales of rough grains to PM production area position points--MT/yr

RPXZO = rate at which rough grains move through the milling process--MT/yr.

In reality, all variables in Equation 4.27 above are non-negative; therefore, the only means by which production area rough grain inventories can increase is through farm sales of rough grains to the PM subsector. Likewise, the only means by which these inventories can decrease is through normal storage losses or by the milling process which transforms rough grains into polished grains and by-products.

Polished grain inventories at production area positions are represented by the following differential equation.

$$\frac{d}{dt} QPZ_i(t) = - L302_i \; QPZ_i(t) + EXZ_i \; RPXZO_i(t) + FSNPZ_i(t) - RMFZ_i(t) - RPCZO_i(t) \qquad (4.28)$$

where:

QPZ = quantity of polished grain inventories at production area position points--MT

L302 = expected loss rate during storage--proportion/yr

EXZ = rough to polished conversion factor--no units

RPXZO = rate at which rough grains move through polishing process--MT/yr

FSNPZ = farm sales of polished grains to production area positions--MT/yr

RMFZ = rate of custom milling operations for farmers--MT/yr

RPCZO = rate at which polished grains move from production areas to consumption areas--MT/yr.

Each term in Equation 4.28 describes a means by which production area polished grain inventories may change. The expected loss from storage is reflected by the first term on the right-hand side of the equation. According to Equation 4.28, inventories may also decline by the movement of custom-milled grains back to the farm subsector and by the transfer of grains from production area positions into consumption areas. The second and third terms of Equation 4.28 indicate that these inventories may increase due to milling operations on rough grains and farm sales of polished grains into PM production area positions.

Next, we will examine the differential equation representing PM inventories of food grains at consumption area terminal point positions.

$$\frac{d}{dt} QCZ_i(t) = - L303_i \; QCZ_i(t) + RPCZO_i(t) + FSNCZ_i - RCRZO_i(t) \qquad (4.29)$$

where:

QCZ = quantity of polished grain at consumption area terminal point positions--MT

L303 = expected loss rate during storage--proportion/yr

RPCZO = rate at which polished grains move from production areas to consumption areas--MT/yr

FSNCZ = farm sales of polished grains to PM consumption area terminal point positions--MT/yr

RCRZO = rate at which grains move from consumption area terminal point positions to retail sales store positions--MT/yr.

In Equation 4.29 a storage loss term is again present. The movement of grains from production area positions to consumption areas (a nonreversible process) is present in Equation 4.29 with a positive sign. Farm sales to consumption area positions are indicated by the second positive term. The last term indicates that these terminal position inventories decrease by the transfer of grains to retail sales store positions.

Retail sales store position inventories include both private and government grains, since registered private market grain retailers are the primary outlet for government-controlled grains. Not all private retail stores handle government grains, but those that do handle both government and private market grains. Since the PM subsector model has only one retail store position representing the aggregate of all sales stores, both government and private stocks are identified at this position. The following differential equations depict the dynamics of private and government grain inventories at PM retail sales store positions.

(Private grains)

$$\frac{d}{dt} QRZ_i(t) = - L304_i \, QRZ_i(t) + RCRZO_i(t) + FSNRZ_i(t) - PSLS_i(t) \qquad (4.30)$$

(Government grains)

$$\frac{d}{dt} QGRZ_i(t) = - L305_i \, QGRZ_i(t) + GMKTS_i - GSLS_i(t) \qquad (4.31)$$

where:

QRZ = quantity of PM grains at retail sales store positions--MT

QGRZ = quantity of government-controlled grains at retail store positions--MT

L304, L305 = expected loss rates during storage--proportion/yr

RCRZO = rate at which grains move from consumption area terminal point positions to retail sales store positions--MT/yr

FSNRZ = farm sales of polished grains to PM retail sales store positions--MT/yr

PSLS = rate of PM grain sales to consumers--MT/yr

GMKTS = government grain releases to retail sales store positions--MT/yr

GSLS = government grain sales to consumers--MT/yr.

Both Equations 4.30 and 4.31 account for expected stock losses while in retail sales store positions. Equation 4.30 indicates that private grain stocks at this position increase by transferring grains from consumption area terminal points into retail store positions and also by farm sales of polished grains into this position of the PM system. Besides the normal losses which occur, these PM inventories decrease only through actual sales to the consumer. Equation 4.31, representing government-controlled grains at this position, indicates that government marketings (or releases) and actual sales to the consumer household are not necessarily simultaneous. The government releases stocks to retail sales store positions, represented by $GMKTS_i$, but the consumer ultimately determines, by his demand and choice between government and private grains, the actual rate of government grain sales, $GSLS_i$, out of retail sales positions. More will be said about simulating consumer choices when we discuss the price and transaction mechanism of the GMP model.

Equations 4.27 through 4.31 above describe the dynamics of PM inventories of domestic grains as they are modelled throughout the PM subsector. At each market position, managers attempt to control inventories according to certain decision rules. Oftentimes these rules differ from one position to another and also change during the year. For example, millers in production areas may be motivated to build large rough grain inventories immediately or soon after harvest in order to assure themselves of adequate supplies to maintain their milling operations.[2] These decision rules may not always have inherent within them grain-storage-for-profit motives. At the retail store and other positions, grain storage behavior may be motivated by projected prices as well as other factors. System constraints are constantly at work, however, influencing or curtailing the results of inventory control strategies throughout the PM subsector. Storage capacities, milling capacity, and transportation bottlenecks are some such constraints which can have large impacts on inventory behavioral patterns throughout the PM system. In the next section we will discuss the basic decision rules for managing the various inventories represented in the PM model. In later sections we will describe the physical processing and flow of grains throughout the system. System constraints and the effects of these constraints on the flow of grains will also be discussed.

Management of Domestic Grain Inventories

It would be an impossibility to model all the decision rules and choice factors going into the management of all PM inventories.

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[2]Based on interviews with directors of the Private Grain Millers Association, Seoul, 1974.

The PM subsector model, with only three major positions represented explicitly, represents a great simplification of reality. Nevertheless, interviews with real world private market participants represented at the various positions in the model have indicated some general inventory control strategies which can be used by the model. Further research, more interviews, and perhaps formal surveys could refine and improve the general inventory control strategies used in the current version of the PM model.

Production Area Inventory Management

The basic inventory management strategies used in the model at this position were developed after interviews with individual private market grain millers and officials from the Private Grain Millers Association, representing over 22,000 private grain millers throughout Korea. From these interviews it became evident that strong competition for rough grains exists during the post-harvest season among private millers. This is due to the fact that the government in the past several years has been taking a larger and larger share of commercialized domestic grains. Government grains are milled only by licensed government grain millers, none of whom deal in nongovernment (private) grains. Many private grain millers offer production credit and free pickup and transportation to farmers who sell their rough grains to them. Free mill warehouse storage is also offered to farmers who agree to eventually release their grains to PM millers or at least allow them to perform the milling at a toll charge of 4 percent of the polished product.

These interviews also verified that, once milling has been accomplished, grains should move quickly into commercial channels.

This is because normal storage loss rates are considered to be higher for polished grains than for rough grains. Polished grains also deteriorate rapidly in terms of taste preference and quality (grade) which can adversely affect selling price. For these reasons, it is advantageous for PM grain millers and other grain handlers in production area positions to hold polished stocks at a minimum level, adequate to provide a buffer stock to cover fluctuations in consumption area grain requirements.

Production Area Rough Grain Inventories--As mentioned previously, marked seasonal variations in the desired level of rough grain inventories at production area positions are evidenced from private market interviews. All indications are that desired rough grain inventories are highest during the latter portion of the harvest season and then decrease to lower levels as time progresses. This phenomenon is reflected in the GMP model through an adjustable "sawtooth" signal which is triggered at harvest time each year and then declines in a ramp-type fashion as time progresses.

The above sawtooth signal represents the desired sustaining time of rough grain stocks for the PM subsector, i.e., the length of time PM rough grain stocks (without replenishment) can sustain current average milling operations. The basic sawtooth signal is fully parameterized and capable of taking on maximum (peak) values in the range (0, 1). For example, a value of one would indicate desired rough grain stock levels sufficient to sustain current average PM grain operations for one year; a value of 0.5 would indicate desired rough grain stock levels sufficient to sustain current average PM grain operations for 0.5 year, etc. Figure 4.6 below depicts this general

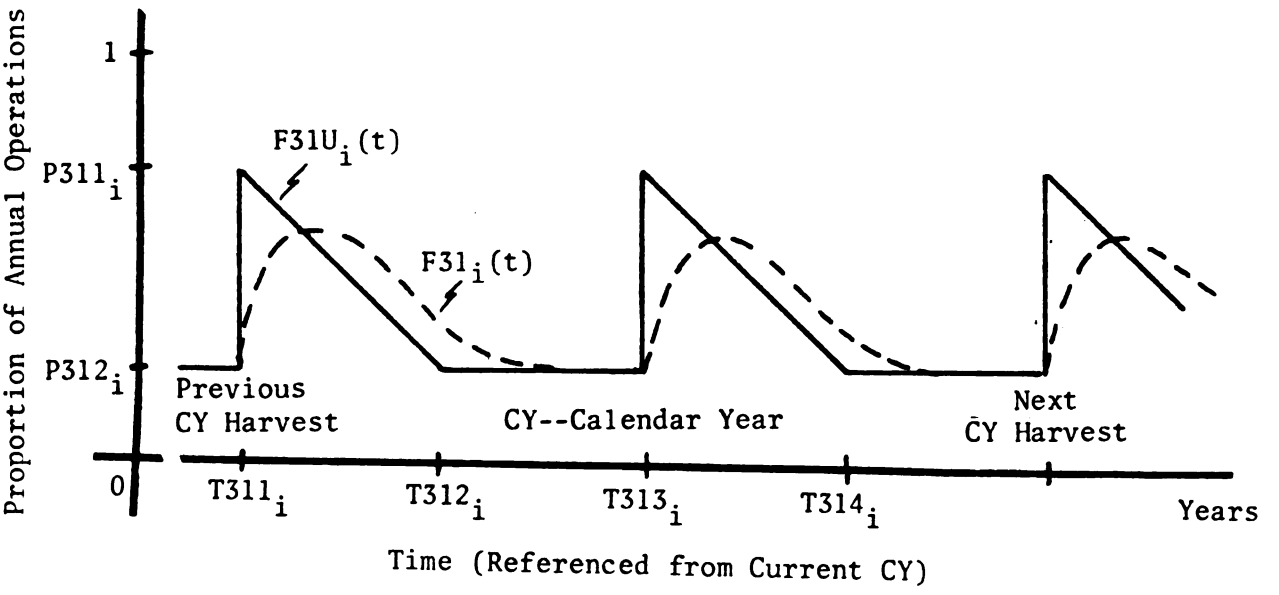


Figure 4.6. Desired PM Rough Grain Inventories

sawtooth (sustaining time) signal both in the unsmoothed and smoothed forms.[3]

Only two parameters are required to specify the signal F31U$_i$(t) in Figure 4.6. The following definitions are given to these parameters.

P311 = proportion of expected annual PM grain dealings which should be accumulated soon after harvest to assure normal milling operations throughout the year--proportion ($0 \leq P311 \leq 1$)

P312 = minimum proportion of annual PM grain dealings which should be on hand at all times during the year--proportion ($0 \leq P312 \leq P311 \leq 1$)

The time-axis parameters of F31U$_i$ in Figure 4.6 are dependent on other model parameters and need not be specified by the user.

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[3]Equations which follow will indicate that F31U$_i$(t) is not smoothed, but used directly as an operator on average annual PM grain dealings to generate an unsmoothed version of desired rough grain inventories through time. This resulting function is then smoothed to lend more reality to the model. Appearance of the smoothed version of desired rough grain inventories will be similar to F31$_i$(t) in Figure 4.6; only the values will differ.

These parameters are defined below.

T311 = time parameter representing the time at which the *previous* calendar year (CY) harvest began, referenced from 1 Jan = 0 ($T311_i = TSH_i - 1.$)

TSH = CY time when harvest season begins--$0 \leq TSH \leq 1$

T312 = time parameter representing the CY time at which only minimum rough grain stocks are desired from *previous* CY harvest ($T312_i = T311_i + P311_i - P312_i$)

T313 = time parameter representing the time of the beginning of *current* CY harvest ($T313_i = TSH_i$)

T314 = time parameter representing the time at which only minimum rough grain stocks are desired from *current* CY harvest ($T314_i = TSH_i + P311_i - P312_i$).

The value of $F31U_i(t)$ is generated by the following singularity function.

$$F31U_i(t) = P311_i - r(t-T311_i) + r(t-T312_i) + P311_i * u(t-T313_i) - r(t-T313_i) + r(t-T314_i) \quad (4.32)$$

where:

F31U = basic function for generation of $QPXD_i$, the desired level of PM rough grain stocks at production area positions throughout the year--proportion

r = unit ramp function--no units

u = unit step function--no units

t = current CY time of year--$0 \leq t \leq 1$.

Current average annual PM grain dealings are given by the solution to the following differential equation.

$$\frac{d}{dt} PSLSA_i(t) = - \frac{1}{D311_i} PSLSA_i(t) + \frac{1}{D311_i} PSLS_i(t) \quad (4.33)$$

where:

PSLSA = exponential average of current PM sales, used here to reflect the expected annual PM grain dealings--MT/yr

PSLS = current PM sales rate--MT/yr

D311 = time constant of smoothing function--yrs.

Now, $F31U_i(t)$ of Equation 4.32 represents the desired sustaining time of PM rough grain stock levels. It also represents the proportion of average annual PM grain dealings, $PSLSA_i(t)$, which are desired to be on hand throughout the year. The unsmoothed version of the desired levels of PM production area rough grain stocks are, therefore, given by the following equation.

$$QPXDU_i(t) = F31U_i(t)\ PSLSA_i(t)/EXZ_i \tag{4.34}$$

where:

QPXDU = unsmoothed version of the desired level of PM rough grain inventories--MT

F31U = desired sustaining time signal for PM rough grain stocks--yrs

PSLSA = current average annual PM grain dealings--MT/yr

EXZ = rough to polished weight conversion factor--proportion.

A smoothed version of $QPXDU_i(t)$ in Equation 4.34 is more realistic for representing desired PM rough grain inventory levels through time. This is accomplished through the following smoothing function.

$$\frac{d}{dt} QPXD_i(t) = -\frac{1}{D312_i} QPXD_i(t) + \frac{1}{D312_i} QPXDU_i(t) \tag{4.35}$$

where, $D312_i$ is the time constant of the smoothing function.

Automatic feedback control techniques are used to transform $QPXD_i(t)$ of Equation 4.35 above into a component of PM demand. The following equations describe the generation of this demand component.

$$QPXER_i(t) = QPXD_i(t) - QPX_i(t) \tag{4.36}$$

$$Z31_i(t) = G31A*QPXER_i(t) + G31B \frac{d}{dt} QPXER_i(t) + G31C \int_o^t QPXER_i(\tau)d\tau \quad (4.37)$$

where:

QPXER = error signal representing the difference between *desired* and *actual* PM rough grain inventory--MT

QPXD = desired PM rough grain inventory--MT

QPX = actual PM rough grain inventory--MT

Z31 = component of the PM demand designed to represent the demand for rough grains by private market millers throughout the year to sustain milling operations (see Equation 4.1)--MT/yr

G31A, B, C = control gain parameters--appropriate units.

Production Area Polished Grain Inventories--Management of polished grain inventories is more critical than the management of rough grain inventories because polished grains are more susceptible to storage loss and quality deterioration. It is common practice to keep polished grain stocks at minimum buffer stock levels, adequate to provide a continuous source of supply for fluctuating market requirements. Polished grain inventories located at production area positions move into consumption area positions to replenish those polished grain stocks. The key concept used for controlling polished grain stocks (throughout the market) is again the notion of a desired *sustaining time* for polished grain inventory levels. How long should polished grain stocks (without replenishment) be able to sustain normal market (outflow) requirements?

The average rate at which polished grains are moving out of production area positions is given by the following equation.

$$\frac{d}{dt} X32B_i(t) = - \frac{1}{DELN6} X32B_i(t) + \frac{1}{DELN6} RPCZO_i(t) \quad (4.38)$$

where:

X32B = exponential average rate of flow of polished grains from production area positions to consumption area terminal point positions--MT/yr

DELN6 = time constant parameter--yrs

RPCZO = instantaneous rate of flow of polished grains from production area positions to consumption area terminal point positions--MT/yr.

Given a value or signal (function of time) representing the desired sustaining time of production area polished grain inventories, the following equation represents the desired level for these inventories throughout time.

$$QPZD_i(t) = PZLT_i(t)\ X32B_i(t) \tag{4.39}$$

where:

QPZD = desired level of PM polished grain inventories located at production area positions--MT

PZLT = desired sustaining time signal for PM polished grain inventories located at production area positions--yrs

Z32B = see Equation 4.38 above--MT/yr.

PM polished grain stocks located in production areas are replenished by milling operations on rough grain stocks. The following equations describe the control process used to keep actual polished grain inventory levels in line with desired levels represented in Equation 4.39.

$$QPZER_i(t) = QPZD_i(t) - QPZ_i(t) \tag{4.40}$$

$$Z32_i(t) = G32A_i\ QPZER_i(t) + G32B_i \frac{d}{dt} QPZER_i(t) + G32C_i \int_o^t QPZER_i(\tau)d\tau \tag{4.41}$$

where:

QPZER = error signal representing the difference between *desired* and *actual* PM production area polished grain inventory levels--MT

QPZD = desired PM production area polished grain inventory level--MT

QPZ = actual PM production area polished grain inventory level--MT

Z32 = control signal representing adjustments to the current rate of PM milling operations to manage production area polished grain inventories toward desired levels--MT/yr

G32A, B, C = feedback control gain parameters--various units.

PM Milling Operations--PM milling operations are driven by three signals: (1) an average (normal) milling rate representing milling requirements to replenish production area polished grain stocks; (2) the control signal Z32 of Equation 4.41 above to manage production area polished grain inventory levels; and (3) a signal (used optionally) to represent milling operations in response to pressures on PM production area storage capacity. Equation 4.42 below represents the total input to the PM milling process.

$$RPXZC_i(t) = \underset{\text{normal milling}}{X32_i(t)} + \underset{\text{inventory control milling}}{Z32_i(t)/EXZ_i} + \underset{\text{storage pressure milling}}{RPXOF_i(t)} + \underset{\text{toll milling}}{RFMXU_i(t)} \qquad (4.42)$$

where:

RPXZC = total (unconstrained) input signal to the PM milling process--MT/yr

X32 = average (normal) milling rate (see Equation 4.44 below)--MT/yr

Z32 = control signal representing adjustment to the current rate of PM milling operations to manage production area polished grain inventories toward desired levels (see Equation 4.41 above)--MT/yr

EXZ = rough to polished weight conversion factor--proportion

RPXOF = component of PM milling rate representing milling operations to reduce pressures on PM production area storage capacity (see Equation 4.49 below)--MT/yr

RFMXU = rate at which toll milling operations on farm grains are requested by farmers (see Equation 3.23)--MT/yr.

The following limiting equation assures that milling is a non-reversible process, limited in maximum capacity, and reflects the curtailment of milling rates when available rough grain stock levels become critically low.

$$RPXZU_i(t) = \max\left\{0., \min\left[RPXZC_i(t), RPXZM, \frac{QPX_i(t)}{DT}\right]\right\} \quad (4.43)$$

where:

RPXZU = constrained input signal to milling process--MT/yr

max, min = maximum and minimum functions, respectively

RPXZC = unconstrained input signal to milling process (see Equation 4.42)--MT/yr

RPXZM = maximum throughput capacity of PM milling operations--MT/yr

QPX = PM rough grain inventories located at production area positions--MT

DT = time increment of the model--yrs.

The second milling component term of Equation 4.42, representing polished grain inventory control, has already been described. The first term, $X32_i(t)$, of the equation represents the average (normal) milling rate and is described mathematically in the following equation.

$$\frac{d}{dt} X32_i(t) = -\frac{1}{DELN5} X32_i(t) + \frac{1}{DELN5_i} RPCZO_i(t) \quad (4.44)$$

where:

DELN5 = time constant parameter--yrs

RPCZO = instantaneous rate of flow of polished grains from production area positions to consumption area terminal point positions--MT/yr.

The reader will note the strong similarity between $X32B_i(t)$ of Equation 4.38 and $X32_i(t)$ of Equation 4.44 above; the only difference being in the values of the time constants used in the exponential averaging equation. This was necessary to lend added flexibility to model tuning.

It is important that the milling control signal, $Z32_i(t)$, operates on a normal milling rate, represented by $X32_i(t)$. The control signal operates in a range about zero, depending on the value and behavior of the error signal between desired and actual polished grain inventory level. Without a normal milling rate upon which to operate, a negative control signal would be chopped at zero by Limiting Equation 4.43, and half the range of the control signal would be lost. This situation, before corrected, caused strong tendencies toward system instability.

The third milling component term of Equation 4.42 is an optimal function, representing milling operations undertaken by the PM subsector to relieve pressures on PM storage capacity caused by rough grain stocks. In the case of rice, rough grain form (paddy rice) occupies twice the volume of polished form. We will now describe this feature of the PM operations model in mathematical detail.

Referring back to Table 4.1, the reader will recall that both rice and the barley (group) commodities, in both rough and polished forms, occupy the same PM production area storage facilities. The function of the overflow aspect of the model under current discussion is to identify overflows, sort out rough grain forms from polished

grain forms, and undertake milling operations on rough grain stocks to help alleviate these storage capacity overflows.

Moving from weight to volume measurements, the number of (100-liter) bags of grain located at production area positions is given by the following equations.[4]

$$QPXB_i(t) = BPMTX_i \; QPX_i(t) \tag{4.45}$$

$$QPZB_i(t) = BPMTZ_i \; QPZ_i(t) \tag{4.46}$$

$$QPB_i(t) = QPXB_i(t) + QPZB_i(t) \tag{4.47}$$

$$TQPB = \sum_{i=1}^{2} QPB_i(t) \tag{4.48}$$

where:

QPXB = number of bags of rough grains located at production area positions by commodity (i = 1, 2)--bags

BPMTX = number of bags per metric ton of rough grains--bags/MT

QPX = production area rough grain inventory--MT

QPZB = number of bags of polished grains located at production area positions by commodity (i = 1, 2)--bags

BPMTZ = number of bags per metric ton of polished grains--bags/MT

QPZ = production area polished grain inventory--MT

QPB = number of bags of grains located at production area positions by commodity--bags

TQPB = total number of bags of grain located at production area positions--bags.

Bag overflows, by commodity, of production area rough grain inventories are identified by the following equation.

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[4]Unless otherwise stated, the nomenclature "bag" used in this thesis will represent a volume unit of 100 liters.

$$QPXOF_i(t) = \min[QPXB_i(t),\ TQPB - \min(TQPB, QPBMAX)] \quad (4.49)$$

where:

QPXOF = rough grain overflow, by commodity, of production area inventories--bags

min = minimum function

QPXB = production area rough grain inventory--bags

TQPB = total production area inventory (rough and polished grains, all commodities)--bags

QPBMAX = maximum PM production area storage capacity--bags.

Equation 4.49 is not very self-evident, and should be explained briefly: the second factor within the major brackets, [ ], of the equation represents the total number of bags by which production area inventory exceeds maximum storage capacity at that position. For example, if maximum storage capacity were 100 units and if current total inventory were 120 units, then the number of units by which current total inventory exceeds maximum storage capacity would be 20 units, i.e., 120 - min(120,100) = 20. Now, to sort this overflow of grains by rough form and commodity, the outside minimum function of Equation 4.49 is used. It is easily seen that the amount of rough grain overflow (by commodity) can neither exceed the amount of rough grain stocks (by commodity) nor the amount of total grain overflow.

Rough grain overflows identified in Equation 4.49 are then converted into milling commands by the following equation.

$$RPXOF_i(t) = G32D_i\ QPXOF_i(t)/BPMTX_i \quad (4.50)$$

where:

RPXOF = optional component of PM milling rate representing milling operations to reduce pressures on PM production area storage capacity--MT/yr

G32D = gain parameter identifying how intensely milling operations respond to rough grain overflows--$\frac{MT/yr}{MT}$

QPXOF = rough grain overflow, by commodity, of production area inventories--bags

BPMTX = number of bags per metric ton of rough grains--bags/MT.

The milling process itself is represented by the solution to the following differential equation.

$$\frac{d}{dt} RPXZO_i(t) = - \frac{1}{DELN7} RPXZO_i(t) + \frac{1}{DELN7} RPXZU_i(t) \quad (4.51)$$

where:

RPXZO = rate of output from the PM milling process--MT/yr

DELN7 = time constant of milling process-yrs

RPXZU = driving function of the milling process (see Equation 4.43 above)--MT/yr.

The GMP model disaggregates milling by-products into cracks and bran. Each of these by-products has a different unit price, so financial accounting is more accurate, especially when various by-product production ratios are used. The following equations separate output from milling operations into polished grains and the two by-products.

$$RPXZ_i(t) = EXZ_i \; RPXZO_i(t) \quad (4.52)$$

$$RZBP1_i(t) = EXY_i(1-EYZ_i)PCRAC_i \; RPXZO_i(t) \quad (4.53)$$

$$RZBP2_i(t) = EXY_i(1-EYZ_i)(1-PCRAC_i) \; RPXZO_i(t) \quad (4.54)$$

$$EXZ_i \triangleq EXY_i \; EYZ_i \quad (4.55)$$

where:

RPXZ = rate of polished grain production--MT/yr

EXZ = rough to polished form weight conversion factor--proportion

RPXZO = total output from milling process--MT/yr

RZBP1 = rate of cracked grain production--MT/yr

EXY = rough to hulled form weight conversion factor--proportion

EYZ = hulled to polished form weight conversion factor--proportion

$PCRAC_i$ = proportion of cracks in total by-product production (less hulls)--proportion

RZBP2 = rate of bran production--MT/yr.

Consumption Area Inventory Management

Key participants in handling grains in consumption areas are grain commissioners and retail sales store owners. Commissioners operate at consumption area terminal points such as railroad terminals and central wholesale markets. These grain dealers are in very close contact with millers, wholesalers, and shippers in production areas and specialize in 'reading' current market situations and manipulating the flow of grains into the consumption areas. Commissioners can act as brokers between parties from production areas and consumption areas or can take title to grain inventories themselves. They operate on large, although limited, funds and have access to sizeable storage capacity for holding grains during periods of price rise. Interviews with members of the Korean Grain Commissioners Association verified that grain inventories at these positions vary considerably throughout the crop year. One commissioner interviewed stated that, in the case of rice, his 3000 bag capacity storage was filled during November each year. The flow of rice through his inventory was 300-400 bags per day in, and approximately 300 bags per day out, during this period. In September, however, just prior to harvest, his flow of rice dropped to

around 30 bags per day in and out of storage. He stated that his inventory during this period was very small or zero. Just how much of this adjustment in inventory levels throughout the year is due to price anticipation, the level of activity at this position, or due to other factors such as the season or storability of grains, has not been determined. The PM subsector, however, does provide for changes in the level of inventories at this position. These changes are related to the time of year and the current level of activity at this position and appear to be consistent with real world phenomena. Price speculation, although most likely inherent in the above factors, can also be modelled explicitly and used to augment the above behavioral patterns.

Retail sales store participants are the second key participants in managing grain inventories in consumption areas. Grain retail businesses are generally small scale with an average operating capital of around 500,000 won. Although small on an individual basis, as a group, retail store inventory management behavior can have much effect on the performance of the overall PM subsector. There are approximately 5200 grain retailers in the Seoul area, with about 3700 being registered grain dealers authorized to deal in both private and government grains. Several interviews with grain retailers throughout Seoul have indicated many consistencies and storage behavioral patterns which should be reflected in the PM subsector model. Retailers dealing in both government and private grains do not have incentive for manipulating their stocks of government-controlled grains. This is because the sale price of government grains is set (by the government), and there seemed to be no evidence from interviews (and understandably so) that dealers would consider any deviation from the rules when dealing in government

grains.[5] Retailers, however, were very open about expressing their awareness of expected price rises during the year and their normal inventory patterns throughout the year. Price speculation, the level of grain activity at that position, and seasonal storability of grains were all mentioned explicitly as factors which influenced retailers' inventory management decisions. Just as with the grain commissioners, it was not possible to determine how much of a role the various factors cited played in these decisions. One retailer, typical of several others interviewed, stated that his total inventory of rice rose to around 70 bags in December and declined to around 10 bags in September. His rice inventory in September (the time of the interview) consisted of government rice only, because of a special decree prohibiting retailers from dealing in anything but government grains from July to October 1973. It was stated very openly in the interview, however, that a customer could obtain all the nongovernment rice he wanted, which would be delivered to his door, for a price of 3000 won above that of government rice. Based on three years of experience, this retailer estimated that during the December-June period, 80-90 percent of his rice dealings were in private market rice; and during the July-November period, 80-95 percent of his rice dealings were in government rice.

The sorts of information described above regarding inventory management decisions in the private subsector do not represent the result of extensive market-wide surveys. They do, however, begin to provide the model designer with the kind of insight and general

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[5]One possible deviation from the rules is the cleaning, sorting, and blending of government-controlled grains with private grains to upgrade its overall quality and therefore increase its price.

knowledge about the PM system necessary to develop *general* inventory control strategies which can be easily reparameterized when more accurate information or actual quantitative market survey results become available. In the following section, we will describe how this type of general behavioral information is incorporated into the PM subsector model.

Consumption Area Terminal Point Inventories--Polished grain inventories located at consumption area terminal point (CZ) positions serve as buffer stocks for grain flows arriving in consumption areas. The following equations are used to calculate desired CZ inventory profiles.

$$\frac{d}{dt} X33B_i(t) = - \frac{1}{DELN6} X33B_i(t) + \frac{1}{DELN6} RCRZO_i(t) \tag{4.56}$$

$$QCZD_i(t) = X33B_i(t)\ CZLT_i \tag{4.57}$$

where:

X33B = average rate at which polished grains move from consumption area terminal positions into retail store (RZ) positions--MT/yr

DELN6 = time constant--yrs

QCZD = desired CZ inventory level--MT

RCRZO = current rate at which polished grains move from CZ positions to RZ positions--MT/yr

CZLT = parameter indicating the length of time CZ stocks should be able to sustain current grain movements into RZ positions--yrs.

Interviews have indicated sizeable shifts in the level of inventories at this position throughout the marketing year; however, it does not seem warranted at this time to make CZLT an empirical function of time. This is because inventories at this position appear to increase and decrease in proportion with the flow of grains at this position. In terms of 'days of supply,' actual interviews with

commissioners indicated that these inventories may vary from ten-day supplies during peak inventory season down to one-two day supplies during the low inventory season. Although this indicates a fluctuation in CZLT by a factor of ten during the year, its size even at peak inventory periods is considerably small, i.e., 0.027 year (ten days). It is doubtful that modelling CZLT empirically at such small values would have much impact on model results, therefore, CZLT is modelled as a constant.

Polished grain inventories located at production area (PZ) positions are used to replenish CZ grain inventories. The following equations identify the control signal used by the model to manage CZ inventory levels.

$$QCZER_i(t) = QCZD_i(t) - QCZ_i(t) \tag{4.58}$$

$$Z33_i(t) = G33A_i\ QCZER_i(t) + G33B_i \frac{d}{dt} QCZER_i(t) + G33C_i \int_o^t QCZER(\tau)d\tau \tag{4.59}$$

where:

QCZER = error signal representing the current difference between desired and actual CZ stock levels--MT

QCZD = desired CZ stock level--MT

QCZ = actual CZ stock level--MT

Z33 = control signal representing adjustments to the current (normal) rate of grain arrivals into CZ positions to manage inventories toward desired levels--MT/yr

G33A, B, C = feedback control gain parameters--appropriate units.

Again, the reader will note the control signal $Z33_i(t)$ of Equation 4.59 operates on a normal grain flow level. This normal grain flow into CZ positions is calculated as the solution to the following differential equation.

$$\frac{d}{dt} X33_i(t) = - \frac{1}{DELN6} X33_i(t) + \frac{1}{DELN6} RCRZO_i(t) \quad (4.60)$$

where:

X33 = exponential average of grain flows out of CZ positions and into retail store (RZ) positions--MT/yr

DELN6 = time constant parameter--yrs

RCZZO = instantaneous rate of grain flow from CZ into RZ positions--MT/yr.

The movement of grains between production area positions and consumption area terminal point positions is refelcted in the PM operations model. This is an important aspect of the model because it lends reality to major grain flows which must be constrained by real world transportation system capacities. Although some portions of total grain transportation capacity are used exclusively for moving either government or private grains, a major portion of total capacity is used for both government and private grains. Rather than increase the complexity of the model to reflect exclusive and shared capacity, the assumption is made that all grain movement capacity is shared between government and nongovernment (private) subsectors. Although some reality is lost to this assumption, the most important constraint of the real world system is captured; i.e., at no time can the total movements of grains in the private and government sectors exceed total system transportation capacity.

Major transportation links identified in the model are those between production and consumption area positions, and between seaport and consumption area positions. Total *major* transportation demand is defined by the following equation.

$$TTD(t) = \sum_{i=1}^{2} [RPCZC_i(t) + RGPCZC_i(t) + RGSCYC_i(t)] + RWSMC(t) \quad (4.61)$$

where:

TTD = total *major* transportation demand--MT/yr

RPCZC = unconstrained private market orders for movements of grain from production to consumption area positions--MT/yr

RGPCZC = unconstrained government orders for movement of grain from production to consumption area positions--MT/yr

RGSCYC = unconstrained government orders for movement of imported grain from seaport to consumption area positions--MT/yr

RWSMC = unconstrained orders for movement of imported wheat from seaport to flour mill positions--MT/yr

i = commodity index (1 = rice, 2 = barley group).

The following limiting equation assures that orders for grain movements from production to consumption area positions reflect (1) limited system transportation capacity, (2) nonreversible grain flows between positions, and (3) curtailment of grain shipments when supply stocks become critically low.

$$RPCZU_i(t) = \max\left\{0., \min\left[RPCZC_i(t), \frac{RPCZC_i(t)\ RTMAX}{TTD}, \frac{QPZ_i(t)}{DT}\right]\right\} \quad (4.62)$$

where:

RPCZU = constrained orders for movement of PM grain from production to consumption area positions--MT/yr

min, max = minimum and maximum functions, respectively

RPCZC = unconstrained orders for movement of PM grain from production to consumption area positions--MT/yr

TTD = total transportation demand--MT/yr

RTMAX = maximum system capacity for transportation between major transportation links as defined in the GMP model--MT/yr

QPZ = current level of PM production area polished grain inventory

DT = time increment of the model--yrs.

Finally, the actual deliveries of grains to consumption area terminal point positions are simulated by the solution to the following differential equation which represents a distributed delay function.

$$a_k \frac{d^k}{dt^k} RPCZO_i(t) + a_{k-1} \frac{d^{k-1}}{dt^{k-1}} RPCZO_i(t) + \ldots + a_o \, RPCZO_i(t) = RPCZU_i(t) \tag{4.63}$$

where:

a_j = coefficients of the distributed delay function,

$a_j = \binom{k}{j}\left(\frac{DEL}{k}\right)^j$, $j = 0, \ldots, k$

DEL = delay parameter--yrs

k = order of the delay equation

RPCZO = deliveries of PM grains from production to consumption area positions--MT/yr

RPCZU = constrained orders for movement of PM grains from production to consumption area positions--MT/yr.

Retail Sales Store Position Inventories--Retailers dealing in both government and nongovernment grains are motivated to manipulate only their own stocks of nongovernment grains. The following equations are used to model desired retail store (RZ) position inventory profiles.

$$\frac{d}{dt} X34B_i(t) = -\frac{1}{DELN6} X34B_i(t) + \frac{1}{DELN6} PSLS_i(t) \tag{4.64}$$

$$QRZD_i(t) = X34B_i(t) \; RZLT_i(t) \tag{4.65}$$

where:

X34B = average rate of PM sales from RZ positions--MT/yr

DELN6 = time constant--yrs

PSLS = current rate of private grain sales from RZ positions--MT/yr

QRZD = desired RZ inventory level--MT

RZLT = parameter indicating the desired length of time RZ stocks should be able to sustain current nongovernment grain sales--yrs

Evidence seems to indicate that the parameter RZLT should be modelled as an empirical function of time. Retailers interviewed in the Seoul area indicate that their rice stocks vary from about one or two months' supply after harvest down to a few days' supply during late summer months. These are long enough times to be significant in the GMP model. Figure 4.7 illustrates the empirical function used for modelling RZLT.

The values given for RZLT are very rough and subject to change as more information is gained. It is useful to have a function like RZLT in the PM system model because it gives an easy means to investigate the probable impacts of price speculation. By flattening RZLT out, only ordinary (nonspeculative) behavior is represented. As function

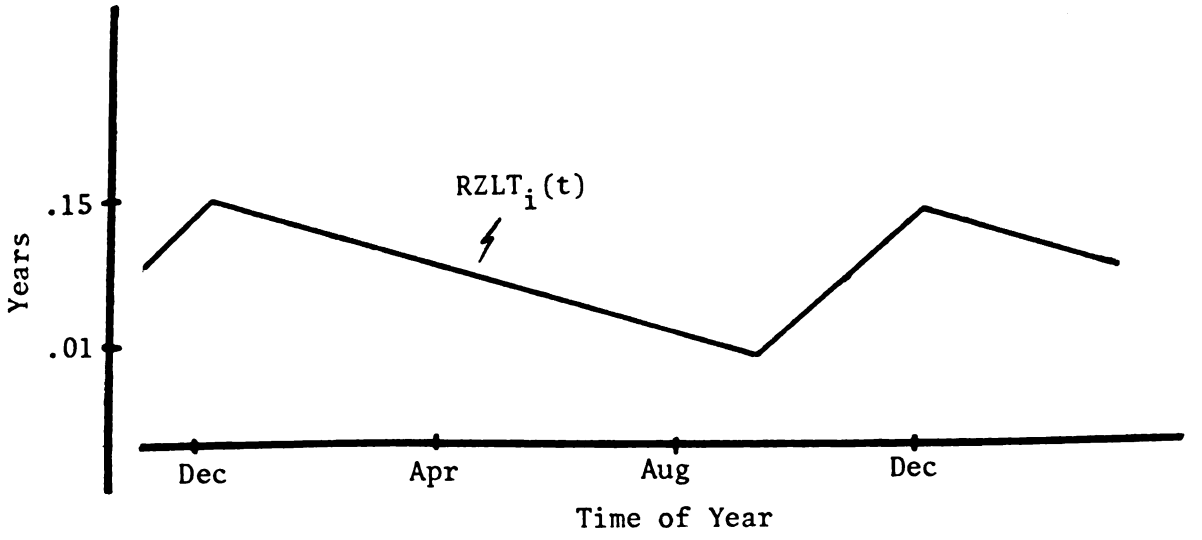


Figure 4.7. Function RZLT

RZLT begins to take *shape*, a number of factors influencing PM grain inventory management behavior (price speculation, storability, etc.) start to come into play. Price speculation can be explored because the *shape* of RZLT is consistent with speculative storage behavior.

Given a value for RZLT and the resulting desired level of retail store stock levels, orders from retail store managers to replenish their stock levels from wholesale suppliers (located at CZ position points) are given by the following equations.

$$QRZER_i(t) = QRZD_i(t) - QRZ_i(t) \tag{4.66}$$

$$Z34_i(t) = G34A_i\ QRZER_i(t) + G34B_i \frac{d}{dt} QRZER_i(t) + G34C_i \int_o^t QRZER_i(\tau)d\tau \tag{4.67}$$

where:

QRZER = error signal between desired and actual RZ inventory level--MT

QRZD = desired RZ inventory level--MT

QRZ = actual RZ inventory level--MT

Z34 = control signal representing adjustments to the current (normal) rate of grain deliveries into RZ positions to manage inventories toward desired levels--MT/yr

G34A, B, C = feedback control gain parameters--appropriate units.

The reader will again note that inventory management adjustments are made about a normal flow rate, rather than zero. This normal order (flow) rate is given by the following exponential averaging equation.

$$\frac{d}{dt} X34_i(t) = -\frac{1}{DELN7} X34_i(t) + \frac{1}{DELN7} PSLS_i(t) \tag{4.68}$$

where:

X34 = exponential average rate of PM sales from RZ positions--MT/yr

DELN7 = time constant--yrs

PSLS = current rate of private grain sales from RZ positions.

So, the following equation represents orders from retail sales store managers for grain deliveries from consumption area terminal point positions.

$$RCRZC_i(t) = X34_i(t) + Z34_i(t) + RCZOF_i(t) \tag{4.69}$$

where:

RCRZC = unconstrained orders for grain deliveries to RZ positions from CZ positions--MT/yr

X34 = normal order rate (see Equation 4.68 above)--MT/yr

Z34 = control signal to adjust deliveries to RZ positions to manage inventory levels--MT/yr

RCZOF = optional variable of the model, designed to represent overflow of CZ position grains into RZ positions due to storage pressures--MT/yr.

The following limiting equation assures nonreversible grain flows and precludes deliveries of grains when CZ stock levels are critically low.

$$RCRZU_i(t) = \max\left\{0., \min\left[RCRZC_i(t), \frac{QCZ_i(t)}{DT}\right]\right\} \tag{4.70}$$

where:

RCRZU = constrained orders for deliveries of grains from CZ to RZ positions--MT/yr

min, max = minimum and maximum functions, respectively

RCRZC = unconstrained orders for deliveries of grains from CZ to RZ positions--MT/yr

QCZ = current CZ position stock level --MT

DT = time increment of the model--yrs.

The (optional) overflow signal $RCZOF_i(t)$ of Equation 4.69 is generated from the following equations.

$$QCZB_i(t) = BPMTZ_i \; QCZ_i(t) \tag{4.71}$$

$$TQCZB = \sum_{i=1}^{2} QCZB_i(t) \tag{4.72}$$

$$QCZOF = TQCZB - \min(TQCZB, QCBMAX) \tag{4.73}$$

$$RCZOF_i(t) = \frac{G33D_i QCZB_i(t) QCZOF}{BPMTZ_i TQCZB} \tag{4.74}$$

where:

QCZB = current CZ inventory level--bags

BPMTZ = bags per metric ton of polished grains--bags/MT

QCZ = current CZ inventory level--MT

TQCZB = total number of bags of grain at CZ positions--bags

QCZOF = number of bags that CZ inventories exceed maximum storage capacity--bags

min = minimum function

QCBMAX = maximum PM storage capacity at CZ positions--bags

RCZOF = rate at which grains are transferred from CZ to RZ positions to relieve storage pressure on CZ position facilities--MT/yr

G33D = a gain parameter reflecting how fast grain movements due to storage overflows at CZ positions take place--$\frac{MT/yr}{MT}$.

The factor $QCZB_i(t)/TQCZB$ of Equation 4.74 above has the effect of apportioning CZ position overflows among grain commodities.

Actual deliveries of grain orders to retail store positions are simulated by the solution to the following differential equation, representing a distributed delay function.

$$a_k \frac{d^k}{dt^k} RCRZO_i(t) + a_{k-1} \frac{d^{k-1}}{dt^{k-1}} RCRZO_i(t) + \ldots$$

$$+ a_o \, RCRZO_i(t) = RCRZU_i(t) \qquad (4.75)$$

where:

a_j = coefficients of distributed delay function

$a_j = \binom{k}{j}\left[\frac{DEL}{k}\right]^j$, $j = 0, \ldots, k$

DEL = delay parameter--yrs

k = order of delay equation

RCRZO = deliveries of grains from CZ to RZ positions--MT/yr

RCRZU = constrained orders for deliveries of grains from CZ to RZ positions--MT/yr.

Augmenting Desired Inventories to Reflect Speculative Storage Behavior

To complete the description of the PM operations model, we must indicate how the overall desired PM inventory level, $QPMDS_i(t)$, calculated in Equation 4.24, is reflected in individual desired position point inventories throughout the PM marketing system.

The model calculates the total PM subsector desired inventory level for *normal* operations from the following summation.

$$QPMD_i(t) = QPXD_i(t)EXZ_i + QPZD_i(t) + QCZD_i(t) + QRZD_i(t) \qquad (4.76)$$

where:

QPMD = PM subsector desired inventory level for normal operations--MT

QPXD = desired PX inventory level--MT (see Equations 4.34 and 4.35)

QPZD = desired PZ inventory level--MT (see Equation 4.39)

EXZ = rough to polished form conversion factor--proportion

QCZD = desired CZ inventory level--MT (see Equation 4.57)

QRZD = desired RZ inventory level--MT (see Equation 4.65).

The factor used to adjust individual desired inventory levels at various PM positions to incorporate speculative storage behavior is calculated as follows.

$$SAF_i(t) = \frac{QPMDS_i(t)}{QPMD_i(t)} \tag{4.77}$$

where:

SAF = adjustment factor for desired inventory levels at various PM positions--proportion

QPMDS = total desired PM inventory level for normal operations *and* speculative storage (see Equation 4.24)--MT

QPMD = desired PM inventory for normal operations without explicit speculation--MT.

The reader can see that by multiplying each normal desired position point inventory by factor $SAF_i(t)$ above, the resulting summation of desired inventory levels at various position points will precisely equal $QPMDS_i(t)$. The effect of this, other than model consistency, is to distribute speculative behavior to all position points of the PM subsector model.

Private Market Domestic Accounting

Performance of the PM subsector, as well as impacts of various government grain management policies upon the PM subsector, are measured through the accounting equations to be described in this section.

Revenues

Revenue flows generated by private market grain operations are calculated by the following equations.

$$RVPSLS_i(t) = PU_i(t)*BPMTZ_i*PSLS_i(t)*ECPIEC \quad (4.78)$$

$$RVPBPS_i(t) = PBP1_i(t)RZBP1_i(t) + PBP2_i(t)RZBP2_i(t) \quad (4.79)$$

where:

RVPSLS = revenue flow from grain sales--won/yr

PU = urban retail price, deflated by consumer price index excluding cereals--won/bag

BPMTZ = bags per metric ton of polished grains--bags/MT

PSLS = rate of PM grain sales--MT/yr

ECPIEC = consumer price index excluding cereals--no units

RVPBPS = revenues from the sale of grain by-products--won/yr

PBP1 = price of cracked grains--won/MT

RZBP1 = rate of crack grain (by-product) production--MT/yr

PBP2 = price of bran--won/MT

RZBP2 = rate of bran production--MT/yr.

Expenditures

Private market expenditures for grain operations are classified into fixed and variable costs. The following equation represents fixed cost flows considered by the PM accounting mechanism.

$$\begin{aligned} FCPM_i(t) = {} & C311A*PDMAX*PDEM_i(t)/TPDEM(t) \\ & + C311B_i RPXZM_i \\ & + C311C*QPBMAX*[QPXB_i(t)+QPZB_i(t)]/TQPB(t) \\ & + C311D*QCBMAX*QCZB_i(t)/TQCZB(t) \\ & + C311E*PMMAX*PMKTS_i(t)/TPMKTS(t) \end{aligned} \quad (4.80)$$

where:

FCPM = PM fixed costs for grain operations--won/yr

C311A = unit cost parameter used to assign fixed cost of PM *domestic grain acquisition capacity*--won/MT

C311B = unit cost parameter used to assign fixed cost of PM *milling capacity*--won/MT

C311C = unit cost parameter used to assign fixed cost of PM *production area storage capacity*--won/MT-yr

C311D = unit cost parameter used to assign fixed cost of PM *consumption area storage capacity*--won/MT-yr

C311E = unit cost parameter used to assign fixed cost of PM *marketing capacity*--won/MT

PDMAX = PM domestic grain acquisition capacity--MT/yr

PDEM = PM domestic grain demand (by commodity)--MT/yr

TPDEM = total PM domestic grain demand--MT/yr

RPXZM = PM milling capacity (by commodity)--MT/yr

QPBMAX = total PM grain storage capacity located at production area positions--bags

QPXB, QPZB = PM rough and polished grain inventories, respectively (by commodity) located at production area positions--bags

TQPB = total PM grain inventory located at production area positions--bags

QCBMAX = total PM grain storage capacity located at consumption area positions--bags

QCZB = PM grain inventory (by commodity) located at consumption area positions--bags

TQCZB = total PM grain inventory located at consumption area positions--bags

PMMAX = total PM grain marketing capacity--MT/yr

PMKTS = PM grain marketings (by commodity)--MT/yr

TPMKTS = total PM grain marketings--MT/yr.

The fixed cost components of Equation 4.80 above are self-explanatory, given the unit cost parameter definitions following the

equation. The reader should note that fixed costs are apportioned to individual food grain commodities.

Variable costs of PM grain operations are given by the following equation.

$$VCPM_i(t) = CPPUR_i(t) + CPSLS_i(t) + CPS_i(t) + CPC_i(t) + CPM_i(t) + CPT_i(t) \quad (4.81)$$

where:

VCPM = variable cost of PM grain operations--won/yr

CPPUR = cost associated with PM *grain purchases*--won/MT

CPSLS = cost associated with PM *grain sales*--won/yr

CPS = cost associated with PM *grain storage*--won/yr

CPC = cost associated with PM *operating credit*--won/yr

CPM = cost associated with PM *milling operations*--won/yr

CPT = cost associated wtih PM *grain transportation*--won/yr.

The individual variable cost components of Equation 4.81 above will now be described.

(Acquisition costs)

$$CPPUR = C301A(t)\ PPUR_i(t) \quad (4.82)$$

where:

C301A = average variable cost of PM grain acquisitions--won/MT

PPUR = PM domestic grain purchases--MT/yr

(Sales costs)

$$CPSLS = C302(t)\ PSLS_i(t) \quad (4.83)$$

where:

C302 = average variable cost of PM grain sales--won/MT

PSLS = PM grain sales--MT/yr

(Storage costs)

$$CPS_i(t) = C333_i(t)\ QPM_i(t) \tag{4.84}$$

$$C333_i(t) = \{C303A_i(t)\ QPX_i(t)*EXZ_i + C303B_i(t)\ QPZ_i(t) + C303C_i(t)\ [QCZ_i(t)+QRZ_i(t)]\}/QPM_i(t) \tag{4.85}$$

$$QPM_i(t) = QPX_i(t)*EXZ_i + QPZ_i(t) + QCZ_i(t) + QRZ_i(t) \tag{4.86}$$

where:

CPS = variable cost associated with PM grain storage--won/yr

C333 = average variable cost of holding PM grains (in current position-form configuration)--won/MT-yr

QPM = total PM grain inventory (in polished equivalent)--MT

C303A = average variable cost of storing PM rough grains--won/MT-yr

C303B = average variable cost of storing PM polished grains at production area positions--won/MT-yr

C303C = average variable cost of storing PM polished grains at consumption area positions--won/MT-yr

QPX = PM rough grain stocks located at production area positions--MT

QPZ = PM polished grain stocks located at production area positions--MT

QCZ = PM polished grain stocks located at consumption area terminal point positions--MT

QRZ = PM polished grain stocks located at retail sales store positions--MT.

As indicated by the above storage cost equations, storage costs are disaggregated by form and position. This is done because different storage costs can be associated with location and form of grains being stored. The reader will note that all average variable cost parameters

are indicated as functions of time. This is due to the fact that the GMP model is designed to operate for any period from 1966 forward. Real world average variable costs vary greatly over this time domain of model operation. Table look-up functions are used to assign appropriate values of average variable costs to the PM accounting parameters throughout the model run [3]. Cost projections are also made for model runs with time domains extending into the future.

(Credit costs)

$$CPC_i(t) = PINT1(t) \int_o^t PMP_i(\tau)d\tau \qquad (4.87)$$

where:

PINT1 = prevailing interest rate for financing PM grain operations--proportion/yr

PMP = current net cash flow from PM operations (see Equation 4.90 below)--won/yr

(Milling costs)

$$CPM_i(t) = C304_i(t)\ RPXZ_i(t) \qquad (4.88)$$

where:

C304 = average variable cost of milling operations--won/MT

RPXZ = polished grain output of milling operations--MT/yr

(Transportation costs)

$$CPT_i(t) = C306(t)\ RPCZO_i(t) \qquad (4.89)$$

where:

C306 = average variable cost of transportation (i.e., moving grains from production to consumption area positions)--won/MT

RPCZO = rate of PM grain movements from production to consumption area positions--MT/yr

Profits

Net cash flows from PM grain operations are given by the following equation.

$$PMP_i(t) = RVPSLS_i(t) + RVPBPS_i(t) - VCPM_i(t) - FCPM_i(t) \quad (4.90)$$

where:

RVPSLS = revenue flow from grain sales (see Equation 4.78)--won/yr

RVPBPS = revenue flow from grain by-product sales (see Equation 4.79)--won/yr

VCPM = variable cost of PM grain operations (see Equation 4.81)--won/yr

FCPM = fixed cost of PM grain operations (see Equation 4.80)--won/yr.

This completes the mathematical discussion of the PM domestic grain accounting mechanism. All revenues and expenditures described have been on a cash flow basis. Summary accounting tables often require that these cash flows (and elements of these cash flows) be integrated over the period of the particular summary account. Both running and arithmetic averages of certain accounting variables are also required at times. These calculations will not be described in detail.

Industrial Wheat Submodel

Private marketing activities in wheat operations are very different than for rice and barley. Less than 10 percent of annual requirements for wheat are produced domestically, with the remaining 90 percent being imported under strict government control. Approximately 75 percent of domestically produced wheat is consumed on the farm,

leaving only around 3 percent of annual nonfarm requirements flowing through the PM domestic grain system as described above. In this section we will describe the mathematical relationships used to simulate the industrial wheat system in Korea.

Industrial Wheat Operations

The industrial wheat operations model simulates wheat import scheduling, wheat import delays, wheat storage and inventory management at various locations, wheat movements, flour milling operations, and wholesale transactions of wheat flour. A detailed system diagram of the industrial wheat operations model is presented in Figure 4.8. Most of the mathematical relationships described in this section are depicted in the diagram in symbolic form. The reader should find the diagram to be a useful reference throughout this discussion.

Wheat Inventories

Industrial wheat inventories are identified at five different position points: (1) import pipeline, (2) import arrival queue, (3) port storage facilities, (4) mill warehouses for wheat grain, and (5) mill warehouses for wheat flour. Each of these wheat inventories will be described mathematically.

Import Pipeline

Import pipeline inventory is defined as wheat import orders not yet arrived at receiving port locations. These inventories are significant due to the delay times required for processing import orders and ship movements from exporting countries. The following equation identifies wheat inventories in the import pipeline.

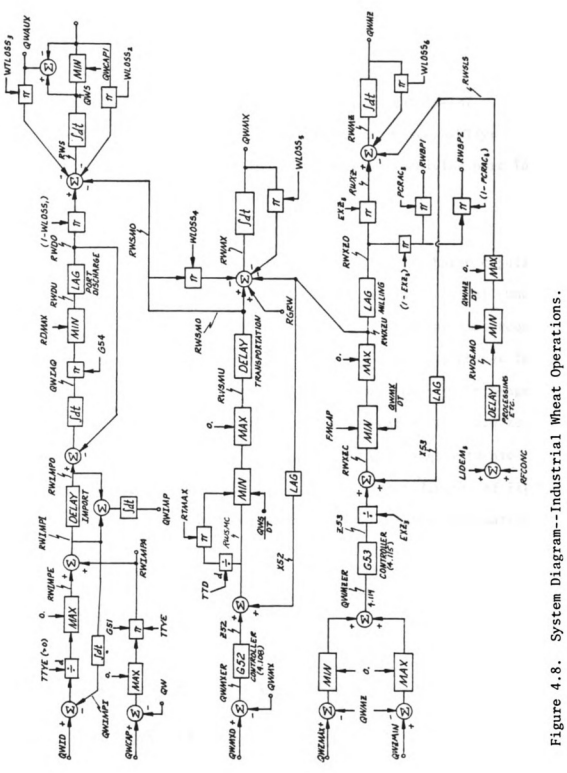


Figure 4.8. System Diagram--Industrial Wheat Operations.

$$QWIMP(t) = \int_{o}^{t} RWIMPI(\tau) - RWIMPO(\tau)d\tau \tag{4.91}$$

where:

QWIMP = current wheat import pipeline inventory--MT

RWIMPI = rate at which import orders are placed--MT/yr

RWIMPO = rate at which imports arrive at receiving port locations (see Equation 4.104)--MT/yr.

Import Arrival Queue

Oftentimes, import arrivals saturate port discharge capacities and ships must queue up to await unloading. It is not at all uncommon for such a delay to be greater than the actual shipping time required for wheat imports. Although millers must pay a penalty charge for these excessive delays, this provides additional critical storage for wheat import arrivals--the benefit of which wheat millers are keenly aware. This discharge queue and the related discharge rate are simulated by the following equations. (The system diagram of Figure 4.8 will be helpful in giving the reader a grasp of these mathematical relationships.)

$$QWIAQ(t) = \int_{t_o}^{t} RWIMPO(\tau) - RWDO(\tau)d\tau \tag{4.92}$$

$$\frac{d}{dt} RWDO(t) = - \frac{1}{DELWI} RWDO(t) + \frac{1}{DELWI} RWDU(t) \tag{4.93}$$

$$RWDU(t) = \min[RDMAX, G54*QWAIQ(t)] \tag{4.94}$$

where:

QWIAQ = import arrival queue awaiting discharge--MT

RWIMPO = rate at which wheat imports arrive at receiving port locations--MT/yr

RWDO = rate of import discharge from ships--MT/yr

RWDU = input signal to discharge delay--MT/yr

DELW1 = time constant for discharge operations--yrs

RDMAX = maximum discharge rate capacity--MT/yr

G54 = gain parameter indicating intensity of discharge operations--$\frac{MT/yr}{MT}$.

Seaport Storage

As wheat is unloaded from ships, it is either trucked directly to flour mill warehouses or moved into seaport storage facilities. When wheat storage capacity is taxed, wheat is sometimes merely bagged and piled at dock locations. The GMP model identifies both normal and auxiliary wheat storage located at seaport locations. The following equations describe how these inventories are computed.

$$\frac{d}{dt} QWS(t) = - WLOSS_2 * \min[QWS(t), QWCAP1] + (1-WLOSS_1)\, RWDO(t) - WLOSS_3 * QWAUX(t) - RWSMO(t) \quad (4.95)$$

$$QWAUX(t) = QWS(t) - \min[QWS(t), QWCAP1] \quad (4.96)$$

where:

QWS = imported wheat inventory located at seaport storage facilities (including auxiliary)--MT

RWDO = rate of wheat import discharge from ships--MT/yr

QWAUX = imported wheat inventory stored under auxiliary storage conditions at seaport locations--MT

RWSMO = rate at which wheat is moved from seaport locations to mill warehouse locations--MT/yr

QWCAP1 = normal seaport wheat storage capacity--MT

$WLOSS_1$ = expected loss from discharge operations--proportion

$WLOSS_{2,\ 3}$ = expected loss rates from normal and auxiliary storage facilities at seaport positions, respectively--proportion/yr.

Flour Mill Wheat Storage

Wheat inventories are held at flour mill locations to act as buffer stocks for flour milling operations. The following equation describes how these wheat inventories are calculated.

$$\frac{d}{dt} QWMX(t) = (1-WLOSS_4)\ RWSMO(t) + RGRW(t) - WLOSS_5 * QWMX(t) - RWXZU(t) \quad (4.97)$$

where:

QWMX = wheat inventory located at flour mill locations--MT

RWSMO = rate at which imported wheat is moved from seaport locations to mill locations--MT/yr

RGRW = optional variable to reflect government releases of domestic wheat purchases to flour mills--MT/yr

RWXZU = wheat input rate to flour milling operations--MT/yr

$WLOSS_4$ = expected loss from transporting wheat from seaports to mill locations--proportion

$WLOSS_5$ = expected loss rate for wheat held in mill storage warehouses--proportion/yr.

Total wheat stock within the PM industrial wheat subsector is calculated by the following summation.

$$\begin{array}{lcccccc} QW(t) & = & QWIMP(t) & + & QWS(t) & + & QWMX(t) \\ \text{total wheat} & = & \text{import pipeline} & + & \text{seaport} & + & \text{flour mill} \end{array} \quad (4.98)$$

Wheat Flour Storage

After milling, wheat flour is stored at flour mill storage facilities to await wholesale transactions. Flour stocks are represented by the following equation.

$$\frac{d}{dt} QWMZ(t) = - WLOSS_6 * QWMZ(t) + EXZ_3 RWXZO(t) - RWSLS(t) \qquad (4.99)$$

where:

QWMZ = wheat flour inventories owned by flour millers--MT

RWXZO = total output rate from flour milling process--MT/yr

EXZ_3 = wheat to flour extraction rate--proportion

RWSLS = rate of wheat flour wholesales--MT/yr

$WLOSS_6$ = expected loss rate from holding wheat flour in storage--proportion/yr.

This completes the mathematical description of the various wheat inventories recognized by the industrial wheat operations model. We will now discuss mathematically some of the important processes and management decisions simulated by the model.

Inventory Management

Wheat Imports

Rigid wheat import quotas are set each year by government grain management policy. The Korean Flour Millers Industrial Association (KOFMIA) handles all wheat import business operations, such as competitive price bidding and contracting with U.S. grain traders for both short- and long-range delivery scheduling. However, strained domestic wheat and wheat flour storage capacity makes it necessary to schedule deliveries on a fairly *even flow* basis.

Of course, there are some flexibilities in import scheduling to relieve pressures on strained domestic wheat storage capacity; but, for the most part, deliveries are scheduled on a fairly even flow basis during each import year. When port silo (and other) facilities are filled, overflow wheat stock arrivals are placed in available auxiliary storage facilities or shipped directly to mill factory warehouses. Under the *even flow* assumption, import orders are modelled by Equation 4.100 below.

$$RWIMPE(t) = \max\{0, [QWID(t)-QWIMPI(t)]/TTYE\} \tag{4.100}$$

$$QWIMPI(t) = \int_{t_o}^{t} RWIMPI(\tau)d\tau \tag{4.101}$$

where:

RWIMPE = rate of wheat import orders to target *even flow* of import arrivals throughout remainder of import year--MT/yr

QWIMPI = quantity of wheat imports ordered during current wheat import year--MT

max = maximum function

QWID = government policy variable indicating wheat import quota for current year--MT

TTYE = time remaining to end of current wheat import year--yr

RWIMPI = rate of wheat import orders--MT/yr.

The even flow import pattern of Equation 4.100 can be modified throughout the wheat import year, providing that the basic wheat import quota is met by the end of the year. This can mean temporarily increasing import orders above the annual even flow pattern to adjust domestic inventories upward, and then falling back to a lower *readjusted* even import rate for the remainder of the year. Conversely, it can also

mean temporarily decreasing import orders to relieve domestic storage pressures, with the necessity of an increased importation rate later in the year to meet the import quota. An adjustment to wheat importation rate to relieve pressure on wheat storage capacity is calculated as follows.

$$RWIMPA(t) = G51*TTYE* \max[0.,QW(t)-QWCAP] \quad (4.102)$$

where:

RWIMPA = adjustment to *even flow* importation rate to relieve pressure on wheat storage capacity

G51 = gain parameter indicating the intensity of input rate adjustments--proportion/yr

TTYE = time remaining in current wheat import year--yr

max = maximum function

QW = total wheat grain inventory (see Equation 4.99)--MT

QWCAP = total wheat grain storage capacity of industrial wheat system--MT.

The variable TTYE in Equation 4.102 is used as a curtailment to wheat import adjustments as the import year draws to a close. At the beginning of the year, large adjustments to importation rates can be made to relieve storage pressure; however, in order to meet given quotas, adjustments must be restricted as the time remaining in the wheat import year decreases. Wheat import orders are then calculated as the following summation.

$$RWIMPI(t) = RWIMPE(t) + RWIMPA(t) \quad (4.103)$$

where:

RWIMPI = rate of wheat import orders--MT/yr

RWIMPE = rate of wheat import orders to target *even flow* of import arrivals throughout remainder of import year (see Equation 4.100)--MT/yr

RWIMPA = adjustment to *even flow* importation rate (see Equation 4.102)--MT/yr.

The solution to the following differential equation is a distributed delay function of wheat import orders and is used to represent arrivals of wheat imports to receiving seaport locations.

$$a_k \frac{d^k}{dt^k} \text{RWIMPO}(t) + a_{k-1} \frac{d^{k-1}}{dt^{k-1}} \text{RWIMPO}(t) + \ldots + a_o \text{RWIMPO}(t) = \text{RWIMPI}(t) \qquad (4.104)$$

where:

a_j = coefficients of the distributed delay function,

$$a_j = \binom{k}{j}\left(\frac{\text{DEL}}{k}\right)^j, \; j = 0, \ldots, k$$

DEL = import delay parameter--yrs

k = order of delay equation

RWIMPO = rate at which wheat imports arrive at receiving port locations--MT/yr

RWIMPI = rate at which import orders are made--MT/yr.

Wheat Stock Levels

Port storage facilities are used as buffer storages for large discrete import arrivals and supply sources for requirements of flour milling operations. As such, no direct management control is required for these stock levels. More important are wheat and wheat flour stock levels located at flour mill locations. Wheat stocks located at flour mills serve as buffer stocks to assure steady (uninterrupted) flour milling operations, while flour stockpiles assure a steady supply source for fluctuating wheat flour wholesale demand.

Desired inventory of wheat grain at mill positions is assumed by the model as being 80 percent of wheat storage capacity at that position.[6]

$$QWMXD(t) = .8\ QWCAP2 \tag{4.105}$$

where:

QWMXD = desired wheat inventory stock level at mill positions--MT

QWCAP2 = storage capacity for wheat at mill positions--MT.

Just as in the PM domestic grain operations model, wheat inventory control signals operate on a normal flow of wheat from port to mill positions. This normal flow is calculated by the following smoothing equation.

$$\frac{d}{dt} X52(t) = -\frac{1}{DEL52} X52 + \frac{1}{DEL52} RWXZU(t) \tag{4.106}$$

where:

X52 = normal flow of wheat grain from port storage to mill storage facilities--MT/yr

DEL52 = time constant--yrs

RWXZU = rate at which wheat stocks move into flour milling process--MT/yr.

The management control signal used to adjust the flow of grain movements into mill wheat storage facilities is calculated as follows.

$$QWMXER(t) = QWMXD(t) - QWMX(t) \tag{4.107}$$

$$Z52(t) = G52A*QWMXER(t) + G52B \frac{d}{dt} QWMXER(t) + G52C \int_{t_o}^{t} QWMXER(\tau)d\tau \tag{4.108}$$

---

[6]Conclusion arrived at after several interviews with managers of KOFMIA.

where:

QWMXER = error signal representing difference between desired and actual stock levels of wheat located at flour mill positions--MT

QWMXD = desired wheat grain stock level at mill positions--MT

QWMX = actual wheat grain stock level at mill positions--MT

Z52 = control signal representing adjustments to current normal rate of wheat grain arrivals into flour mill positions to manage inventories toward desired levels--MT/yr

G52A, B, C = feedback control gain parameters--appropriate units.

The *unconstrained* signal representing *orders* to move wheat stocks forward to mill positions is given by the following summation.

$$RWSMC(t) = X52(t) + Z52(t). \tag{4.109}$$

However, several limiting constraints must be applied to RWSMC(t) above to assure that (1) reverse grain flows are not possible, (2) flow is curtailed if port stock levels are critically low, and (3) total system transportation capacity is not exceeded. The following limiting equation assures that the above constraints are present.

$$RWSMU(t) = \max\left\{0.,\min\left[RWSMC(t),\frac{RWSMC(t)\ RTMAX}{TTD},\ \frac{QWS(t)}{DT}\right]\right\} \tag{4.110}$$

where:

RWSMU = constrained orders for movement of wheat grain from port to mill storage facilities--MT/yr

max, min = maximum and minimum functions

RWSMC = unconstrained version of RWSMU--MT/yr

RTMAX = maximum system capacity for transportation between major transportation links as defined in the GMP model--MT/yr

TTD = total transportation demand (see Equation 4.61)--MT/yr

QWS = current wheat stock level at seaport storage facility positions--MT

DT = time increment of the simulation model--yrs.

The actual deliveries of wheat to mill positions are simulated by the solution to the following differential equation which represents a distributed delay function.

$$a_k \frac{d^k}{dt^k} RWSMO(t) + a_{k-1} \frac{d^{k-1}}{dt^{k-1}} RWSMO(t) + \ldots + a_o \, RWSMO(t) = RWSMU_i(t) \qquad (4.111)$$

where:

a_j = coefficients of the distributed delay function,

$$a_j = \binom{k}{j} \left[\frac{DEL}{k}\right]^j, \; j = 0, \ldots, k$$

DEL = delay parameter--yrs

k = order of delay equation

RWSMO = deliveries of wheat from seaport to mill positions--MT/yr

RWSMU = constrained orders for movement of wheat from seaport to mill positions--MT/yr.

Flour Stock Levels

Wheat millers strive to maintain steady flour milling operations since, as with most industrial processes, production rate changes mean added costs. Millers maintain sizeable wheat flour stocks to absorb fluctuations in wholesale flour demands, but also try to avoid excessive stock levels. By milling at a rate equal to projected average wholesale demand for flour and adjusting production rates only when flour stocks violate acceptable (maximum or minimum) levels, these requirements can be met. Normal flour milling production rate is calculated by the following equation.

$$\frac{d}{dt} X53(t) = - \frac{1}{DELW4} X53 + \frac{1}{DELW4} RWSLS \qquad (4.112)$$

where:

X53 = exponential average of flour wholesales by millers--MT/yr

DELW4 = time constant--yrs

RWSLS = rate of wheat flour wholesales by millers.

Milling rate adjustments are not made unless wheat flour stock levels move outside an acceptable range. The following equations reflect this production control strategy.

$$QWZMIN(t) \leq QWMZD(t) \leq QWZMAX \tag{4.113}$$

$$QWMZER(t) = \max[0., QWZMIN(t)-QWMZ(t)] + \min[0., QWZMAX(t)-QWMZ(t)] \tag{4.114}$$

$$Z53(t) = G53A*QWMZER(t) + G53B* \frac{d}{dt} QWMZER(t) + G53C \int_{t_o}^{t} QWMZER(\tau)d\tau \tag{4.115}$$

where:

QWZMIN = minimum critical level of wheat flour stocks, signaling need for increased flour production rate--MT

QWZMAX = maximum critical level of wheat flour stocks, signaling need for decreased flour production rate--MT

QWMZD = range of acceptable wheat flour stock level--MT

QWMZER = error signal indicating amount by which wheat flour stock level is outside acceptable range of QWMZD--MT

max, min = maximum and minimum functions

QWMZ = current wheat flour stock level--MT

Z53 = control signal designed to adjust normal flour milling rate when wheat flour stock levels violate critical levels--MT/yr

G53A, B, C = feedback control gain parameters--appropriate units.

The unconstrained command signal for the wheat flour production process is given by the following summation.

$$RWXZC(t) = X53(t) + Z53(t)/EXZ_3 \tag{4.116}$$

where, EXZ_3 is the extraction rate used to produce wheat flour. This signal is then constrained to assure that (1) the milling process is nonreversible, (2) maximum milling capacity is not exceeded, and (3) milling rate is curtailed when available wheat stocks at mill locations become critically low. These constraints are all reflected in the following limiting equation.

$$RWXZU(t) = \max\left\{0., \min\left[RWXZC(t), FMCAP, \frac{QWMX(t)}{DT}\right]\right\} \tag{4.117}$$

where:

RWXZU = constrained signal representing wheat input to the flour milling process--MT/yr

min, max = minimum and maximum functions

RWXZC = unconstrained version of RWXZU--MT/yr

FMCAP = system flour production capacity--MT/yr

QWMX = current stock level of wheat grain located at mill positions--MT

DT = time increment of the simulation model--yrs.

The actual flour milling process is represented by the following differential equation.

$$\frac{d}{dt} RWXZO(t) = -\frac{1}{DELW3} RWXZO(t) + \frac{1}{DELW3} RWXZU(t) \tag{4.118}$$

where:

RWXZO = total output from the wheat flour milling process--MT/yr

DELW3 = time constant--yrs

RWXZU = constrained input signal to the flour milling process--MT/yr.

By-products are separated from total milling output by the following equations.

$$RWBP1(t) = (1-EXZ_3)\ PCRAC_3\ RWXZO(t) \tag{4.119}$$

$$RWBP2(t) = (1-EXZ_3)\ (1-PCRAC_3)\ RWXZO(t) \tag{4.120}$$

where:

RWBP1 = rate of nonbran wheat by-product production--MT/yr

RWBP2 = rate of wheat bran by-product production--MT/yr

EXZ_3 = extraction rate used for wheat flour production--proportion

$PCRAC_3$ = proportion of useable by-products going to nonbran production--proportion

RWXZO = total output from flour milling process--MT/yr.

Wheat Flour Wholesale

It is assumed that consumer demand for wheat flour and wheat flour products is directly reflected through wholesale flour demand felt by flour millers.[7] Seasonal consumer demand for "wheat" in the model represents aggregate demand for wheat grains (whole, pressed, or polished), household wheat flour, and all commercial wheat flour products (all measured in whole wheat equivalents). Given the total aggregate consumer wheat demand, the wholesale demand for wheat flour from millers is represented by the following differential equation.

$$a_k \frac{d^k}{dt^k} RWDEMO(t) + a_{k-1} \frac{d^{k-1}}{dt^{k-1}} RWDEMO(t) + \ldots + a_o\ RWDEMO(t) = UDEM_3(t) + RFCONC(t) \tag{4.121}$$

---

[7]Later refinements of the model could reflect disaggregation of consumer demand for various wheat flour food products such as noodles, bakery products, confectionaries, beverages, etc. Correspondingly, the various wheat flour food processing industries could also be explicitly represented in the model.

where:

a_j = coefficients of distributed delay function,

$$a_j = \binom{k}{j}\left[\frac{DEL}{k}\right]^j, \quad j = 0, \ldots, k$$

DEL = delay parameter--yrs

k = order of delay equation

RWDEMO = demand for wholesale wheat flour from flour millers--MT/yr

UDEM = aggregate urban demand for wheat, wheat flour, and wheat flour products (in wheat grain equivalence)--MT/yr

RFCONC = rate of farm demand for commercial wheat flour and wheat flour products (in wheat grain equivalence)--MT/yr.

The following limiting equation assures nonreversible wheat flour sales, and that wheat flour wholesales from mills are curtailed when flour stock levels are at critically low levels.

$$RWSLS(t) = \max\left\{0., \min\left[RWDEMO(t), \frac{QWMZ(t)}{DT}\right]\right\} \tag{4.122}$$

where:

RWSLS = rate of wheat flour wholesales by millers--MT/yr

max, min = maximum and minimum functions

RWDEMO = demand for wholesale wheat flour from flour millers

QWMZ = current stock level of wheat flour owned by flour millers--MT

DT = time increment of the simulation model--yrs .

This completes the mathematical description of the important aspects of the industrial wheat operations model of the PM subsector. We will now describe some of the important accounting relationships used to measure the fiscal performance of the industrial wheat system.

Industrial Wheat Accounting

Performance of the industrial wheat system, as well as impacts of various government wheat policies upon the industrial wheat subsector, are measured through the accounting equations to be described in this section.

Expenditures

Expenditures incurred by the industrial wheat system are classified into fixed, variable, and import financing costs.

Fixed Costs

Overhead costs for the Korean flour milling industry are represented in the model by storage facility and milling capacity costs. The following equation represents total fixed cost expenditures associated with the industrial wheat submodel.

$$CWFIX(t) = C231(t)\ QWCAP(t) + C232(t)FMCAP(t) \qquad (4.123)$$

where:

CWFIX = total rate of fixed costs associated with the industrial wheat industry--won/yr

C231 = unit fixed cost of total wheat and wheat flour storage capacity--won/MT-yr

QWCAP = total wheat and wheat flour storage capacity--MT

C232 = unit fixed cost of flour milling capacity of industry--won/MT-yr

FMCAP = flour milling capacity--MT/yr.

Variable Costs

Total variable cost represented in the model is the sum of (variable) storage cost, handling cost, and milling cost. The following

equation represents total variable cost associated with the industrial wheat submodel.

$$CWV(t) = CWS(t) + CWH(t) + CWM(t) \quad (4.124)$$

where:

CWV = total variable cost of industrial wheat operations--won/yr

CWS = storage costs--won/yr

CWH = handling costs--won/yr

CWM = milling costs--won/yr.

The individual variable cost components of Equation 4.124 will now be described.

Storage Costs--The total costs associated with holding KOFMIA wheat and wheat flour stocks are represented by the following equation.

$$CWS(t) = C201(t)\ QWIAQ(t) + C202(t)\ [QWS(t)-QWAUX(t)] + C203(t)\ QWMX(t) + C204(t)\ QWMZ(t) + C205(t)\ QWAUX(t) \quad (4.125)$$

where:

CWS = total cost of holding wheat and wheat flour stocks--won/yr

C201 = penalty charge for excessive port discharge delays--won/MT-yr

QWIAQ = wheat import arrivals awaiting discharge--MT

C202 = average cost of normal port storage--won/MT-yr

QWS = imported wheat inventory located at seaport storage facilities (including auxiliary)--MT

C203 = average cost of mill warehouse storage for wheat grain--won/MT-yr

QWMX = current wheat inventory at mills--MT

C204 = average cost of mill warehouse storage for wheat flour--won/MT-yr

QWMZ = current wheat flour inventory at mills--MT

C205 = average cost of auxiliary port storage--won/MT-yr

QWAUX = current wheat inventory in auxiliary storage--MT.

Handling Costs--Wheat handling costs include stevedore charges for import arrivals, wheat bagging, transportation, and rebagging of flour and wheat flour by-products at the mill. These charges are identified in the model by the following equation.

$$CWH(t) = C211(t)\ RWDO(t) + C212(t)\ RWSMO(t) + C213(t)\ RWXZO(t) + C214(t)\ RWZBP(t) \quad (4.126)$$

where:

CWH = total cost of wheat handling operation--won/yr

C211 = unit stevedore charge (includes wheat bagging)--MT/yr

RWDO = rate of wheat import arrivals at port--MT/yr

C212 = unit cost of transportation to mill--won/MT

RWSMO = rate at which wheat is transported to mills--MT/yr

C213 = unit cost of flour bagging--won/MT

RWXZ = rate of wheat flour production--MT/yr

C214 = unit cost of flour by-product bagging--won/MT

RWZBP = rate of wheat flour by-product production--MT/yr.

Milling Costs--Flour production cost is represented by the following equation.

$$CWM(t) = C221(t)\ RWXZ(t) \quad (4.127)$$

where:

CWM = variable cost of wheat flour production--won/yr

C221 = unit cost of wheat flour production--won/MT

RWXZ = rate of wheat flour production--MT/yr.

Total Operating Cost

The total operating cost of the industrial wheat subsector is defined as the sum of fixed cost plus variable cost.

$$\underset{\text{total operating cost}}{TCWOP(t)} = \underset{\text{fixed cost}}{CWFIX(t)} + \underset{\text{variable cost}}{CWV(t)}. \qquad (4.128)$$

Wheat Import Financing

Wheat is imported into Korea under a number of financial agreements between the United States and Korean governments. The KOFMIA, however, must repay wheat import investments from revenues generated from domestic sales, government subsidies paid on sales receipts, or funds from commercial loans. These repayment schedules are very rigid and, therefore, can be easily represented in the model.

The model first distinguishes the relative portion of wheat imported on a cash payment basis. Payment for this portion of wheat imports must be made immediately either from existing funds, commercial bank loans, or special six-month usance loans granted by U.S. grain traders. KOFMIA cash payments for wheat imports are represented by the following equation.

$$RWICSH(t) = PCTCSH_3(t)\ PWLD_3(t)\ WONPD(t) \left\{ PCTUSW(t)\ RWIMPI(t-.5) * \exp\left[\frac{RUS(t)}{2}\right] + [1-PCTUSW(t)]\ RWIMPI(t) \right\} \qquad (4.129)$$

where:

RWICSH = rate of wheat import payments (cash basis)--won/yr

$PCTCSH_3$ = proportion of wheat imports financed on cash payment basis--proportion

$PWLD_3$ = world CIF price of wheat delivered at Korean ports--dollars/MT

WONPD = won-dollar conversion factor--won/dollar

PCTUSW = proportion of cash wheat imports financed under surplus grain loan programs--proportion

RWIMPI = rate at which import orders are placed--MT/yr

exp = natural exponential function

RUS = special usance interest rate--proportion/yr.

Payment for wheat imported under long-term loan agreements (such as PL480) between the U.S. and ROK governments must be made by KOFMIA within three months. The payment schedule is as follows.

i) 5 percent due USG upon opening letter of credit (L/C),

ii) 25 percent of balance due ROKG at L/C + 2 months,

iii) remaining balance due ROKG at L/C + 3 months.

These payments are modelled by the following equation.

$$RWIRP(t) = [1-PCTCSH_3(t)]\ PWLD_3(t)\ WONPD(t)$$
$$[.05\ RWIMPI(t) + .25*.95\ RWIMPI(t-1/6)$$
$$*\exp(RGINT/6) + .75*.95\ RIMPI(t-1/4)\ *\exp(RGINT/4)] \quad (4.130)$$

where:

RWIRP = rate of wheat import payments (noncash basis)--won/yr

$PCTCSH_3$ = proportion of wheat imports financed on cash payment basis--proportion

RWIMPI = rate at which import orders are placed--MT/yr

exp = natural exponential function

RGINT = government interest rate--proportion/yr.

Revenue, Profit, and Debt Obligations

KOFMIA revenues are generated from domestic flour and flour by-product sales and from government subsidies on flour sales receipts. This revenue flow is used to cover total operating costs represented by Equation 4.128, to make import payments as described in Equations 4.129 and 4.130, and to retire commercial loan obligations.

Commercial debt obligations are modelled as simply the accumulated net cash flow within KOFMIA. This net cash flow (or current profit) is given by the equation below.

$$\begin{aligned} RFMCF(t) = {} & RWSLS(t)\ PW_3(t)\ BPMT_3 + RWBP1(t)*PBP1_3(t) + RWBP2(t)\ PBP2_3(t) \\ & + RWSLS(t)*GWSUB(t) - TCWOP(t) - RWICSH(t) - RWIRP(t) \\ & - FMDEBT(t)\ RCINT(t) \end{aligned} \tag{4.131}$$

where:

RFMCF = net cash flow within KOFMIA (current net profits)--won/yr

RWSLS = rate of flour wholesales by millers--MT/yr

PW_3 = wholesale price of wheat flour--won/22-kg bag

$BPMT_3$ = bags per metric ton of wheat flour--bags/MT

RWBP1, 2 = rate of wheat flour by-product sales--MT/yr

PBP1, 2 = price of wheat flour by-products--won/MT

GWSUB = government wheat flour subsidy payments to flour millers--won/MT

TCWOP = total cost of flour milling industrial operations--won/yr

RWICSH = rate of wheat import payments (cash basis)--won/yr

RWIRP = rate of wheat import payments (noncash basis)--won/yr

FMDEBT = flour milling industry commercial debt obligations--won

RCINT = commercial interest rate--proportion/yr.

By integrating Equation 4.131 over time, the accumulated net cash flow of KOFMIA is generated.

$$QFMCF(t) = QFMCF(t_o) + \int_{t_o}^{t} RFMCF(\tau)d\tau . \qquad (4.132)$$

Commercial debt obligations, indicated in Equation 4.132 above, are clarified by

$$FMDEBT(t) = abs\{min[0.,QFMCF(t)]\} \qquad (4.133)$$

where, abs is the absolute operator.

This concludes the detailed description of the private marketing (and industrial wheat) subsector component of the GMP model. In the following chapter, the government subsector component will be described in detail. Many of the grain operation processes described in this chapter are similar for the government subsector model.



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CHAPTER 5

GOVERNMENT SUBSECTOR MODEL

Introduction

The government subsector model of the GMP performs four major functions. *First*, it provides the mechanisms whereby a wide range of alternative grain management program and policy issues can be addressed and analyzed by the GMP model. *Secondly*, it simulates government grain operations, including domestic purchases, imports, storage, milling, handling, transportation, and releases. These government grain activities are constrained to reflect real world system limits of the various processes involved. *Thirdly*, the model simulates government-controlled warehousing operations. In this component, government warehousing construction and leasing programs are simulated. Government-controlled warehousing is disaggregated by class and position, and seasonal expected storage loss rates are computed in a detailed manner. And, *finally*, the government subsector model makes a number of detailed fiscal accounting calculations which are used to measure (in part) the impacts of various grain management programs and policies. This chapter will provide a detailed mathematical description of the government grain operations processes simulated by the GMP model, indicate some of the important mathematical relationships used to orient the GMP model toward addressing a number of important grain management problem issues, and also describe the important fiscal accounting equations used

to measure the relative costs of alternative grain management programs to the Korean government.

Government Grain Supply and Demand

Several important grain management program and policy issues have already been discussed under the general description of the GMP model given in Chapter 2. In theory, essentially all objectives underlying these grain management issues can be accomplished through official government decree, provided, of course, that multiple objectives are consistent and physically possible. The Korean government has, by grain management laws promulgated since 1950 and special countermeasure authority, the legal right to "order any necessary matters" to grain producers, grain dealers, transporters, processors, inns, restaurants, and consumers (through rationing) and to obtain reports from them [22, 36]. Penal provisions range from a possible death penalty for illegal export of grain to lesser penalties for not adhering to government grain laws. However, the effectiveness of government policy by decree only is very limited. Enforcement cost is prohibitive in areas such as controlling market price where black market forces are continually at work. Therefore, (in reality) several objectives underlying grain management issues can only be realized through government involvement and participation in the food grain marketing system. Decree and countermeasure authority can play an important part in government grain management programs and policies; however, active government participation in the demand and supply of food grains is also very necessary if the government is to fulfill the primary purpose of the Korean Grain Management Law: to secure food for the people and ensure stabilization of the national economy.

In this section we will describe the mathematical relationships used in the GMP model to simulate government food grain supply and demand aimed at accomplishing objectives of various grain management programs. Included in the discussion will be the development of annual food plans, import planning, generation of government import orders, domestic grain procurement programs, government grain release programs, and market price stabilization and control.

Development of Annual Food Plans: GMP Front-End Mechanism

Although the GMP model is primarily concerned with small time-increment calculations (from two to nine days) to produce seasonal time series of variables, it is also necessary to make some longer term calculations at the initiation of a model run and then, perhaps, periodically throughout the run. These calculations represent annual food plans developed each year by the Ministry of Agriculture and Fisheries (MAF) under the Grain Management Law and are necessary in order to give the GMP model a realistic basis upon which to operate throughout the year. The model can be operated so that food plans may be programmed to change year to year for multiple-year runs; but this would represent quite a large advance in current planning techniques and most likely would not be done except in special cases, such as in developing five-year plans in which policies were planned to change over an extended period. Basically, the food (grain) plan consists of estimates of food grain requirements and supplies for the upcoming year. Food grain requirements are estimated as the total of expected farm and nonfarm food requirements, government use requirements for military and government institutions, prisons and relief, livestock

feed requirements, seed requirements for the next planting season, and requirements for food processing and industrial use.[1] Expected waste and losses are also accounted for in the total requirements estimate. Food grain supplies are estimated as the total of expected production for the upcoming crop year, *plus* carry-in, *plus* programmed imports which are given values to equate supplies with expected requirements. A number of methods can be used to arrive at estimates of food grain requirements, depending on the issues at hand. For example, relative world market prices may be such that grain management officials responsible for developing a particular food (grain) plan may desire to change the diet mix of food grains (rice, barley, and wheat) to economize on foreign exchange expenditures for food grain imports. Self-sufficiency goals for certain food grain commodities may be important issues concerning officials formulating a food plan. In deciding on a zero import requirement for these commodities, officials developing the food plan must be reasonably confident that domestic supplies are adequate to support normal consumption levels over the period of self-sufficiency and/or adequate supplies of substitute grains are planned to preclude drastic price increases in the "self-sufficient" commodities. Socially tolerable limits of consumption pattern shifts to less-preferred food grains must also be considered from a political standpoint. Basic food grain price structure may also be of primary concern, since food grains play a dominant role in the consumer price index. In short, formulating a typical food

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[1]The current version of the GMP model aggregates household consumption of food grains by commodity. That is, food grain equivalents contained in industrial processed foods such as breads, cakes, noodles, and alcoholic beverages are included in each basic commodity.

plan requires keen concern for the economic, social, and political implications. The utility of the GMP model as a grain management tool is greatly enhanced by including the analytical capability of formulating alternative annual food (grain) plans and measuring the consequences of these plans in conjunction with seasonal grain management policies and programs.

Generalized Demand-Price Analyzer

It was pointed out in the preceding paragraph that government officials concerned with formulating a basic annual food (grain) plan are concerned with both quantities and prices of food grains for the upcoming planning period. The generalized demand-price analyzer (or GMP front-end mechanism) enables the model user to specify a mix of prices and/or demands for food grains for a particular food plan. The model then uses linear algebraic techniques to solve for the unspecified prices and/or demands, resulting in a full set of annual average food grain prices and demands which are consistent with the Korean food grain demand system specified in the model.

The annual demand model used in the GMP front-end mechanism is of the form of a Cobb-Douglas function. Since farm and urban populations in Korea exhibit unique consumption behavioral characteristics, the model is disaggregated accordingly. The two basic annual demand models for farm and urban population sectors are shown below.

$$PCCFA_i(t) = CF1_i \prod_{j=1}^{3} \left[PFA_j(t)^{CF2_{ij}}\right] YF(t)^{CF3_i} \qquad (5.1)$$

$$PCCUA_i(t) = CU1_i \prod_{j=1}^{3} \left[PUA_j(t)^{CU2_{ij}}\right] YU(t)^{CU3_i} \qquad (5.2)$$

where:

PCCFA = annual average consumption per capita for farm population--kg/capita-yr

PCCUA = annual average consumption per capita for urban population--kb/capita-yr

PFA = annual average price received by farmers--won/bag

PUA - urban retail price--won/bag

CF1, CU1 = constant terms of Cobb-Douglas functions for farm and urban demand equations, respectively

CF2, CU2 = annual price elasticity of demand for farm and urban demand functions, respectively

CF3, CU3 = income elasticity of demand for farm and urban demand functions, respectively

YF, YU = annual per capita income of farm and urban populations, respectively--won/capita-yr.

The demand function constants CF1 and CU1, in Equations 5.1 and 5.2, are calculated from initial starting conditions for the model. Average consumption levels, prices, and incomes used to calculate these parameters are given values as close as possible to actual average values existing at the time of model initialization. The effect of this is to place the demand curves through the initial conditions of the model run. These calculations are made as follows.

$$CF1_i = PCCFA_i(t_o) \Big/ \left[\prod_{j=1}^{3} \left\{ PFA_i(t_o)^{CF2_{ij}} \right\} YF(t_o)^{CF3_i} \right] \tag{5.3}$$

$$CU1_i = PCCUA_i(t_o) \Big/ \left[\prod_{j=1}^{3} \left\{ PUA_j(t_o)^{CU2_{ij}} \right\} YU(t_o)^{CU3_i} \right] \tag{5.4}$$

When the variables of Equations 5.1 and 5.2 are given their logarithmic values, the equations can be transformed into linear forms. Since the equations for farm and urban demand functions are handled

in exactly the same manner, the following discussion will indicate operations performed on Equation 5.2 for the urban sector only. The reader can substitute the letter "F" in place of the letter "U" appearing in the equations to get the corresponding equations for farm population. In log-log form, Equation 5.2 can be written in the following linear form.

$$\ln PCCUA_i(t) = \ln CU1_i + \sum_{j=1}^{3} CU2_{ij} \ln PUA_j(t) + CU3_i \ln YU(t) \qquad (5.5)$$

where, ln is the natural log operator. This equation can be written in explicit matrix form, for i=1, 2, and 3 (rice, barley, and wheat) as follows.

$$\ln \begin{bmatrix} PCCUA_1(t) \\ PCCUA_2(t) \\ PCCUA_3(t) \end{bmatrix} = \ln \begin{bmatrix} CU1_1 \\ CU1_2 \\ CU1_3 \end{bmatrix} + \begin{bmatrix} CU2_{11} & CU2_{12} & CU2_{13} \\ CU2_{21} & CU2_{22} & CU2_{23} \\ CU2_{31} & CU2_{32} & CU2_{33} \end{bmatrix} \ln \begin{bmatrix} PUA_1(t) \\ PUA_2(t) \\ PUA_3(t) \end{bmatrix} + \begin{bmatrix} CU3_1 \\ CU3_2 \\ CU3_3 \end{bmatrix} \ln YU(t). \qquad (5.6)$$

For notational ease in illustrating the manipulations done on Equation 5.6, the following variable names are substituted:

$Q_i = \ln PCCUA_i(t)$, $C_i = \ln CU1_i$, $\varepsilon_{ij} = CU2_{ij}$, $P_i = \ln PUA_i(t)$, $m_i = CU3_i$, and $I = \ln YU(t)$, with the equivalent of Equation 5.6 being written as:

$$\begin{bmatrix} Q_1 \\ Q_2 \\ Q_3 \end{bmatrix} = \begin{bmatrix} C_1 \\ C_2 \\ C_3 \end{bmatrix} + \begin{bmatrix} \varepsilon_{11} & \varepsilon_{12} & \varepsilon_{13} \\ \varepsilon_{21} & \varepsilon_{22} & \varepsilon_{23} \\ \varepsilon_{31} & \varepsilon_{32} & \varepsilon_{33} \end{bmatrix} \begin{bmatrix} P_1 \\ P_2 \\ P_3 \end{bmatrix} + \begin{bmatrix} m_1 \\ m_2 \\ m_3 \end{bmatrix} I, \qquad (5.7)$$

or, in abbreviated matrix form,

$$Q = C + EP + MI. \tag{5.8}$$

Rearranging Equation 5.8, we have

$$Q - EP = C + MI \tag{5.9}$$

or,

$$[U \quad -E] \begin{bmatrix} Q \\ P \end{bmatrix} = C + MI \tag{5.10}$$

where, U is a 3X3 unit matrix. Simplifying further for notational ease, we can write

$$BX = D \tag{5.11}$$

where, B = [U -E], a 3X6 matrix; $X = \begin{bmatrix} Q \\ P \end{bmatrix}$, a 6X1 matrix; and D = C+MI, a 3X1 matrix.

Now, if three of the variables of the X matrix of Equation 5.11, prices and/or consumptions, are specified and called X_1, with the remaining variables being unknown and called X_2, the following relationship can be written.

$$BX = [A_1 \; A_2] \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = D \tag{5.12}$$

where, $[A_1 \; A_2]$ is a matrix of columns of B rearranged to correspond to the elements of X_1 and X_2.

Solving for the unknown prices and/or consumptions, X_2 in Equation 5.12, we have

$$X_2 = A_2^{-1}[D - A_1X_1]. \tag{5.13}$$

To put Equation 5.13 back into the perspective of the GMP model, suppose, for example, that for a particular food (grain) plan, circumstances are such that decision makers wish to specify (or target) annual average rice consumption, rice price, and wheat flour price for the urban sector. The generalized demand-price analyzer will then solve for the corresponding annual average barley price, barley consumption, and wheat flour consumption, which will satisfy the demand equation expressed in Equation 5.2. Using the indices 1, 2, and 3 to correspond to rice, barley, and wheat flour, respectively; and using the original variable names of Equation 5.2, the solution for the unknown variables in this example is expressed as follows.

$$\overbrace{\begin{bmatrix} PUA_2(t) \\ PCCUA_2(t) \\ PCCUA_3(t) \end{bmatrix}}^{\text{(Unknowns)}} = EXP\left\{ \begin{bmatrix} -CU2_{12} & 0 & 0 \\ -CU2_{22} & 1 & 0 \\ -CU2_{32} & 0 & 1 \end{bmatrix}^{-1} \left(\ln \begin{bmatrix} CU1_1 \\ CU1_2 \\ CU1_3 \end{bmatrix} + \begin{bmatrix} CU3_1 \\ CU3_2 \\ CU3_3 \end{bmatrix} \ln YU(t) \right. \right.$$

$$\left. \left. - \begin{bmatrix} 1 & -CU2_{11} & -CU2_{13} \\ 0 & -CU2_{21} & -CU2_{23} \\ 0 & -CU2_{31} & -CU2_{33} \end{bmatrix} \ln \overbrace{\begin{bmatrix} PUCCA_1(t) \\ PUA_1(t) \\ PUA_3(t) \end{bmatrix}}^{\text{(Knowns)}} \right) \right\} \tag{5.14}$$

where, EXP is the base of the natural logarithm e.

There is no guarantee that the set of annual food grain prices and consumption levels generated from the demand-price analyzer will be realized for the coming year. These prices and consumption levels

are merely a set representing a particular food (grain) plan and consistent with the Korean food grain demand function specified in the model. As the model run proceeds throughout the year, government grain activities must be aimed at achieving these program objectives.

Import Planning

One of the basic outcomes of a particular food (grain) plan is the programmed level of grain imports for the coming year. Imports are used to balance estimated food grain supplies with estimated requirements. Although the actual level of imports at the year end (both in reality and in the model) may differ from the basic plan, the calculations are necessary in the GMP model to generate a normal level of imports to which adjustments can be made during the year.

Annual Food Grain Requirements

Annual food grain requirements are estimated using the following equation.

$$QTR_i(t) = (1+TSLOSS_i) * [QUF_i(t) + QFF_i(t) + QGU_i(t) + QFLV_i(t) + QFSE_i(t) + QCO_i(t)] \quad (5.15)$$

where:

QTR = estimated total annual food grain requirement--MT

TSLOSS = estimated total system annual expected loss and waste--proportion/yr

QUF = estimated total annual nonfarm (urban) food grain requirement--MT

$$\text{i.e., } QUF_i(t) = PCCUA_i(t)*UPOP(t)/1000 \quad (5.16)$$

PCCUA = estimated average annual consumption per capita for urban population (see Equation 5.2)--kg/capita-yr

UPOP = urban population--persons

QFF = estimated total farm household food grain requirement--MT

$$\text{i.e., } QFF_i(t) = PCCFA_i(t)*FPOP(t)/1000 \qquad (5.17)$$

PCCFA = estimated average annual consumption per capita for farm population (see Equation 5.1)--kg/capita-yr

FPOP = farm population--persons

QGU = estimate of annual government-use requirements (exogenous model input)--MT

QFLV = estimate of annual food grain requirements for livestock feed (exogenous model input)--MT

QFSE = estimate of seed requirements for next planting season--MT

$$\text{i.e., } QFSE_i(t) = SRPHAZ_i*AREA(t) \qquad (5.18)$$

SRPHAZ = seeding rate per hectare--MT/ha

AREA = expected area to be planted[2]--ha

QCO = desired carry-over stock levels (exogenous model input)--MT.

Annual Food Grain Supply

Annual food grain supplies are estimated using the following equation.

$$QTS2_i(t) = QTS_i(t) + QPROD_i(t) \qquad (5.19)$$

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[2]The variable AREA is calculated in the production response mechanism of the GMP model. The user may also specify AREA exogenously if desired.

where:

QTS2 = estimated total available food grain supply for upcoming year (excluding unscheduled imports)--MT

QTS = current total food grain supply (carry-in)--MT

$$\text{i.e., } QTS_i(t) = QF_i(t) + QPM_i(t) + QG_i(t) + QU_i(t) \quad (5.20)$$

QF = total farm storage--MT

QPM = total private market storage--MT

QG = total government storage, including imports ordered but not yet delivered--MT

QU = total urban household storage--MT

QPROD = estimate of domestic food grain production for upcoming year--MT.

There is a difficulty with Equation 5.19 for estimating total available food grain supply for the upcoming year. Domestic production (harvest), represented by $QPROD_i$, does not occur until sometime later in the planning year; i.e., barley harvest occurs around June and rice harvest does not occur until around October. If the above calculations are made at the beginning of a calendar year, there will be a delay of at least six months before the estimated barley production is available and ten months before the estimated rice production is available. Several methods can be used to solve this timing difficulty, such as changing the time of the planning calculations for each commodity to occur closer to the relative harvest seasons. However, a well-planned carry-over variable, $QCO_i(t)$ in Equation 5.15, seems to do an adequate job of assuring sufficient supplies until the actual harvest occurs. This is also similar to the planning method which occurs in reality. The actual food plan period in Korea is from 1 November

to 31 October and is referred to as a "rice year." Technical difficulties with beginning the model during a harvest season make it better to start the model at the beginning of the calendar year when no harvest is occurring.

Annual Food Grain Deficit

Annual food grain deficit supply is calculated as the difference between estimated requirements and supply; i.e., Equations 5.15 and 5.19, respectively.

$$QTDEF_i(t) = QTR_i(t) - QTS2_i(t). \quad (5.21)$$

Current grain law in Korea prohibits the exportation of food grains. This constraint is reflected in the GMP model with planned imports for the upcoming year being represented by the following equation.

$$QIMP_i(t) = \max[0, QTDEF_i(t)] \quad (5.22)$$

where:

QTDEF = estimated total annual food grain deficit--MT

QTR = estimated total annual food grain requirement--MT

QTS2 = estimated total available food grain supply for upcoming year (excluding unscheduled imports)--MT

QIMP = estimated quantity of imported grains required to balance requirement and supply estimates for upcoming year--MT.

Government Grain Import Orders

Imports of foreign rice and barley are done through the government subsector. Imports of foreign wheat and wheat flour, although closely regulated by the Korean government, are done through the private

subsector, namely, the Korean Flour Millers Industrial Association (KOFMIA). The GMP model description of wheat import operations has already been given in Chapter 4 (Private Market). A description of the mathematical relationships used to model government rice and barley import orders will be given here.

Several schemes can be used to generate government grain import orders. The one currently used in the GMP model and described here is one of the simplest, but seemingly most consistent with the current situation. A slightly more sophisticated import control scheme, using $QIMP_i(t)$ of Equation 5.22, will also be described.

The first import scheme assumes government import policy such that a minimum grain reserve stock level is maintained within the *government subsector* alone. No regard is given to estimates of overall system grain supplies in farm, private market, and urban consumer households. (Another obvious scheme would be to consider overall grain system supply.) The following equations describe the model generation of government grain import orders.

$$QG_i(t) = QGPX_i(t)*EXZ_i + QGPY_i(t)*EYZ_i + QGPZ_i(t) + QGCY_i(t)*EYZ_i + QGCZ_i(t) + QGSY_i(t)*EYZ_i + QGIMP_i(t) + QGIAQ_i(t) \qquad (5.23)$$

where:

QG = total government subsector grain stock level in polished equivalent--MT

QGPX = quantity of government rough grains located at production area positions--MT

QGPY = quantity of government grains in hulled form located at production area positions--MT

QGPZ = quantity of government grains in polished form located at production area positions--MT

QGCY = quantity of government grains in hulled form located at consumption area positions--MT

QGCZ = quantity of government grains in polished form located at consumption area positions--MT

QGSY = quantity of government imported grains located at seaport positions--MT

EXZ = rough to polished form conversion factor--proportion

EYZ = hulled to polished form conversion factor--proportion

QGIMP = quantity of government imported grains currently in import pipeline (i.e., ordered, but not yet arrived at port facilities)--MT

QGIAQ = quantity of government imported grains in import arrival queue (i.e., arrived at ports and awaiting discharge)--MT.

Given current government inventory stock levels, $QG_i(t)$, the model generates the following error signal.

$$QGER_i(t) = QGD_i(t) - QG_i(t) \tag{5.24}$$

where:

QGER = error signal between desired government stock level and actual stock level--MT

QGD = desired government grain inventory stock level--MT.

Actual import orders to maintain minimum government grain reserve stock levels are generated by the following control function.

$$Z10_i(t) = G10A*QGER_i(t) + G10B \frac{d}{dt} QGER_i(t) + G10C \int_{t_o}^{t} QGER_i(\tau)d\tau \tag{5.25}$$

(Limiter)

$$RGIMPI_i(t) = \max [0., Z10_i(t)] \tag{5.26}$$

where:

Z10 = control signal representing import orders made in order to maintain government grain reserve stock levels above a predetermined minimum level--MT/yr

G10A, B, C = feedback control gain parameters--various units

QGER = error signal between desired government stock level and actual stock level--MT

RGIMPI = constrained control signal for government grain import orders, precluding exports--MT/yr

max = maximum function.

The reader will note that the import control signal, $Z10_i(t)$ of Equation 5.25 above, is chopped at values equal to or less than zero. The next import ordering scheme to be described allows $Z10_i(t)$ to operate both in the positive and negative ranges of values.

$$RGIMPI_i(t) = \max [0., Z10_i(t) + QIMP_i(t)] \quad (5.27)$$

where, $QIMP_i(t)$ is the estimated quantity of imported grains required to balance requirement and supply estimates for the current year (Equation 5.22). Exports of grains are still prohibited by Equation 5.27; however, the control signal $Z10_i(t)$ may now operate in a much larger range than in Equation 5.26.

The actual importation process for government grains is modelled through the use of distributed delay functions. A detailed mathematical description of the import pipeline, import arrival queues, and port discharge operations on imported government grains is given under the government grain operations section of this chapter.

Government Grain Purchase and Release Programs

An important set of government grain management issues which the GMP model is designed to address consists of investigating the outcome of various government purchase and/or release (P/R) programs.

On the purchase program side, the major objectives are (1) to replenish government domestic grain stocks used for urban price stabilization; (2) to encourage farmers to produce high-yielding rice varieties which tend to have a lower free market value than traditional rice varieties; (3) to encourage increased barley production, especially in marginal double-cropping areas; and (4) to maintain a support price level for farmers, especially during and right after new crop harvest when the glut of grain marketings occurs. On the release program side, the major objectives are (1) to stabilize urban grain prices which have a large impact on the stability of the national economy; and (2) to encourage urban consumption of "less preferable" food grain varieties, such as high-yielding rice varieties and barley, which tends to supplement urban demand for traditional rice varieties which are highly preferred and in typically short supply.

Other than replenishment of government domestic grain stocks, all the objectives of government P/R programs mentioned above can be realized by proper stabilization and control of farm and urban food grain prices. In this section we will describe two basic methods which can be used by the GMP model to replicate government P/R programs. The first method described is an *open-loop* price stabilization scheme in which the timing and quantity of government grain purchases and/or releases are preplanned. The second method described is a *closed-loop* price stabilization scheme in which the rate of government demand and supply is governed by an automatic feedback control mechanism which compares the relationship between targeted and actual market prices.

Open-Loop P/R Programs: Price Stabilization

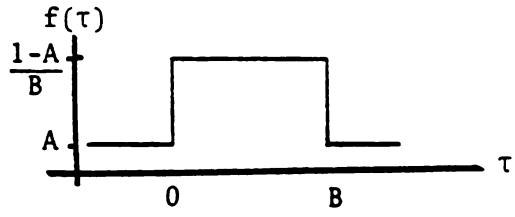
Domestic grain purchase programs undertaken by the Korean government are typically open-loop farm price stabilization programs. The government buying price is established, and the government purchases domestic food grains at this price for a predetermined period of time, regardless of free market grain prices. The purpose of this section is to describe fully the underlying mathematics which enables the model user to easily define the precise P/R program he wishes to investigate. As the reader will see, a wide variety of open-loop programs can be addressed to the model.

To simplify the P/R program definition process, the following attributes of the particular preplanned P/R program are all that need concern the user.

1. Targeted amount of purchases and/or releases
2. Time of year to start P/R program
3. Duration of P/R program
4. Type of distribution of P/R program
5. Government buying and/or selling price during P/R program

Figure 5.1 illustrates the four common distribution functions inherent in the GMP model which can be utilized to define particular P/R programs. Beside each distribution sketch in the figure is the mathematical equation used in the model to represent the particular function. In specifying a particular P/R program to be investigated by the GMP model, the user simply chooses the type of distribution to be used and stipulates the value of the P/R program parameters. Government demand and/or supply of food grains is then generated throughout the simulation run by the following equations.

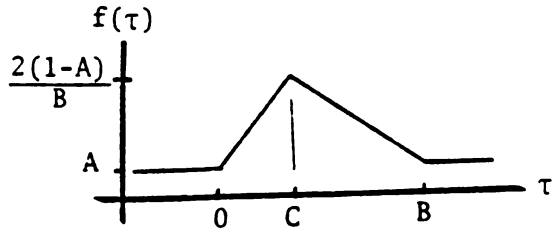
Uniform Distribution



$$f(\tau) = \frac{1-A}{B}[u(\tau)-u(\tau-B)] \qquad (5.30)$$

where: u = unit step function

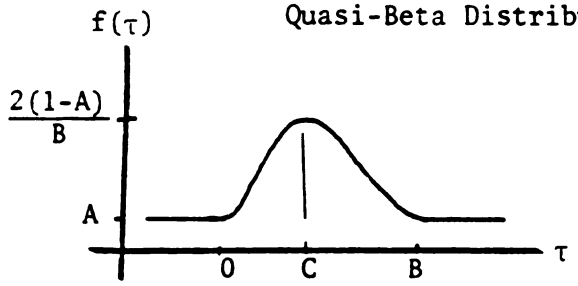
Triangular Distribution



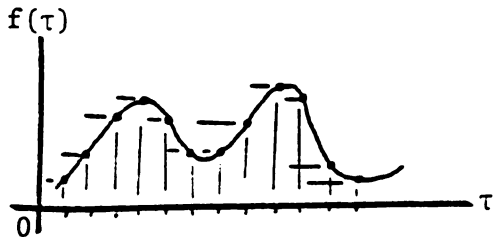
$$f(\tau) = \frac{2(1-A)}{BC}[r(\tau)-r(\tau-C)] - \frac{2(1-A)}{B(B-C)}[r(\tau-C)-r(\tau-B)] \qquad (5.31)$$

where: r = unit ramp function

Quasi-Beta Distribution



$$f(\tau) = \frac{1-A}{B}[1-\cos\frac{\pi\tau}{C}][u(\tau)-u(\tau-C)] + \frac{1-A}{B}[1+\cos\frac{\pi(\tau-C)}{B-C}][u(\tau-C)-u(\tau-B)] \qquad (5.32)$$



$$\int_0^1 f(\tau)d\tau = 1 \qquad (5.33)$$

Figure 5.1. Optional Purchase/Release Program Distribution Functions.

$$GDEM_i(t) = f_i(\tau_i)*QPP_i(t) \tag{5.28}$$

$$GMKTS_i(t) = g_i(\tau_i')*QRP_i(t) \tag{5.29}$$

where:

GDEM = rate of government demand for domestic food grain -- MT/yr

GMKTS = rate of government releases of domestic food grain-- MT/yr

f, g = distribution functions associated with particular P/R programs--no units

$$\int_0^1 f(\tau)d\tau = 1 \quad ; \quad \int_0^1 g(\tau)d\tau = 1$$

QPP, QRP = amount of targeted purchases and/or releases for particular P/R programs--MT

τ, τ' = P/R program time clock (reset to zero at start of P/R program)--yrs

t = simulation time clock--yrs.

The advantage of open-loop price stabilization P/R programs is in the simplicity of implementation. Government purchases and/or releases are preplanned so that the logistics of government P/R programs can be prepared for, and carried out on a scheduled basis. As was mentioned, open-loop government purchase programs have been used in Korea quite successfully; however, to assure price stability in consumer marketplaces, it is necessary for the government to monitor current market conditions closely and play an active role in providing adequate food grain supplies on the market.

Closed-Loop P/R Programs: Seasonal Price Control

Seasonal price control is undoubtedly one of the most important issues facing Korean grain management officials. Domestic food grain prices may vary widely during the year, depending on market demand and supply relationships. These variations, if too large, can have adverse effects on both farm and urban populations, especially the lower income groups. To assure seasonal price stability in domestic food grain prices, it is necessary for the government to monitor current market conditions closely and play an active role in domestic grain dealings (buying and selling).

The design of the seasonal price control mechanism of the GMP model is aimed at developing a set of management strategies which can be adopted by government administrators when ordering government market activities (buying and/or selling) for purposes of stabilizing or controlling domestic market food grain prices. General in design, the GMP seasonal price control mechanism enables the investigation of a much broader range of seasonal price control programs than have been tried in Korea in the past. For example, Korea has never had an active program for (rigid) control of farm prices to prespecified seasonal patterns. Government purchase programs have always been preplanned (open-loop) and occur during and immediately after harvest. The GMP seasonal price control mechanism, however, is designed to prescribe both government purchase and release patterns necessary for controlling either or both farm and urban prices to prespecified seasonal targets. The mechanism is also designed for the study and development of various cross-price decoupling strategies which can be incorporated into seasonal price control programs. That is, the

seasonal price control mechanism can not only prescribe government market activity in rice for controlling rice price to a prespecified seasonal target, but can also prescribe compensating government market activity in barley required to cancel the effect that government rice marketing activity alone has on barley price due to substitution effects between the two grains. This, too, is something which has never been under serious consideration in the past. This is another example of the generalized nature of the GMP seasonal price control mechanism, making it a potential tool for studying possible price control programs of the future.

Seasonal Price Control Mechanism

Figure 5.2 depicts the basic design of the GMP seasonal price control mechanism. Important points along the figure are lettered to assist in the following narrative description. Point A of Figure 5.2 identifies the desired seasonal price patterns (to be discussed later) which are reference inputs to the seasonal price control mechanism. These seasonal price patterns represent what grain management decision makers feel would produce the "most desirable" grain system response in meeting the objectives of seasonal price policies. Several alternative seasonal price patterns can be tested with the model in arriving at a "most desirable" pattern.

Point B identifies the error signals which are produced by comparing desired price patterns with information on actual price patterns produced by the simulation model.

Point C identifies the prescribed government buying and selling activities produced by applying specific decision rules (mathematical

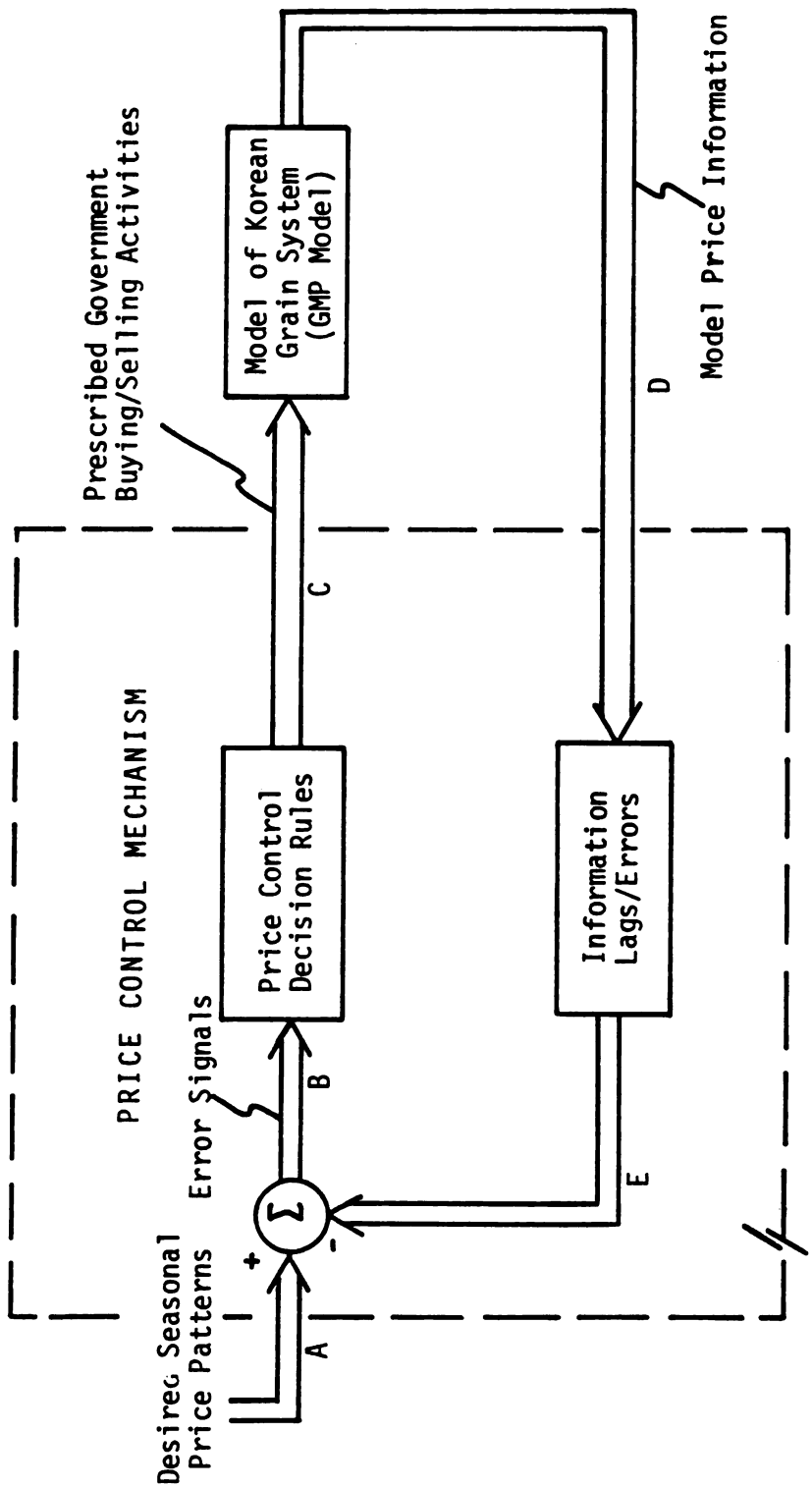


Figure 5.2. Seasonal Price Control Mechanism.

operations) to the error signals represented at Point B. These decision rules are developed by model designers, using control systems theory and a process of trial and error, until the resulting prescriptions produce the most acceptable system responses.

Point D identifies food grain prices produced by the GMP simulation model with the government undertaking the actions prescribed at Point C. These model prices are then fed back into the price control mechanism for comparison with the reference desired price patterns. Note that an attempt can be made to replicate information lags and errors in observing market price information (Point E). This is done to effect a controller design more applicable to the real world situation [5].

Controller Design -- A general control scheme (proportional-plus-derivative-plus-integral control) is used for the automatic price controller design. The following equations describe the basic mathematical relationships underlying the design of the GMP price control mechanism.

(Farm price controller)

$$PFER_i(t) = PFD_i(t) - PF_i(t) \tag{5.34}$$

$$DPFER_i(t) = \frac{d}{dt} PFD_i(t) - \frac{d}{dt} PF_i(t) \tag{5.35}$$

$$SPFER_i(t) = \int_{t_o}^{t} PFD(\tau)d\tau - \int_{t_o}^{t} PF_i(\tau)d\tau \tag{5.36}$$

$$\begin{bmatrix} GDEMU_1(t) \\ GDEMU_2(t) \end{bmatrix} = \begin{bmatrix} a'_{11} & a'_{12} \\ a'_{21} & a'_{22} \end{bmatrix} \begin{bmatrix} PFER_1(t) \\ PFER_2(t) \end{bmatrix} + \begin{bmatrix} b'_{11} & b'_{12} \\ b'_{21} & b'_{22} \end{bmatrix} \begin{bmatrix} DPFER_1(t) \\ DPFER_2(t) \end{bmatrix}$$

$$+ \begin{bmatrix} c'_{11} & c'_{12} \\ c'_{21} & c'_{22} \end{bmatrix} \begin{bmatrix} SPFER_1(t) \\ SPFER_2(t) \end{bmatrix} \qquad (5.37)$$

where:

PFER = farm price error signal--won/bag

PFD = desired seasonal farm price signal--won/bag

PF = farm market price--won/bag

DPFER = error signal representing difference in desired *rate of change* in farm price and actual *rate of change* in farm price--won/bag-yr

SPFER = error signal representing difference in desired *accumulation* in farm price and actual *accumulation* in farm price--won-yr/bag

GDEMU = unlagged version of government demand on the farm market--MT/yr

A', B', C' = control gain parameter matrices

(Urban price controller)

$$PUER_i(t) = PUD_i(t) - PU_i(t) \qquad (5.38)$$

$$DPUER_i(t) = \frac{d}{dt} PUD_i(t) - \frac{d}{dt} PU_i(t) \qquad (5.39)$$

$$SPUER_i(t) = \int_{t_o}^{t} PUD_i(\tau)d\tau - \int_{t_o}^{t} PU_i(\tau)d\tau \qquad (5.40)$$

$$\begin{bmatrix} GMKTSU_1(t) \\ GMKTSU_2(t) \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} PUER_i(t) \\ PUER_2(t) \end{bmatrix} + \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \begin{bmatrix} DPUER_1(t) \\ DPUER_2(t) \end{bmatrix}$$

$$+ \begin{bmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{bmatrix} \begin{bmatrix} SPUER_1(t) \\ SPUER_2(t) \end{bmatrix} \qquad (5.41)$$

where:

PUER = urban price error signal--won/bag

PUD = desired seasonal urban price signal--won/bag

PU = urban market price--won/bag

DPUER = error signal representing difference in desired *rate of change* in urban price and actual *rate of change* in urban price--won/bag-yr

SPUER = error signal representing difference in desired *accumulation* in urban price and actual *accumulation* in urban price--won-yr/bag

GMKTSU = unlagged version of government grain marketings (releases) on the urban market--MT/yr

A, B, C = control gain parameter matrices.

Because of the similarity between farm and urban price controllers, the remainder of this discussion will address urban price control only.

The matrix Equation 5.41 above describes the automatic feedback control design used for controlling urban rice and barley prices simultaneously. The elements of the control gain parameter matrices (A, B, and C) in Equation 5.41 describe how government grain release orders (should) respond to various functions of the error signals. The diagonal elements describe release orders in response to own-price errors (e.g., rice releases to eliminate errors in urban rice price),

while the off-diagonal elements describe release orders required to compensate for cross effects among commodity prices being controlled (e.g., barley releases to compensate for changes in barley price caused by rice releases) [11].

Logistical considerations imply a time lag between *prescribed* government food grain demand and supply calculated in Equations 5.37 and 5.41, and *actual* government market response. The following differential equations give the required lag effect to the outputs of the seasonal price control mechanism.

$$\frac{d}{dt} GDEM_i(t) = -\frac{1}{DELG7} GDEM_i(t) + \frac{1}{DELG7} GDEMU_i(t) \tag{5.42}$$

$$\frac{d}{dt} GMKTS_i(t) = -\frac{1}{DELG8} GMKTS_i(t) + \frac{1}{DELG8} GMKTSU_i(t) \tag{5.43}$$

where:

GDEMU, GDEM = unlagged and lagged versions of government domestic food grain demand, respectively--MT/yr

GMKTSU, GMKTS = unlagged and lagged versions of government food grain releases, respectively--MT/yr

DELG7, DELG8 = time constant parameters--yrs.

Seasonal Target Price Patterns--The targeted seasonal price patterns, $PFD_i(t)$ and PUD_i, used as reference signals for the price control mechanism must be specified by the model user. Although the user may input virtually any empirical price signals into the model by utilizing table look-up functions, a generalized singularity function is also available enabling the user to specify a wide variety of target price signals with very little effort.

The procedure used in the GMP model to generate a target seasonal food grain price pattern is to specify a desired seasonal price index based on average annual food grain price as defined or calculated in the GMP front-end mechanism (annual food plan). This index then operates on the average annual food grain price through time to generate the seasonal target price signal. The following equations show the relationships between target price patterns, target price indices, and average annual food grain prices.

$$PFD_i(t) = [1+SFPID_i(t)]PFAO_i(t) \tag{5.44}$$

$$PUD_i(t) = [1+SUPID_i(t)]PUAO_i(t) \tag{5.45}$$

where:

PFD, PUD = targeted seasonal farm and urban market prices, respectively--won/bag

SFPID, SUPID = targeted seasonal farm and urban market price indices, respectively--no units

PFAO, PUAO = smoothed average annual farm and urban prices, respectively (as generated in GMP front-end mechanism)--won/bag.

Smoothed versions of annual average farm and urban prices are used to preclude discontinuities at year's end when new annual average farm and urban prices are generated. The following differential equations are used to effect this smoothing process.

$$\frac{d}{dt} PFAO_i(t) = -\frac{1}{DEL.} PFAO_i(t) + \frac{1}{DEL.} PFA_i(t) \tag{5.46}$$

$$\frac{d}{dt} PUAO_i(t) = -\frac{1}{DEL.} PUAO_i(t) + \frac{1}{DEL.} PUA_i(t) \tag{5.47}$$

where, the DEL. variables are the time-constant parameters used for smoothing.

Figure 5.3 illustrates the general shape of targeted seasonal price indices which can be specified by the model user by utilizing the generalized singularity function inherent in the GMP model for this purpose.

Since the procedure is exactly the same for generating farm and urban seasonal target prices, the following discussion will concern itself with target urban prices only. The equation for the generalized seasonal price index signal shown in Figure 5.3 can be written as follows.

$$SUPID_i(t) = B_i + S_{1i}*r(t-T_1) - S_{1i}*r(t-T_2) - S_{2i}*r(t-T_3) + S_{2i}*r(t-T_4) \quad (5.48)$$

where:

SUPID = targeted seasonal price index--proportion

B = y-axis intercept of targeted seasonal price index function--proportion

r = unit ramp function

S_1 = slope of SUPID function between T_1 and T_2 (rise region)--proportion/yr

S_2 = slope of SUPID function between T_3 and T_4 (fall region)--proportion/yr

T_1 = time of year to begin rise region of SUPID--yr

T_2 = time of year to begin high-level region of SUPID--yr

T_3 = time of year to begin fall region of SUPID--yr

T_4 = time of year to begin low-level region of SUPID--yr.

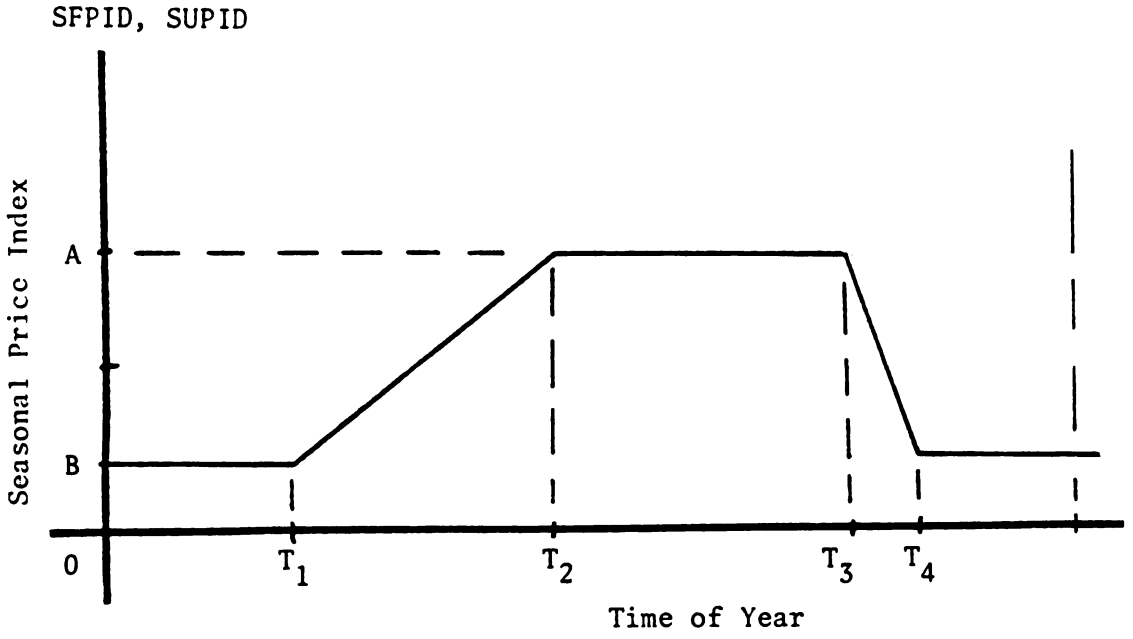


Figure 5.3. Seasonal Price Index Signal.

When specifying a particular targeted seasonal price index signal to be addressed to the model, the user need only specify the following parameters.

1) values of T_1, T_2, T_3, and T_4 of Figure 5.3
2) value of S (i.e., the slope of SUPID in rise region of the signal--proportion/yr

All other parameters of the SUPID function are calculated internally. These internal calculations will now be described.

Internal calculation of S_2 (the slope of the SUPID function between T_3 and T_4) assumes that the fall between T_3 and T_4 must be equal to the rise between T_1 and T_2; therefore,

$$S_{2i} = S_{1i} \frac{T_{2i}-T_{1i}}{T_{4i}-T_{3i}}, \text{ assuming } T_1<T_2<T_3<T_4 . \tag{5.49}$$

By definition, the integral of SUPID over a one-year period should be zero, that is

$$\int_0^1 SUPID_i(t)dt = 0 . \tag{5.50}$$

Performing this integration on the expression for SUPID given in Equation 5.48 and solving for the y-axis intercept term B, we have

$$B_i = -\frac{S_{1i}}{2}(1-T_{1i})^2 + \frac{S_{1i}}{2}(1-T_{2i})^2 + \frac{S_{2i}}{2}(1-T_{3i})^2 - \frac{S_{2i}}{2}(1-T_{4i})^2. \tag{5.51}$$

Special cases exist for Equations 5.48, 5.49, and 5.51 when the SUPID curve is defined such that the condition $T_1<T_2<T_3<T_4$ is not true. An example of such a curve would be when, say, the seasonal price index curve began rising at the end of the year and then levelled off after the beginning of the new year. In this case the condition $T_1<T_2$ would not hold. The model is designed to handle all special cases internally so that the user's only concern need be to specify the parameter values for all cases in the same manner.

Controller Utilization--In utilizing the GMP model for determining actual government buying and selling activities required to control market prices, the following approach might be taken.

1) The GMP simulation model would be initialized as closely as possible to the current real world situation. This would include current food grain price levels, rates of change of prices, system inventory levels, current urban consumption demand, and other states of the real world system which are reflected in the model.

2) The model would then be run over a desired time horizon, say, one year, to determine a tentative schedule of government grain activities (e.g., the amounts and timing of government grain releases) prescribed to control (urban) food grain prices to desired patterns.

3) The schedule of government grain activities derived in step 2 would then be used for the basic planned scheduling for government grain releases. As time evolved, real world prices would almost certainly deviate from the desired patterns. This error would be due to model errors, measurement errors in the real world, incomplete model specification, and random disturbances which affect the real world system.

4) To compensate for the price deviations observed in step 3, a corrective action release schedule would be determined, again using the system model. This time the error signals observed in the real world would be input to the model price control mechanism. The prescribed corrective action releases would then be superimposed on the original basic plan for government grain releases.

5) The above process would be repeated as frequently as necessary to keep the model prescriptions well in line with the real world situation.

Government Grain Operations

In this section we will describe the mathematical structure of the government subsector model which enables it to replicate real world (government) grain storage, grain movements and grain processing operations occurring within the government subsector. A detailed system diagram of the government grain operations model is presented in Figure 5.4. Most of the mathematical relationships described in this section are depicted in the diagram in symbolic form. The reader should find the diagram to be a useful reference throughout this discussion, especially in grasping the interrelationships among individual variables and equations used to represent the overall system.

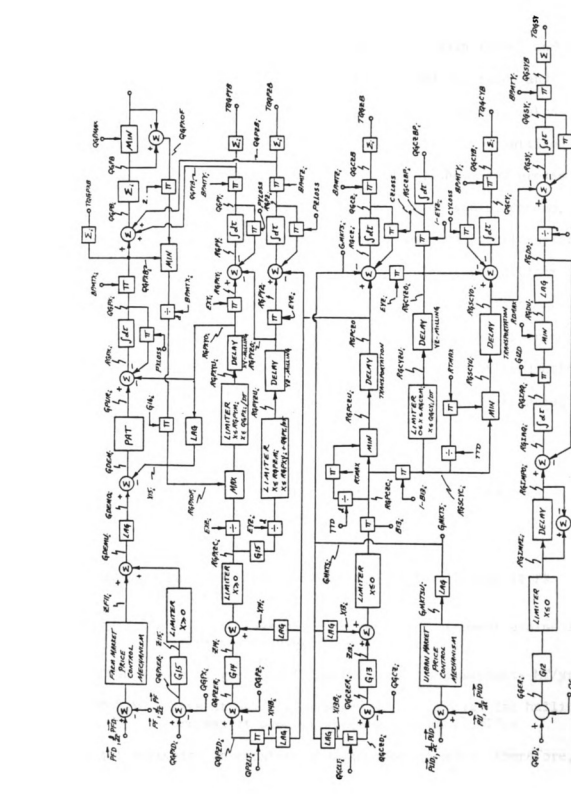


Figure 5.4. System Diagram--Government Grain Operations.

Government Inventories

Government grain inventories are disaggregated across three dimensions: (1) commodity groups, (2) physical grain forms, and (3) position points. The commodity groups identified are rice; and barley, with "barley" being an aggregate of common barley, naked barley, and domestic wheat. Physical forms explicitly identified are rough (or paddy), hulled (or brown), and polished (and pressed) grains. Position points identified are production areas, consumption areas, terminal points, port storage facilities, and retail outlets for government-controlled grains. Table 5.1 below gives a clear picture of the disaggregation of government-controlled grain inventories.

The government procures domestically produced grains (rice and barley) in rough form. These rough grain inventories at production area (PX) positions are represented by the following differential equation.

$$\frac{d}{dt} QGPX_i(t) = -PXLOSS_i(t)\ QGPX_i(t) + GPUR_i(t) - RGPXYO_i(t) \qquad (5.52)$$

where:

QGPX = quantity of government rough grains located at PX positions--MT

PXLOSS = expected seasonal loss rate of government grains located at PX positions--proportion/yr

GPUR = rate of government domestic grain procurement--MT/yr

RGPXYO = rate at which government grains undergo the hulling process at production area positions--MT/yr.

All variables in Equation 5.52 are non-negative; therefore, as indicated, rough grain inventories increase only through government

Table 5.1. Disaggregation of Government-Controlled Grain Inventories.

Position points	Grain Forms					
	Rough		Hulled		Polished	
	Rice	Barley	Rice	Barley	Rice	Barley
Production areas	X	X	X		X	X
Consumption area terminal points		X	X		X	X
Seaport positions		X	X			
Retail sales stores					X	X

procurement and decrease only through storage loss and processing into a different form.

The government-controlled grain operations model identifies rice in the intermediate hulled form (i.e., "brown rice" form). Although currently, and in the past, Korean government grain management policy has been to procure domestic rice in paddy form only and to process paddy rice directly into the final polished state, the generalized nature of the GMP model allows for the investigation of alternatives to this policy. Storage space requirements for brown rice are only one-half that for paddy rice. Brown rice, although less storable than paddy rice, is more suitable for prolonged storage than polished rice, both in terms of expected quantity losses and quality (taste) deterioration. Of course, the additional handling costs involved with two-stage processing of rice must also be taken into consideration in determining the feasibility of altering current practices. The GMP model provides a useful vehicle for such a feasibility study.

Hulled grain inventories (if they were to exist) at production area (PY) positions are represented by the following differential equations.

$$\frac{d}{dt} QGPY_i(t) = -PYLOSS_i(t)\ QGPY_i(t) + RGPXY_i(t) - RGPYZO_i(t) \qquad (5.53)$$

where:

QGPY = quantity of government grains in hulled form (brown rice) located at PY positions--MT

PYLOSS = expected seasonal loss rate of government hulled grains located at PY positions--proportion/yr

RGPXY = rate of hulled grain output from the hulling process on government grains located at production area positions--MT/yr

RGPYZO = rate of total output (products and by-products) from the polishing process on government grains located at production area positions--MT/yr.

Equation 5.53 indicates that hulled grain inventories can increase only through the hulling process and decrease only through storage loss and further processing into polished form. Physical characteristics of barley preclude two-stage processing; therefore, the hulling and polishing processes occur simultaneously, and Equation 5.53 is always zero in the case of barley. It should be noted that Equation 5.53 does not include the possibility of moving brown rice from production areas into consumption areas for final processing. Such a practice is very possible and used by several other Asian countries [10, 40]. If such a practice were to be investigated for Korea, the GMP could easily be redesigned to address the problem directly.

Government polished grain inventories located at production area (PZ) positions are represented by the following equation.

$$\frac{d}{dt} QGPZ_i(t) = - PZLOSS_i(t)\ QGPZ_i(t) + RGPYZ_i(t) - RGPCZO_i(t) \qquad (5.54)$$

where:

QGPZ = quantity of government grains located at PZ positions--MT

PZLOSS = expected seasonal loss rate of government grains located at PZ positions--proportion/yr

RGPYZ = rate of polished grain output from the polishing process on government grains located at production area positions--MT/yr

RGPCZO = rate at which government grains are moved into consumption area from production area positions--MT/yr.

As indicated in Equation 5.54, these polished grain inventories can increase only through the polishing process and decrease only through storage loss and movement out of the production area position.

Government grains located at consumption area terminal point (CY) positions consist of imported as well as domestic grains. Before processing, imported rice and barley can be identified explicitly at consumption area positions since domestic grains are processed in production areas before they are moved into this position. After processing, however, imported grains merge (are mixed) with domestic grains and both lose their identity.

Unprocessed (imported) government grain inventories located at consumption area positions are identified by the following equation.

$$\frac{d}{dt} QGCY_i(t) = - CYLOSS_i(t)\ QGCY_i(t) + RGSCYO_i(t) - RGCYZO_i(t) \qquad (5.55)$$

where:

QGCY = quantity of unprocessed government (imported) grains located at CY positions--MT

CYLOSS = expected seasonal loss rate of unprocessed imported grains located at CY positions--proportion/yr

RGSCYO = rate at which unprocessed imported grains move into CY positions--MT/yr

RGCYZO = rate of total output (products and by-products) from processing of imported grains located at consumption area positions--MT/yr.

Again, with all variables in Equation 5.55 necessarily being non-negative, these unprocessed inventories can increase only through the movement of unprocessed grains into this position (from seaport positions) and can decrease only through storage loss and processing into the "polished" state.[3]

Government inventories of polished grains located at consumption area (CZ) positions are identified by the following equation.

$$\frac{d}{dt} QGCZ_i(t) = - CZLOSS_i(t)\ QGCZ_i(t) + RGPCZO_i(t) + EYZ_i RGCYZO_i(t) - GMKTS_i(t) \quad (5.56)$$

where:

QGCZ = quantity of polished government grains located at CZ positions--MT

CZLOSS = expected seasonal loss rate of polished government grains located at CZ positions--proportion/yr

RGPCZO = rate at which government grains are moved into consumption areas from production area positions--MT/yr

EYZ = weight conversion factor from unprocessed to polished state for imported grains--no units

RGCYZO = rate of total output (products and by-products) from processing of imported grains located at consumption area positions--MT/yr

GMKTS = rate of government grain releases to retail sales outlets--MT/yr.

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[3]In the case of barley, the nomenclature "polished" includes both polished and pressed barley.

Equation 5.56 indicates that, all variables being non-negative, government polished grain inventories located at CZ positions can increase through the movement of domestic grains into this position from production areas and through processing of imported grains. These inventories can decrease only through storage loss and government grain releases to retail sales outlets.

Government-controlled grains held at port storage (SY) positions are identified by the following equation.

$$\frac{d}{dt} QGSY_i(t) = - SYLOSS_i(t)\ QGSY_i(t) + RGDO_i(t)/EYZ_i - RGSCYO_i(t) \quad (5.57)$$

where:

QGSY = quantity of government grains located at SY positions--MT

SYLOSS = expected seasonal loss rate of unprocessed imported grains located at SY positions--proportion/yr

RGDO = rate at which government grain imports are discharged from vessels and enter port storage facilities[4]

EYZ = weight conversion factor from unprocessed to polished state for imported grains--no units

RGSCYO = rate at which unprocessed imported grains move into consumption area positions--MT/yr.

Examination of Equation 5.57 indicates that port storage inventories can increase only through the arrival (discharge) of imported grains, and can decrease only through storage loss and movement of grains from this position into consumption areas.

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[4]By definition, grain imports enter port storage facilities upon being discharged; hence, dock storage is also included in these facilities.

Management and Control of Government Grain Inventories

Unlike the private market, government-controlled grain inventory management strategies are not driven by profit incentives, nor are the decisions for the processing, storage, and movement of grains left to the various members making up the government grain operations system. All activities in government-controlled grains are precisely directed by the central government through the Ministry of Agriculture and Fisheries. The general practice used in managing government grain inventories is to leave grains in unprocessed form as long as possible and then to process the grains just prior to release. Buffer stocks of processed grains are needed because it is impossible for milling operations to keep pace with varying release rates. The objective is to keep the storage time of processed grains to a minimum while still maintaining adequate processed grain supplies in the right positions to meet current needs as well as unanticipated emergency release situations which may arise at any time during the year.

The government grain operations subsector model uses this same type of grain inventory management scheme. Automatic feedback controllers are placed on all government polished grain inventories. These controllers govern the processing rates of government grains in production and consumption area positions as well as the movement of domestic and imported grains into consumption area positions.

Control of Production Area Polished Grain Inventories

Polished grain inventories located at production area positions are controlled by manipulating the milling rates of government grain stocks located at these positions. The general control scheme used

is to adjust the actual milling rate around that required to maintain production area polished grain inventories at current levels. Recall from Equation 5.54 that government polished grain inventories located at production area positions decrease only through storage loss and the movement of these grains into consumption area positions, $RGPCZO_i(t)$. Discounting the storage loss term, a good estimate of this stock maintenance milling rate is given by the solution to the following exponential average equation.

$$\frac{d}{dt} X14_i(t) = - \frac{1}{DEL14} X14_i(t) + \frac{1}{DEL14} RGPCZO_i(t) \qquad (5.58)$$

where:

X14 = average (normal) milling rate; i.e., that required to maintain production area polished grain inventories at their current level--MT/yr

RGPCZO = rate at which polished grains move from production area positions into consumption area positions--MT/yr

DEL14 = time constant parameter--yrs.

The output from the inventory controller at this position is then superimposed on this estimate of the stock maintenance milling rate. If polished grain inventories are above the current desired levels, the controller will call for a decrease in the maintenance milling rate; if polished grain inventories are below the current desired levels, the controller will call for an increase in the maintenance milling rate.

The desired level of polished grain inventories at production area positions changes with the intensity of the movement of grains out of this position. When grains are moving slowly out of this position, relatively low buffer stock levels will suffice; however,

when grains are moving rapidly, it is necessary to maintain relatively high buffer stock levels. These varying desired stock levels are calculated through the use of a parameter referred to as the desired inventory sustaining time. This parameter is the length of time inventory stocks should last at expected depletion rates with no replenishment of stocks. The expected depletion rates of polished grain inventories at production area positions are calculated in exactly the same manner as the expected maintenance milling rates of Equation 5.58. The only difference is with the value placed on the lag parameter of the exponential averaging equation.

$$\frac{d}{dt} X14B_i(t) = - \frac{1}{DEL14B} X14B_i(t) + \frac{1}{DEL14B} RGPCZO_i(t) \qquad (5.59)$$

where:

X14B = expected depletion rate of polished grain inventories located at production area positions--MT/yr

RGPCZO = rate at which polished grains move from production area positions into consumption area positions--MT/yr

DEL14B = time constant parameter--yrs.

The desired inventory level at this position is then calculated by the following equation.

$$QGPZD_i(t) = GPZLT_i(t) * X14B_i(t) \qquad (5.60)$$

where:

QGPZD = current desired inventory level of polished grain located at production area positions--MT

GPZLT = desired sustaining time of polished grain stocks located at production area positions--yrs

X14B = expected depletion rate of polished grain inventories located at production area positions--MT/yr.

An error signal depicting the difference between desired and actual inventory levels is calculated by the following equation.

$$QGPZER_i(t) = QGPZD_i(t) - QGPZ_i(t) \tag{5.61}$$

where:

QGPZER = current error between desired and actual inventory levels of polished grains located at production area positions--MT

QGPZD = current desired inventory levels of polished grains located at production area positions--MT

QGPZ = current actual inventory levels of polished grains located at production area positions--MT.

The inventory controller at this position operates on the error signal produced by Equation 5.61 and, in turn, produces a milling rate signal which, when superimposed on the maintenance milling rate of Equation 5.58, will result in a command milling rate which tends to bring the actual inventory level in line with the desired level. In mathematical terms, this control process is described precisely by the following equations.

$$Z14_i(t) = G14A_i * QGPZER_i(t) + G14B_i \frac{d}{dt} QPGZER_i(t) + G14C_i \int_o^t QPGZER_i(\tau)d\tau \tag{5.62}$$

$$RGPXZC_i(t) = \max [0., Z14_i(t) + X14_i(t)] \tag{5.63}$$

where:

Z14 = control signal representing adjustments to be made in current (normal) rate of grain processing to manage inventories at PZ positions toward desired levels--MT/yr

G14A, B, C = feedback control gain parameters--various units

X14 = estimate of maintenance milling rate (Equation 5.58)--MT/yr

max = maximum function

RGPXZC = command milling rate for production area grain inventories, constrained to be non-negative since milling process is irreversible--MT/yr.

Milling Operations at Production Area Positions

To this point, the command milling rate signal for control of production area polished grain stocks, $RGPXZC_i(t)$, has been described. This signal must go through some further modifications and constraints before it can represent an actual physical flow of unprocessed grains into the milling process. First, the signal itself is in terms of polished grain equivalents. Therefore, it must be modified to represent the appropriate grain forms from which polished grains can be produced, namely, rough or hulled grain forms. These modifications to the signal are equivalent to putting the hulls and bran back on the grains (in theory only). Secondly, if government grain management policy were to hull overflow rough grain stocks to reduce storage space requirements, the command milling rate signal should be modified to reflect this phenomenon. Thirdly, the actual milling capacity of government-licensed grain millers in production areas must not be exceeded if the model is to reflect the real world situation. And, finally, the milling rate must also be constrained by the size of available unprocessed grain stocks.

The hulling and polishing processes are modelled separately. This is because the model offers the option of identifying government brown rice inventories in production area positions. The milling and hulling processes may occur simultaneously, representing one-stage

processing into the polished state; or separately, representing the generation of brown rice inventory stocks. The following two equations represent the driving signals into the hulling and polishing processes. These equations reflect precisely what has been described in words thus far in this section.

(Hulling process)

$$RGPXYU_i(t) = \max [RGPXZC_i(t)/EXZ_i(t), RGXOF_i(t)] \quad (5.64)$$

(limiters)

$$RGPXYU_i(t) \leq RGPYM_i(t) \quad (5.64A)$$

$$RGPXYU_i(t) \leq QGPX_i(t)/DT \quad (5.64B)$$

(Polishing process)

$$RGPYZU_i(t) = G15 * RGPXZC_i(t)/EYZ_i \quad (5.65)$$

(limiters)

$$RGPYZU_i(t) \leq RGPZM_i(t) \quad (5.65A)$$

$$RGPYZU_i(t) \leq RGPXY_i(t) + QGPY_i(t)/DT \quad (5.65B)$$

where, for the hulling process (Equation 5.64):

RGPXYU = driving signal for actual hulling operations on production area rough grain stocks--MT/yr

max = maximum function

RGPXZC = command milling rate signal from polished grain inventory controller (Equation 5.63)--MT/yr

EXZ = rough to polished conversion factor--no units

RGPXOF = rate of paddy rice stock overflow into hulling process--MT/yr[5]

RGPYM = maximum hulling capacity in production areas--MT/yr

QGPX = rough grain inventory stock levels located at production area positions--MT

DT = time increment of the simulation model--yrs

and where, for the polishing process (Equation 5.65):

RGPYZU = driving signal for actual polishing operations on production area hulled grain stocks--MT/yr

G15 = parameter which determines how rapidly brown rice stocks are polished relative to rough grain stocks--proportion

RGPXZC = command milling rate signal from polished grain inventory controller (Equation 5.63)--MT/yr

EYZ = hulled to polished conversion factor--no units

RGPZM = maximum polishing capacity in production areas--MT/yr

RGPXY = rate at which hulled grains are produced from hulling process--MT/yr

QGPY = brown rice inventory stock levels located at production area positions--MT

DT = time increment of the simulation model--yrs.

To this point, we are still describing an inventory control signal and not actual grain flows between forms. The milling processes themselves are represented by distributed delay functions. Although actual processing time of a single bag of grain occurs instantaneously in terms of any conceivable time increment used in the simulation model, the milling delay represents the time lag involved in changing the rates of milling operations. First-order delays are used to describe the milling process.

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[5]Although subscripted, the variable $RGPXOF_2(t)$, representing (rough grain) barley overflow, is always zero. Calculation of the variable RGPXOF will be described in a subsequent section of this chapter.

$$\frac{d}{dt} RGPXYO_i(t) = - \frac{1}{DELG1} RGPXYO_i(t) + \frac{1}{DELG1} RGPXYU_i(t) \quad (5.66)$$

$$\frac{d}{dt} RGPYZO_i(t) = - \frac{1}{DELG2} RGPYZO_i(t) + \frac{1}{DELG2} RGPYZU_i(t) \quad (5.67)$$

where:

RGPXYO = output from the hulling process on rough grain located at production area positions (products and by-products)--MT/yr

RGPXYU = driving signal for hulling operations (Equation 5.64)--MT/yr

DELG1 = time constant for the hulling process--yrs

RGPYZO = output from the polishing process on rough and hulled grains located at production area positions (products and by-products)--MT/yr

RGPYZU = driving function for actual polishing operations (Equation 5.65)--MT/yr

DELG2 = time constant for the polishing process--yrs.

It should be noted that instantaneous transformation of rough grains into hulled grains, and of hulled grains into polished grains, is reflected in the model. Referring back to Equations 5.52 and 5.53 for rough and hulled grain inventories, respectively, the reader will find that $RGPXYO_i(t)$ and $RGPYZO_i(t)$ are used for the depletion rates of those inventory stocks.

Products and by-products can easily be broken out from the milling process equations. For the hulling process, hulled grain and hulls production are separated by the following equations.

$$RGPXY_i(t) = EXY_i * RGPXYO_i(t) \quad (5.68)$$

$$RGPYBP_i(t) = (1-EXY_i) * RGPXYO_i(t) \quad (5.69)$$

where:

RGPXY = rate of hulled grain production at production area positions--MT/yr

EXY = rough to hulled conversion factor--no units

RGPXYO = total output from hulling process--MT/yr

RGPYBP = rate of by-product (hulls) production from hulling process--MT/yr.

For the polishing process, polished grain, cracked grain, and bran production are separated by the following equations.

$$RGPYZ_i(t) = RGPYZO_i(t)\ EYZ_i \tag{5.70}$$

$$RGPBP1_i(t) = (1\text{-}EYZ_i)\ PCRAC_i\ RGPYZO_i(t) \tag{5.71}$$

$$RGPBP2_i(t) = (1\text{-}EYZ_i)\ (1\text{-}PCRAC_i)\ RGPYZO_i(t) \tag{5.72}$$

where:

RGPYZ = rate of polished grain production at production area positions--MT/yr

RGPYZO = total output from polishing process--MT/yr

EYZ = hulled to polished conversion factor--no units

RGPBP1 = rate of crack grain production--MT/yr

RGPBP2 = rate of bran production--MT/yr

PCRAC = expected crack rate--proportion

Grain Inventory Overflows at Production Area Positions

It has been mentioned that the government grain operations model has the capability of addressing alternative grain management policies regarding handling of hulled rice at production area positions. In the current version of the model, brown rice inventories can be generated from inventory overflows, i.e., when government-held grain

stocks exceed existing storage capacity. Another possible way to generate brown rice inventories (not currently in the model) would be for the government to purchase domestic rice, in part, in hulled form. Little indication of government interest in this type of variation to current grain management policy has been perceived so far, although the idea has not been actively solicited. Should interest in this ever be discerned, the model can easily be modified to reflect such an alternative grain management policy.

The model equations for generating brown rice stocks in production areas to alleviate temporary pressures on grain storage capacity will now be described. The 100-liter bag unit is used as the common denominator for measuring the volume of existing grain stocks and available storage capacity. The total number of bags of government rice and barley located at production area positions is given by the following equation.

$$QGPB(t) = \sum_{i=1}^{2} [QGPX_i(t)BPMTX_i + QGPY_i(t)BPMTY_i + QGPZ_i(t)BPMTZ_i] \quad (5.73)$$

where:

i = commodity subscript: 1 = rice, 2 = barley

QGPB = total number of 100-liter bag units of government rice and barley (in all forms) located at production area positions--bags

QGPX, Y, Z = quantity of government grains located at production area positions in rough X, hulled Y, and polished Z forms--MT[6]

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[6]Although hulled barley inventories, $QGPY_2(t)$, are indicated in Equation 5.73, model design is such that these inventories are always equal to zero. The only possible hulled grain inventories are in the form of hulled rice.

BPMT$\underline{X}$, $\underline{Y}$, $\underline{Z}$ = conversion factors, 100-liter bags per metric ton of rough $\underline{X}$, hulled $\underline{Y}$, and polished $\underline{Z}$ grains--bags/MT.

The number of bags by which current government production area grain stocks exceed available storage capacity is given by the following expression.

$$QGPXOF(t) = QGPB(t) - \min [QGPMAX, QGPB(t)] \tag{5.74}$$

where:

QGPXOF = number of bags by which current government production area grain stocks exceed adequate grain storage capacity--bags

QGPB = total quantity of government grain stocks located at production area positions--bags

QGPMAX = existing grain storage capacity for government grains at production area positions--bags.

The design of the government grain operations model allows for hulling operations on rice stocks only. The following equation describes precisely how rice-hulling operations are keyed to the amount of storage overflow and the amount of available paddy rice stocks.

$$RGPXOF_1(t) = G16_1 \min[QGPXB_1(t), QGPXOF(t)*2.]/BPMTX_1 \tag{5.75}$$

where:

$RGPXOF_1$ = command hulling rate (for paddy rice) stimulated by production area grain storage overflow--MT/yr

$G16_1$ = gain parameter describing the intensity that hulling operations are undertaken in response to storage overflow--no units

min = minimum function

$QGPXB_1$ = quantity of paddy rice available for hulling at production area positions--bags

QGPXOF = number of bags by which current government production area grain stocks exceed adequate grain storage capacity--bags

$BPMTX_1$ = conversion factor, bags per metric ton of paddy rice--bags/MT.

Equation 5.75 simply states that the amount of paddy rice stocks on which hulling operations can be performed is limited by the current paddy rice stocks at production area positions. By recalling Equation 5.64, which describes the driving signal for actual hulling operations on production area rough grain stocks, the reader will note that the overflow signal $RGPXOF_1(t)$ will not come into play if it is exceeded by the command milling rate signal from the polished grain inventory controller.

Control of Consumption Area Polished Grain Inventories

Government polished grain inventories located at consumption area positions are controlled in two ways: (1) by managing the flow of government polished grains from production areas into consumption areas, and (2) by managing the milling rate of imported grains. The general control scheme used is to adjust the rate at which consumption area polished grain stocks are replenished from these two sources around that rate required to maintain consumption area polished grain inventories at their current levels. Recall from Equation 5.56 that government polished grain stock levels in consumption areas are depleted only through storage loss and grain releases to registered retail outlets. Discounting the storage loss term, a good estimate of this polished stock maintenance replenishment rate is given by the solution to the following exponential averaging equation.

$$\frac{d}{dt} X13_i(t) = - \frac{1}{DEL13} X13_i(t) + \frac{1}{DEL13} GMKTS_i(t) \quad (5.76)$$

where:

X13 = estimate of the polished stock maintenance replenishment rate, i.e., that replenishment rate required to maintain consumption area polished grain inventories at their current level--MT/yr

GMKTS = rate of government grain releases to retail sales outlets--MT/yr

DEL13 = time constant parameter--yr.

The output from the polished grain inventory controller for consumption area positions is then superimposed on this estimate of the polished stock maintenance replenishment rate. If polished grain inventories are above the current desired levels, the controller will call for a reduction in the maintenance replenishment rate; if polished grain inventories are below the current desired levels, the controller will call for an increase in the maintenance replenishment rate.

The desired levels of polished grain inventories at consumption area positions are calculated in the same manner as the desired levels for production area polished grain stocks discussed earlier. When grains are moving slowly out of this position, relatively low release (polished) stock levels will suffice. When grains are moving rapidly, however, it is necessary to maintain larger release stock levels. A desired inventory sustaining time parameter is again used for calculating the desired polished grain stock levels at consumption area positions. Recall that such a parameter denotes the length of time an inventory should last at expected depletion rates, with no replenishment of stocks. The expected depletion rate of government polished grain inventories located at consumption area positions is

given by Equation 5.77 below. The only difference from Equation 5.76 is that the value is placed on the lag parameter DEL13B.

$$\frac{d}{dt} X13B_i(t) = - \frac{1}{DEL13B} X13B_i(t) + \frac{1}{DEL13B} GMKTS_i(t) \quad (5.77)$$

where:

X13B = expected depletion rate of polished grain inventories located at consumption area positions--MT/yr

GMKTS = rate of government grain releases to retail sales outlets--MT/yr

DEL13B = time constant parameter--yrs.

The desired inventory level at this position is then calculated by the following equation.

$$QGCZD_i(t) = GCZLT_i(t) * X13B_i(t) \quad (5.78)$$

where:

QGCZD = current desired inventory level of polished grain located at consumption area positions--MT

GCZLT = desired expected sustaining time of polished grain release stocks--yrs

X13B = expected depletion rate of polished grain stocks located at consumption area positions--MT/yr .

An inventory error signal depicting the difference between desired and actual polished grain inventory levels at this position is calculated by the following equation.

$$QGCZER_i(t) = QGCZD_i(t) - QGCZ_i(t) \quad (5.79)$$

where:

QGCZER = current error between the desired and actual inventory level of polished grains located at consumption area positions--MT

QGCZD = current desired inventory level of polished grains located at consumption area positions--MT

QGCZ = current actual inventory level of polished grains located at consumption area positions--MT.

The inventory controller at this position operates on the error signal produced by Equation 5.79 and, in turn, produces a stock replenishment rate adjustment signal $Z13_i$. This signal moves in a range of positive and negative values and, when superimposed on the estimate of the polished stock maintenance replenishment rate of Equation 5.76, will result in a command replenishment rate signal which will tend to bring actual polished grain stock levels in line with desired stock levels. Although awkward to put precisely into words, this function is easily expressed in mathematical terms.

$$Z13_i(t) = G13A_i QGCZER_i(t) + G13B_i \frac{d}{dt} QGCZER_i(t) + G13C_i \int_0^t QGCZER_i(\tau)d\tau \quad (5.80)$$

where:

Z13 = control signal representing adjustments to be made in the current estimated polished stock maintenance replenishment rate to manage consumption area polished stocks toward desired levels--MT/yr

G13A, B, C = feedback control gain parameters--various units

QGCZER = current error between desired and actual inventory levels of polished grains located at consumption area positions--MT.

As mentioned in the discussion, the output signal from the inventory controller $Z13_i(t)$ is superimposed on the estimate of the polished stock maintenance replenishment rate, $X13_i(t)$. The resulting signal must be constrained to be non-negative to preclude the possibility

of reversed grain flows between consumption and production areas, as well as reversed milling of imported grains. Again, two sources for the replenishment of consumption area polished grain stocks exist: (1) domestic grains moved into consumption areas from production area positions, and (2) the milling of imported grains. The decision of how rapidly to transport domestic grains versus how rapidly to mill imported grain stocks to replenish consumption area polished grain inventories can be quite complex and involve a large range of alternative grain management policies. Since this type of policy investigation is not of primary concern at the current time, the government grain operations model is set at one basic scheme for replenishing consumption area polished grain stocks from domestic and imported grains. The following two equations describe precisely how the output signal from the inventory controller is processed into these two separate command signals.

$$RGPCZC_i(t) = \max [0., Z13_i(t) + X13_i(t)] * B13_i(t) \quad (5.81)$$

$$RGSCYC_i(t) = \max [0., Z13_i(t) + X13_i(t)] * (1-B13_i(t)) \quad (5.82)$$

where:

RGPCZC = command signal to move polished grain stocks into consumption areas from production area positions--MT/yr

RGSCYC = command signal to move unpolished imported grains into consumption areas for milling--MT/yr

Z13 = output signal from the consumption area polished grain inventory controller (Equation 5.80)--MT/yr

X13 = estimate of the polished stock maintenance replenishment rate for consumption area polished grain inventories--MT/yr

max = maximum function

B13 = factor which determines the relative amounts of domestic and imported grains used to replenish consumption area polished grain stocks ($0 \leq B13 \leq 1$)--proportion.

The time varying factor $B13_i(t)$ of the previous equation is described mathematically as follows.

$$B13_i(t) = QGPZ_i(t)/[QGPZ_i(t) + QGCY_i(t) * EYZ_i + QGSY_i(t) * EYZ_i] \quad (5.83)$$

where:

QGPZ = quantity of polished domestic grain inventories located at production area positions--MT

QGCY = quantity of unpolished imported grains located at consumption area positions--MT

QGSY = quantity of unpolished imported grains located at seaport storage facilities--MT

EYZ = unpolished to polished conversion factor for imported grains--no units

The expression for $B13_i(t)$ states that the split between domestic and imported grain sources for replenishing consumption area polished grain inventories is determined by the ratio of polished domestic grain stocks located at production area positions to the total amount of these stocks plus unprocessed imported grain stocks (in polished form equivalent). This scheme is consistent with sound grain management practices because it assures the simultaneous movement of imported and domestic grains through the government grain operations system. Alternatives to this scheme can be investigated should interest in this area of grain management be discerned.

The two command signals $RGPCZC_i(t)$ and $RGSCYC_i(t)$ of Equations 5.81 and 5.82 must be brought into realistic bounds before they can

represent inputs to the transportation and consumption area milling process. Each of these processes will be discussed at this time.

Transportation of Government-Controlled Grains

The government grain operations model identifies the transportation of domestic grains from production to consumption area positions, and the transportation of imported grains from seaports to consumption area positions. A large portion of government grain transport services is contracted through private transportation companies such as the Korean Express Company. The private subsector utilizes many of the same transportation services available to the government subsector and can compete with the government for these transportation services. Both the private and government grain operations models reflect this phenomenon to the extent that grains can never move into consumption areas more rapidly than existing physical grain transportation capacity. Although some portions of total grain transportation capacity are used exclusively for moving either government or private grains, a major portion of total capacity is used for both government and private grains. Rather than increase the complexity of the model to reflect exclusive and shared capacity, the assumption is made that all grain movement capacity is shared between government and nongovernment (private) subsectors. Although some reality is lost to this assumption, a most important constraint of the real world system is captured; i.e., at no time can the total movements of grains in the private and government sectors (combined) exceed total grain system transportation capacity to move grain between major position points.

At any instant of time, total transportation system demand between

major position points is defined by the following equation.[7]

$$TTD(t) = \sum_{i=1}^{2} [RPCZC_i(t) + RGPCZC_i(t) + RGSCYC_i(t)] + RWSMC(t) \qquad (5.84)$$

where:

TTD = total transportation demand between major position points--MT/yr

RPCZC = unconstrained private market orders for movement of grains from production to consumption area positions--MT/yr

RGPCZC = unconstrained government orders for movement of grains from production to consumption area positions--MT/yr

RGSCYC = unconstrained government orders for movement of imported grains from seaport to consumption area positions--MT/yr

RWSMC = unconstrained orders for movement of imported wheat from seaport to flour mill positions--MT/yr

i = commodity index (1 = rice, 2 = barley group).

Now, the following limiting equations assume that orders for the movement of government-controlled grains between the major transportation links identified in the GMP model reflect (1) limited system transportation capacity, (2) nonreversible grain flows between positions, and (3) curtailment of government grain shipments when supply stocks become critically low.

(Production to consumption area positions)

$$RGPCZU_i(t) = \min \left[RGPCZC_i(t), \frac{RGPZC_i(t)RTMAX}{TTD}, \frac{QGPZ_i(t)}{DT} \right] \qquad (5.85)$$

---

[7]Equation 5.84 is Equation 4.61, for the private market, repeated. The reader can return to that equation for more discussion regarding this model aspect.

(Seaport to consumption area positions)

$$RGSCYU_i(t) = \min \left[RGSCYC_i(t), \frac{RGSCYC_i(t)RTMAX}{TTD}, \frac{QGSY_i(t)}{DT} \right] \quad (5.86)$$

where:

RGPCZU = constrained orders for movement of government-controlled grains from production to consumption area positions--MT/yr

RGSCYU = constrained orders for movement of imported grains from seaports to consumption area positions--MT/yr

min = minimum function

RGPCZC = command signal to move polished grain stocks into consumption areas from production area positions (Equation 5.81)--MT/yr

RGSCYC = command signal to move (unpolished) imported grain stocks into consumption areas from seaport positions (Equation 5.82)--MT/yr

RTMAX = maximum system capacity for transportation between major transportation links as defined by the GMP model--MT/yr

TTD = total transportation demand--MT/yr.

It is obvious from Equations 5.85 and 5.86 that if total transportation demand, TTD, is less than current grain transportation capacity, RTMAX, the transportation bottleneck constraint will not be active. However, if total transportation demand is greater than current grain transportation capacity, each grain movement command signal is reduced to an appropriate portion of current grain transportation capacity.

Actual deliveries of government-controlled grains to consumption area positions are simulated by the solutions to the following differential equations which represent distributed delay functions.

(Deliveries from production area positions)

$$a_k \frac{d^k}{dt^k} RGPCZO_i(t) + a_{k-1} \frac{d^{k-1}}{dt^{k-1}} RGPCZO_i(t) + \ldots = RGPCZU_i(t) \quad (5.87)$$

(Deliveries from seaport positions)

$$a_k \frac{d^k}{dt^k} RGSCYO_i(t) + a_{k-1} \frac{d^{k-1}}{dt^{k-1}} RGSCYO_i(t) + \ldots = RGSCYU_i(t) \quad (5.88)$$

where:

a_j = coefficients of the particular distributed delay function,
$a_j = \binom{k}{j}\left[\frac{DEL.}{k}\right]^j$, $j = 0, \ldots, k$

DEL. = delay parameter of the particular delay function--yrs

k = order of the delay of the particular delay function--no units

RGPCZO = deliveries of polished government grains from production areas to consumption area positions--MT/yr

RGSCYO = deliveries of unpolished imported grains from seaports to consumption area positions--MT/yr

RGPCZU = constrained orders for movement of government-controlled grains from production to consumption area positions--MT/yr

RGSCYU = constrained orders for movement of imported grains from seaports to consumption area positions--MT/yr.

Milling Operations at Consumption Area Positions

Recall that the command signal $RGSCYC_i(t)$, which calls for the movement of unprocessed imported grains from seaports into consumption area positions, is stimulated by the consumption area polished grain inventory controller. Since the purpose of the signal is to increase consumption area polished grain inventories, it is logical to use this same signal as an input to milling operations on imported grains located

at consumption area positions. (Recall that only imported grains are milled at consumption area positions.) Before the signal can represent physical grain inputs to the milling process, it must be limited to realistic bounds. First, the signal may not exceed current milling capacity for government grains at consumption area positions, and, secondly, the signal must be limited by available unprocessed grain stocks at seaport positions. These limitations to $RGSCYC_i(t)$ are reflected by the following equation.

$$RGSCYU_i(t) = \min [RGSCYC_i(t), RGCZM_i(t), QGCY_i(t)/DT] \quad (5.89)$$

where:

RGSCYU = input signal to the milling process on government grains located at consumption area positions--MT/yr

min = minimum function

RGCZM = current maximum milling capacity of government grains located at consumption area positions--MT/yr

QGCY = government unprocessed imported grain stocks located at consumption area positions--MT

DT = time increment of the simulation model--yrs.

The milling process itself is next modelled by the following differential equation.

$$\frac{d}{dt} RGCYZO_i(t) = - \frac{1}{DELG4} RGCYZO_i(t) + \frac{1}{DELG4} RGCYZU_i(t) \quad (5.90)$$

where:

RGCYZO = total output (products and by-products) from milling operations on government imported grains located at consumption area positions--MT/yr

DELG4 = time constant parameter--yrs.

Products and by-products are easily separated from the output of the milling process on imported grains.

$$RGCYZ_i(t) = RGCYZO_i(t) * EYZ2_i \quad (5.91)$$

$$RGCBP1_i(t) = (1-EYZ2_i) * PCRAC2_i * RGCYZO_i(t) \quad (5.92)$$

$$RGCBP2_i(t) = (1-EYZ2_i) * (1-PCRAC2_i) * RGCYZO_i(t) \quad (5.93)$$

where:

RGCYZ = rate of polished (or pressed) grain production at consumption area positions--MT/yr

RGCYZO = total output from the milling process--MT/yr

EYZ2 = hulled to polished (pressed) conversion factor for imported grains--no units

RGCBP1 = rate of crack grain production--MT/yr

RGCBP2 = rate of bran production--MT/yr

PCRAC2 = expected crack rate for imported grains--proportion.

Government Grain Import Operations

The model process by which annual food grain deficit supplies and import orders are generated throughout a simulation run of the GMP have already been described under the Government Grain Supply and Demand section of this chapter. At this time, we will describe in mathematical terms the model function of simulating actual import operations. This includes modelling the time delays between import orders and ship arrivals at port facilities, the amount of grain in the import pipeline, and port discharge operations which are dependent of discharge capacities at receiving port facilities.

Import Pipeline

The time lags between placing orders for foreign grain imports and ship arrivals at receiving port facilities are modelled by the following distributed delay function.

$$a_k \frac{d^k}{dt^k} RGIMPO_i(t) + a_{k-1} \frac{d^{k-1}}{dt^{k-1}} RGIMPO_i(t) + \ . \ . \ . \qquad = RGIMPI_i(t) \tag{5.94}$$

where:

a_j = coefficients of the particular distributed delay function;
$a_j = \binom{k}{j}\left[\frac{DEL.}{k}\right]^j$, $j = 0, \ . \ . \ . \ , k$

DEL. = delay parameter of the particular delay function--yrs

k = order of the particular delay function--no units

RGIMPO = port arrivals of foreign grain imports--MT/yr

RGIMPI = control signal for government grain import orders--MT/yr.

Import Arrival Queue

Oftentimes import arrivals saturate port discharge capacities and ships must queue up to await unloading. It is not uncommon for such a delay to be greater than actual shipping time required for grain imports. This discharge queue and the related discharge rate are simulated by the following equations. Figure 5.4 will be useful to the reader in grasping these interrelationships.

$$QGIAQ_i(t) = \int_{t_o}^{t} [RGIMPO_i(\tau) - RGDO_i(\tau)]d\tau \tag{5.95}$$

$$TQGIAQ(t) = \sum_{i=1}^{2} QGIAQ_i(t) \tag{5.96}$$

$$\frac{d}{dt} RGDO_i(t) = - \frac{1}{DELG6} RGDO_i(t) + \frac{1}{DELG6} RGDU_i(t) \quad (5.97)$$

$$RGDU_i(t) = \min \left[G12D*QGIAQ_i(t), \frac{QGIAQ_i(t)RDMAX}{TQGIAQ(t)} \right] \quad (5.98)$$

where:

QGIAQ = quantity of government grain in import arrival queue--MT

RGIMPO = port arrivals of foreign grain imports--MT/yr

TQGIAQ = total quantity of government grain (rice and barley) in import arrival queue--MT

RGDO = rate of discharge of foreign grain imports--MT/yr

RGDU = unlagged version of the rate of discharge of foreign grain imports--MT/yr

min = minimum function

G12D = response parameter--1/yr

RDMAX = maximum discharge capacity--MT/yr.

The reader will note that Equation 5.98 above accounts for competition for discharge capacity between rice and barley imports. Of course, this equation must be made consistent with current discharge policies (e.g., rice discharges taking priority over barley, etc.). In general, wheat discharges do not compete with rice and barley discharges. However, if the situation were to change, wheat import arrival queues would have to enter into these equations also.

This completes the description of the government grain operations model. To put things more in perspective, a review of this model is given in the following section.

Review of the Government Grain Operations

The government grain operations model describes the flow of government-controlled grains through the government subsector. Only

two of six inventories identified in the model are controlled through grain movements and processing: (1) production area polished grain inventories, and (2) consumption area polished grain inventories. The model has the capability of testing the feasibility of two-stage processing of domestic grains in production areas. The purpose of this is to reduce the storage capacity requirements for government grains should the government undertake a grain management strategy requiring large volumes of government-controlled grains. A rudementary transportation bottleneck constraint is reflected. This constraint assures that the flow of government and private grains between production and consumption areas does not exceed current total grain transportation capacity between these major position points. Milling operations on government-controlled grains are also constrained so that processing cannot exceed existing processing capacity nor can milling occur if unprocessed grains are not physically present at milling positions. Time delays and grain storage occurring within the foreign grain import pipeline and port discharge operations are also modelled.

Government Warehousing

This aspect of the GMP model has less significance when the model is used for short-term policy issues, say, one or two years. However, when using the model for addressing longer term policy issues, government warehousing programs may have major implications in grain policy formulations. Specific warehousing construction programs may themselves be the central issue in a particular grain management program study. In such instances, this component of the GMP model stands ready and available to provide important information to researchers and decision makers.

Government-owned or -leased warehousing facilities are classified into four major categories: (1) low temperature, (2) class A, (3) class B, and (4) class C. Basically, these categories are based on construction design and suitability for grain storage, with low-temperature facilities being most elaborate and class C being least elaborate (usually deteriorated in condition and least suitable for grain storage). The GMP model identifies four classes of government-controlled warehousing facilities. Each of these warehouse classifications has inherent with it different unit construction costs (or storage charges, if not government owned), and storage loss characteristics over the four seasons of the year. Government warehouse construction programs can add additional warehouse facilities to the first three categories (low temperature, class A, and class B), but not to the last (class C). As the process goes, class A and class B facilities can depreciate to lower categories as time evolves.

Figure 5.5 is a system diagram showing the model process whereby government warehousing and warehouse construction programs are simulated. The reader should find the diagram a useful reference during the mathematical description which follows.

Warehouse Construction, Acquisition, and Life Processes

Two controllers are used to simulate government-controlled warehouse construction and/or acquisition programs. The first controller monitors the current capacity of *all* government-controlled warehousing (leased and government owned), while the second controller monitors the current capacity of government-owned warehousing only.

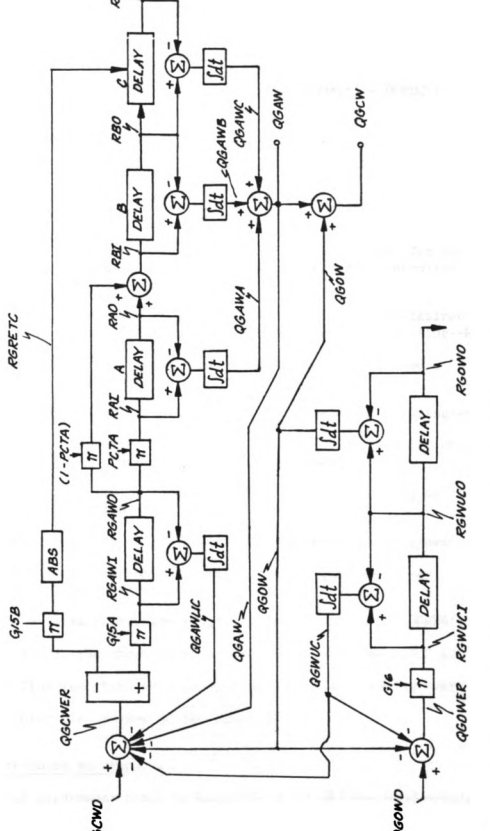


Figure 5.5 System Diagram -- Government-Controlled Warehousing.

The following equations describe the two error signals that drive these two warehousing controllers.

(Government-controlled warehousing)

$$QGCWER(t) = QGCWD(t) - QGAWUC(t) - QGAW(t) - QGOW(t) - QGWUC(t) \quad (5.99)$$

(Government-owned warehousing)

$$QGOWER(t) = QGOWD(t) - QGWUC(t) - QGOW(t) \quad (5.100)$$

where:

QGCWER = error signal measuring difference between desired and actual capacity of overall government-controlled warehousing--MT

QGOWER = error signal measuring difference between desired and actual capacity of government-owned warehousing--MT

QGCWD = desired capacity of all government-controlled warehousing--MT

QGOWD = desired capacity of government-owned warehousing--MT

QGAWUC = capacity of government-authorized warehousing under construction (or lease arrangement)--MT

QGAW = capacity of government-authorized warehousing in operation--MT

QGOW = capacity of government-owned warehousing in operation--MT

QGWUC = capacity of government-owned warehousing under construction--MT.

The desired capacities of government warehousing, QGCWER(t) and QGOWD(t), in the above equations are input into the model as empirical time functions consistent with warehouse planning over the particular time period of the model run.

Government-Owned Warehousing

Most government-owned warehousing is of the low-temperature type described earlier. Other classes of government-owned warehouse

facilities are also possible; however, the GMP model recognizes only low-temperature facilities as government owned and operated. All other government-controlled warehouse facilities are assumed to be leased by the government.

Given the error signal of Equation 5.100, the following equations are used to simulate construction, operating life, and retirement of government-owned warehouse facilities.

$$RGWUCI(t) = G16 * QGOWER(t) \tag{5.101}$$

$$a_k \frac{d^k}{dt^k} RGWUCO(t) + a_{k-1} \frac{d^{k-1}}{dt^{k-1}} RGWUCO(t) + \ . \ . \ . \quad = RGWUCI(t) \tag{5.102}$$

$$b_k \frac{d^k}{dt^k} RGOWO(t) + b_{k-1} \frac{d^{k-1}}{dt^{k-1}} RGOWO(t) + \ . \ . \ . \quad = RGWUCO(t) \tag{5.103}$$

where:

RGWUCI = rate at which government warehouse construction projects are begun--MT/yr

G16 = response parameter--1/yr

QGOWER = error signal measuring difference between desired and actual capacity of government-owned warehousing--MT

RGWUCO = rate at which government-owned warehousing becomes obsolete or is retired from operation--MT/yr

a_j, b_j = coefficients of the particular distributed delay function, i.e.,

$$a_j = \binom{k}{j} \left[\frac{DEL.}{k}\right]^j, \quad j = 0, \ . \ . \ . \ , k$$

DEL. = delay parameter for particular function--yrs

k = order of particular delay.

The reader will note from the system diagram of Figure 5.5 and Equations 5.102 and 5.103 that the two delay functions representing

the construction phase and operational phase of government-owned warehousing are cascaded. That is, warehousing construction begins, and the construction process occurs, over time. As newly constructed warehousing becomes available, it immediately becomes operational and enters the second delay function which simulates the operational life of the newly constructed warehousing over time. The capacity of government-owned warehousing, both under construction and operational, is measured by the following two integral equations. This capacity is fed back to help generate the error signal of Equation 5.100 and the process continues.

$$QGWUC(t) = QGWUC(t_o) + \int_{t_o}^{t} [RGWUCI(\tau)-RGWUCO(\tau)]d\tau \qquad (5.104)$$

$$QGOW(t) = QGOW(t_o) + \int_{t_o}^{t} [RGWUCO(\tau)-RGOWO(\tau)]d\tau \qquad (5.105)$$

where:

QGWUC = quantity of warehouse capacity currently under construction--MT

QGOW = quantity of government-owned warehousing currently operational--MT

and, the other variables of these equations are defined numerous times under early equations.

Government-Leased Warehousing

Observing the system diagram of Figure 5.5, the reader can see that the construction (or leasing) process and life stages for other than government-owned warehousing are much similar to that of government-owned warehousing. The only difference is that three classes of

government-leased warehousing are identified. As mentioned earlier, construction (or leasing) can add capacity to the first two warehouse classes (A and B), and overcapacity is retired from class C facilities.

The error signal of Equation 5.99 can be either positive or negative. If positive, it indicates that more overall government storage capacity (leased and/or owned) is desired, and the controller acts to add storage capacity to either class A or class B facilities. If negative, it indicates that overall government-controlled storage capacity is more than desired, so the controller acts to reduce this overall capacity by retiring class C facilities (or putting them into other uses). The following sequence of equations describes the construction (or leasing) process and life stages of government-leased warehousing as simulated in the GMP model. Controlled retirement of class C warehousing will be described subsequently.

$$RGAWI(t) = 0, \text{ if } QGCWER(t) \leq 0 \tag{5.106}$$

$$RGAWI(t) = G15A*QGCWER(t), \text{ if } QGCWER(t) > 0 \tag{5.107}$$

where:

RGAWI = rate at which government authorized warehousing begins under construction or leasing arrangements--MT/yr

QGCWER = error signal measuring difference between current desired and current actual capacity of overall government-controlled warehousing--MT.

The construction or leasing process of this nonowned government storage capacity is simulated by the following distributed delay equation.

$$a_k \frac{d^k}{dt^k} RGAWO(t) + a_{k-1} \frac{d^{k-1}}{dt^{k-1}} RGAWO(t) + \ldots = RGAWI(t) \tag{5.108}$$

$$QGAWUC(t) = QGAWUC(t_o) + \int_{t_o}^{t} [RGAWI(\tau)-RGAWO(\tau)]d\tau \qquad (5.109)$$

where:

a_j = coefficients of the distributed delay function,

$a_j = \binom{k}{j}\left[\frac{DEL.}{k}\right]^j$, $j = 0, \ldots, k$

DEL. = delay parameter--yrs

k = order of delay equation

RGAWO = rate at which government-authorized storage capacity becomes available--MT/yr

RGAWI = see Equations 5.106 and 5.107--MT/yr

QGAWUC = current capacity of government-authorized warehousing (classes A and B) under construction or lease processing--MT.

As shown in Figure 5.5, as government-authorized warehousing becomes available, RGAWO(t), it is apportioned between class A and class B warehousing according to government warehouse policy. The following equations describe the life process of nonowned government-authorized warehousing.

(Class A warehousing)

$$a_k \frac{d^k}{dt^k} RAO(t) + a_{k-1} \frac{d^{k-1}}{dt^{k-1}} RAO(t) + \ldots = RAI(t) \qquad (5.110)$$

$$RAI(t) = PCTA(t)*RGAWO(t) \qquad (5.111)$$

$$QGAWA(t) = QGAWA(t_o) + \int_{t_o}^{t} RAI(\tau)-RAO(\tau)d\tau \qquad (5.112)$$

where:

a_j = coefficients of distributed delay function,

$$a_j = \binom{k}{j}\left[\frac{DEL.}{k}\right]^j,\ j = 0, \ldots, k$$

DEL. = delay parameter--yrs

k = order of delay equation

RAO = rate at which class A warehousing is declassified to class B--MT/yr

RAI = rate at which class A warehousing becomes available--MT/yr

RGAWO = rate at which class A and/or class B warehousing becomes available--MT/yr

PCTA = proportion of RGAWO which is class A warehousing--proportion

QGAWA = current capacity of government-authorized class A warehousing--MT

(Class B warehousing)

$$a_k \frac{d^k}{dt^k} RBO(t) + a_{k-1} \frac{d^{k-1}}{dt^{k-1}} RBO(t) + \ldots = RBI(t) \qquad (5.113)$$

$$RBI(t) = RAO(t) + [1-PCTA(t)]\ RGAWO(t) \qquad (5.114)$$

$$QGAWB(t) = QGAWB(t_o) + \int_{t_o}^{t} [RBI(\tau)-RBO(\tau)]d\tau \qquad (5.115)$$

where:

a_j = coefficients of distributed delay function,

$$a_j = \binom{k}{j}\left[\frac{DEL.}{k}\right]^j,\ j = 0, \ldots, k$$

DEL. = delay parameter--yrs

k = order of delay equation

RBO = rate at which class B warehousing is declassified to class C--MT/yr

RBI = rate at which class B warehousing becomes available--MT/yr

RAO = rate at which class A warehousing is declassified to class B--MT/yr

PCTA = proportion of newly acquired government-authorized warehousing which is class A type--proportion

RGAWO = rate at which government-authorized storage capacity becomes available--MT/yr

QGAWB = current capacity of government-authorized class B warehousing--MT

(Class C warehousing)

$$a_k \frac{d^k}{dt^k} RCO(t) + a_{k-1} \frac{d^{k-1}}{dt^{k-1}} RCO(t) + \ldots = RBO(t) \qquad (5.116)$$

$$QGAWC(t) = QGAWC(t_o) + \int_{t_o}^{t} [RBO(\tau)-RCO(\tau)]\, d\tau \qquad (5.117)$$

where:

a_j = coefficients of distributed delay function,

$$a_j = \binom{k}{j}\left[\frac{DEL.}{k}\right]^j, \quad j = 0, \ldots, k$$

DEL. = delay parameter--yrs

k = order of delay equation

RCO = rate at which class C warehousing becomes obsolete (or underclassed)--MT/yr

RBO = rate at which class B warehousing is declassified to class C--MT/yr

QGAWC = current capacity of government-authorized class C warehousing--MT.

Whenever the error signal QGCWER(t) of Equation 5.99 is negative, it indicates that the government has an excess of authorized storage capacity. Action is then taken to reduce the amount of this overall storage capacity by retiring class C facilities (or putting them to alternative uses). The following equations describe this process.

RGRETC(t) = 0 , if QGCWER(t)>0 (5.118)

RGRETC(t) = abs[G15B*QGCWER(t)] , otherwise (5.119)

where:

RGRETC = rate at which class C facilities are retired due to overcapacity of government-authorized warehousing--MT/yr

QGCWER = error signal measuring difference between desired and actual capacity of overall government-controlled warehousing--MT

G15B = response parameter--1/yr.

To apply this attrition rate to the class C warehousing delay function of Equation 5.116, the following modification is made.

$$a_k \frac{d^k}{dt^k} RCO(t) + a_{k-1} \frac{d^{k-1}}{dt^{k-1}} RCO(t) + \ldots = RBO(t) - RGRETC(t) \quad (5.120)$$

and,

$$QGAWC(t) = QGAWC(t_o) + \int_{t_o}^{t} [RBO(\tau)-RCO(\tau)-RGRETC(\tau)]d\tau. \quad (5.121)$$

The following summation equations generate total government-controlled warehousing capacities.

QGAW(t) = QGAWA(t) + QGAWB(t) + QGAWC(t) (5.122)

(class A) (class B) (class C)

QGCW(t) = QGAW(t) + QGOW(t) (5.123)

where:

QGAW = total (nonowned) government-authorized warehouse storage capacity in operation--MT

QGCW = total overall government-controlled warehouse storage capacity in operation--MT.

This concludes the description of construction, lease, and life processes for government-controlled warehousing simulated by the GMP model. Next, we will describe the method whereby govermnent-controlled warehousing is distributed to various position points.

Distribution of Government-Controlled Warehousing

The government warehousing component design allows for construction (or leasing) programs in the first three categories of warehouse classes (low temperature, class A, and class B), and also a choice of construction locations at seaports, production areas, or consumption areas. The model accounts for the amount, distribution, and location of all government-controlled warehousing facilities through time, based on new construction/lease programs (if they exist), the normal declassification process of A and B facilities, and the salvage or disappearance of class C facilities.

The following equations are used to allocate (distribute) existing government-controlled warehouse classes among position points.

$$APCAP(t) = QGAWA(t) * PGAWP * 12.5 \quad (5.124)$$

$$BPCAP(t) = QGAWB(t) * PGAWP * 12.5 \quad (5.125)$$

$$CPCAP(t) = QGAWC(t) * PCAWP * 12.5 \quad (5.126)$$

$$ACCAP(t) = [QGAWA(t)*PCAWC+QGOW(t)] * 12.5 \quad (5.127)$$

$$BCCAP(t) = QGAWB(t) * PCAWC * 12.5 \quad (5.128)$$

$$CCCAP(t) = QGAWC(t) * PCAWC * 12.5 \quad (5.129)$$

$$ASCAP(t) = QGAWA(t) * PCAWS * 12.5 \quad (5.130)$$

$$BSCAP(t) = QGAWB(t) * PCAWS * 12.5 \quad (5.131)$$

$$CSCAP(t) = QGAWC(t) * PCAWS * 12.5 \quad (5.132)$$

where:

__CAP = capacities of government-controlled warehousing in classes A, B, and C (first letter) located at production areas P, consumption areas C, and seaports S (second letter)--100-liter bags

QGAW_ = current capacity of government-authorized class A, B, or C (last letter) warehousing--MT

PGAW_ = proportion of government-authorized warehousing located at production areas P, consumption areas C, and seaports S (last letter)--proportion

12.5 = conversion factor--bags of polished rice per metric ton storage capacity--bags/MT.

Note that government-owned (low-temperature) storage facilities are assumed all located at consumption area positions and classed with other class A facilities (see Equation 5.127 above).

Maximum storage capacities are calculated as follows.

(Production area capacity)

$$QGPMAX(t) = APCAP(t) + BPCAP(t) + CPCAP(t) \quad (5.133)$$

(Consumption area capacity)

$$QGCMAX(t) = ACCAP(t) + BCCAP(t) + CCCAP(t) \quad (5.134)$$

(Seaport capacity)

$$QGSMAX(t) = ASCAP(t) + BSCAP(t) + CSCAP(t). \quad (5.135)$$

Storage Losses

A fairly simple, but detailed, calculation of seasonal storage loss rates for government-controlled grains is made within the GMP model. Each class of warehousing has inherent expected seasonal storage loss rates. These loss rates are also dependent on the form in which grain is being stored. The basic assumption used in these computations is that, in general, the best storage facilities (class A) are utilized first--on down to the worst storage facilities (class C and field storage) being utilized only when better facilities are filled or not available. Higher classed facilities are also assumed to be utilized for processed grains when available.

The following equations allocate existing government grain inventories to existing warehouse capacity by (1) warehouse class, (2) position point, and (3) grain form.

(Production area polished grain storage by warehouse class)

$$APZUSE(t) = \min[APCAP(t), TQGPZB(t)] \tag{5.136}$$

$$BPZUSE(t) = \min[BPCAP(t), TQGPZB(t) - APZUSE(t)] \tag{5.137}$$

$$CPZUSE(t) = \min[CPCAP(t), TQGPZB(t) - APZUSE(t) - BPZUSE(t)] \tag{5.138}$$

$$FPZUSE(t) = \max[0, TQGPZB(t) - APZUSE(t) - BPZUSE(t) - CPZUSE(t)] \tag{5.139}$$

(Production area hulled grain storage by warehouse class)

$$APYUSE(t) = \min[APCAP(t) - APZUSE(t), TQGPYB(t)] \tag{5.140}$$

$$BPYUSE(t) = \min[BPCAP(t) - BPZUSE(t), TQGPYB(t) - APYUSE(t)] \tag{5.141}$$

$$CPYUSE(t) = \min[CPCAP(t) - CPZUSE(t), TQGPYP(t) - APYUSE(t) - BPYUSE(t)] \tag{5.142}$$

FPYUSE(t) = max[0,TQGPYB(t)-APYUSE(t)-BPYUSE(t)-CPYUSE(t)] (5.143)

(Production area rough grain storage by warehouse class)

APXUSE(t) = min[APCAP(t)-APZUSE(t)-APYUSE(t),TQGPXB(t)] (5.144)

BPXUSE(t) = min[BPCAP(t)-BPZUSE(t)-BPYUSE(t),TQGPXB(t)-APXUSE(t)] (5.145)

CPXUSE(t) = min[CPCAP(t)-CPZUSE(t)-CPYUSE(t),TQGPXB(t)
-APXUSE(t)-BPXUSE(t)] (5.146)

FPXUSE(t) = max[0,TQGPXB(t)-APXUSE(t)-BPXUSE(t)-CPXUSE(t)] (5.147)

(Consumption area polished grain storage by warehouse class)

ACZUSE(t) = min[ACCAP(t),TQGCZB(t)] (5.148)

BCZUSE = min[BCCAP(t),TQGCZB(t)-ACZUSE(t)] (5.149)

CCZUSE(t) = min[CCCAP(t),TQGCZB(t)-ACZUSE(t)-BCZUSE(t)] (5.150)

FCZUSE(t) = max[0,TQGCZB(t)-ACZUSE(t)-BCZUSE(t)-CCZUSE(t)] (5.151)

(Consumption area hulled grain storage by warehouse class)

ACYUSE(t) = min[ACCAP(t)-ACZUSE(t),TQGCYB(t)] (5.152)

BCYUSE(t) = min[BCCAP(t)-BCZUSE(t),TQGCYB(t)-ACYUSE(t)] (5.153)

CCYUSE(t) = min[CCCAP(t)-CCZUSE(t),TQGCYB(t)-ACYUSE(t)-BCYUSE(t)] (5.154)

FCYUSE(t) = max[0,TQGCYB(t)-ACYUSE(t)-BCYUSE(t)-CCYUSE(t)] (5.155)

(Seaport area imported grain storage by warehouse class)

ASYUSE(t) = min[ASCAP(t),TQGSYB(t)] (5.156)

BSYUSE(t) = min[BSCAP(t),TQGSYB(t)-ASYUSE(t)] (5.157)

$$CSYUSE(t) = \min[CSCAP(t), TQGSYB(t)-ASYUSE(t)-BSYUSE(t)] \quad (5.158)$$

$$FSYUSE(t) = \max[0, TQGSYB(t)-ASYUSE(t)-BSYUSE(t)-CSYUSE(t). \quad (5.159)$$

The reader will notice that each set of four equations above is very similar; the only differences being the particular position point and grain forms under consideration. Rather than define each variable, only the variables in the first set of Equations, 5.136 through 5.139, will be defined explicitly. The scheme for the mnemonic names will be described so that the reader can decipher the meaning of the variables in the remaining equations.

APZUSE = current utilization of class A, B, C, and F (auxiliary) warehouse facilities located at production area P, consumption area C, and seaport S positions in rough X, hulled Y, and polished Z forms--bags

APCAP = current capacity of government-controlled warehousing of class A, B, and C located at production area P, consumption area C, and seaport S positions--bags

TQGPZB = total quantity of government grains (rice and barley) located at production area P, consumption area C, and seaport S positions in rough X, hulled Y, and polished Z forms--bags

min = minimum function

max = maximum function

The following equations calculate the seasonal expected losses to current government grain inventories by position points and grain forms.

(Production area loss for rough grains)

$$PXLOSS(t) = [APXUSE(t)*RLOSS_{11}(t) + BPXUSE(t)*RLOSS_{21}(t) + CPXUSE(t)*RLOSS_{31}(t) + FPXUSE(t)*RLOSS_{41}(t)]/TQGPXB(t) \quad (5.160)$$

(Production area loss for hulled grains)

$$PYLOSS(t) = [APYUSE(t)*RLOSS_{12}(t) + BPYUSE(t)*RLOSS_{22}(t) + CPYUSE(t)*RLOSS_{32}(t) + FPYUSE(t)*RLOSS_{42}(t)]/TQGPYB(t) \quad (5.161)$$

(Production area loss for polished grains)

$$PZLOSS(t) = [APZUSE(t)*RLOSS_{13}(t) + BPZUSE(t)*RLOSS_{23}(t) + CPZUSE(t)*RLOSS_{33}(t) + FPZUSE(t)*RLOSS_{43}(t)]/TQGPZB(t) \quad (5.162)$$

(Consumption area loss for hulled grains)

$$CYLOSS(t) = [ACYUSE(t)*RLOSS_{12}(t) + BCYUSE(t)*RLOSS_{22}(t) + CCYUSE(t)*RLOSS_{32}(t) + FCYUSE(t)*RLOSS_{42}(t)]/TQGCYB(t) \quad (5.163)$$

(Consumption area loss for polished grains)

$$CZLOSS(t) = [ACZUSE(t)*RLOSS_{13}(t) + BCZUSE(t)*RLOSS_{23}(t) + CCZUSE(t)*RLOSS_{33}(t) + FCZUSE(t)*RLOSS_{43}(t)]/TQGCZB(t) \quad (5.164)$$

(Seaport loss for imported grains)

$$SYLOSS(t) = [ASYUSE(t)*RLOSS_{12}(t) + BSYUSE(t)*RLOSS_{22}(t) + CSYUSE(t)*RLOSS_{32}(t) + FSYUSE(t)*RLOSS_{42}(t)]/TQGSYB(t) \quad (5.165)$$

where:

PXLOSS = expected seasonal loss rate for government grains stored at production area P, consumption area C, and seaport S positions in rough X, hulled Y, and polished Z forms--proportion/yr

APXUSE = current utilization of class A, B, C, and F (auxiliary) warehouse facilities located at production area P, consumption area C, and seaport S positions in rough X, hulled Y, and polished Z forms--bags

$RLOSS_{jk}$ = seasonal loss rate function for government grains stored in j-class facilities in k-form--proportion/yr

TQGPXB = total quantity of government grains (rice and barley) located at production area P, consumption area C, and seaport S positions in rough X, hulled Y, and polished Z forms--bags.

The seasonal loss rate functions, $RLOSS_{jk}(t)$, in the above government storage loss equations are empirical functions of time over the year. Data used in the model are best guestimates of actual expected seasonal losses [20]. If and when improved data become available, they can be used to replace those which are currently used in the model. Figure 5.6 depicts the general shape of the $RLOSS_{jk}(t)$ functions used in the model.

Mathematically, the seasonal loss rate functions are generated by the following equations.

$$SLOPE1_{jk} = [LOSSHI_{jk} - LOSSLO_{jk}]/[T_2-T_1] \quad (5.166)$$

$$SLOPE2_{jk} = [LOSSHI_{jk} - LOSSLO_{jk}]/[T_4-T_3] \quad (5.167)$$

$$\begin{aligned} RLOSS_{jk}(t) = {} & LOSSLO_{jk}*u(toy) \\ & + SLOPE1_{jk}*r(toy-T_1) \\ & - SLOPE1_{jk}*r(toy-T_2) \\ & - SLOPE2_{jk}*r(toy-T_3) \\ & + SLOPE2_{jk}*r(toy-T_4) \end{aligned} \quad (5.168)$$

where:

LOSSHI = seasonal high loss rate--proportion/yr

LOSSLO = seasonal low loss rate--proportion/yr

u( ) = unit step function

r( ) = unit ramp function

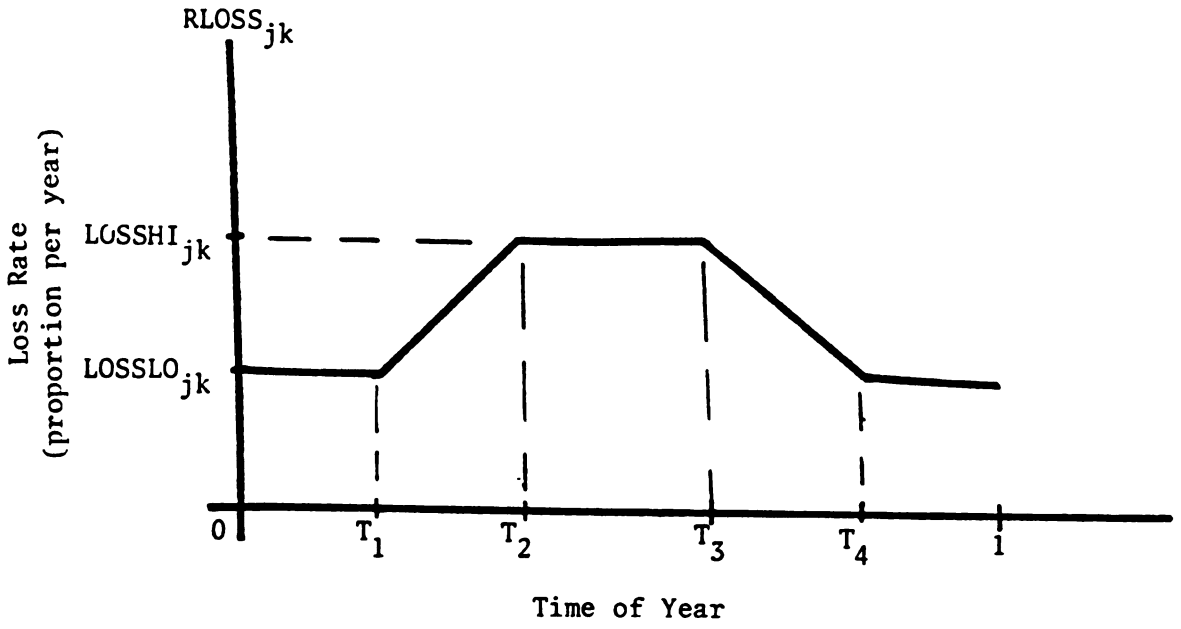


Figure 5.6. Seasonal Loss Rates.

toy = time of (calendar) year, $0 \leq toy \leq 1$--yr.

Government Grain Management Accounting

Performance of the government subsector, as well as impacts of various government grain management programs and policies, can be measured in fiscal terms. The equations presented in this section describe precisely the function of the government grain management accounting mechanism used in the GMP model.

Revenues

Revenue flows generated by government grain operations are calculated by the following equations.

(Product sales)

$$RVSLS_i(t) = PS_i(t)*GSLS_i(t)*BPMTZ_i \qquad (5.169)$$

(By-product sales)

$$RVBPS_i(t) = PBP1_i(t)[RGPZBP_i(t)+RGCZBP_i(t)]\ PCRAC_i(t) + PBP2_i(t)[RGPZBP_i(t)+RGCZBP_i(t)][1-PCRAC_i(t)] \quad (5.170)$$

where:

RVSLS = revenue flow from government grain sales--won/yr

PS = government grain retail sale price--won/bag

GSLS = rate of government grain sales--MT/yr

BPMTZ = number of 100-liter bags per metric ton (polished equivalent)--bags/MT

RVBPS = revenue flow from government grain by-product sales--won/yr

PBP1 = price of cracked grains--won/MT

PBP2 = price of bran--won/MT

RGPZBP = rate of by-product production from government domestic grains--MT/yr

PCRAC = proportion of cracked grain from total by-product production (less hulls)--proportion.

Equation 5.170 above depicts the model assumption that sales of government grain by-products occur concurrently with by-product production. Although not always true, little accuracy is lost from this simplifying assumption.

Revenue accumulations (total revenue) can be calculated for any time period during the model run for generating summary accounting tables. This is done by integrating the revenue flows generated in Equations 5.169 and 5.170 over the accounting period desired.

Expenditures

Government grain management program expenditures are analyzed (broken down) into considerable detail.

Grain Purchases

Expenditures for government grain purchases are broken down into expenditures for domestic grains and expenditures for imported grains. The obvious reason for this is differing purchase prices for domestic and imported grains. Also, terms of payment for imported grains can vary from cash to long-term repayment plans (e.g., PL480) in which payments to principal and interest must be calculated.

Expenditures for Domestic Grain Purchases

These expenditures consist of purchasing costs for government domestic grains. The following equations depict these calculations.

(Purchasing costs)

$$EXPUR_i(t) = PB_i(t)GPUR_i(t)BPMTZ_i(t) \quad (5.171)$$

where:

EXPUR = cost flow of government domestic grain purchases--won/yr

PB = government purchase price for domestic grains--won/bag

BPMTZ = number of 100-liter bags per metric ton (polished equivalent)--bags/MT.

Expenditures for Imported Grain Purchases

These expenditures consist of foreign exchange costs for cash payments for imported grains plus payments to principal and interest on long-term grain import repayment plans (e.g., PL480). The equations used for these calculations, and to be described in this section, are depicted in the systems diagram of Figure 5.7.

Cash payments for imported grains are calculated by the following equation.

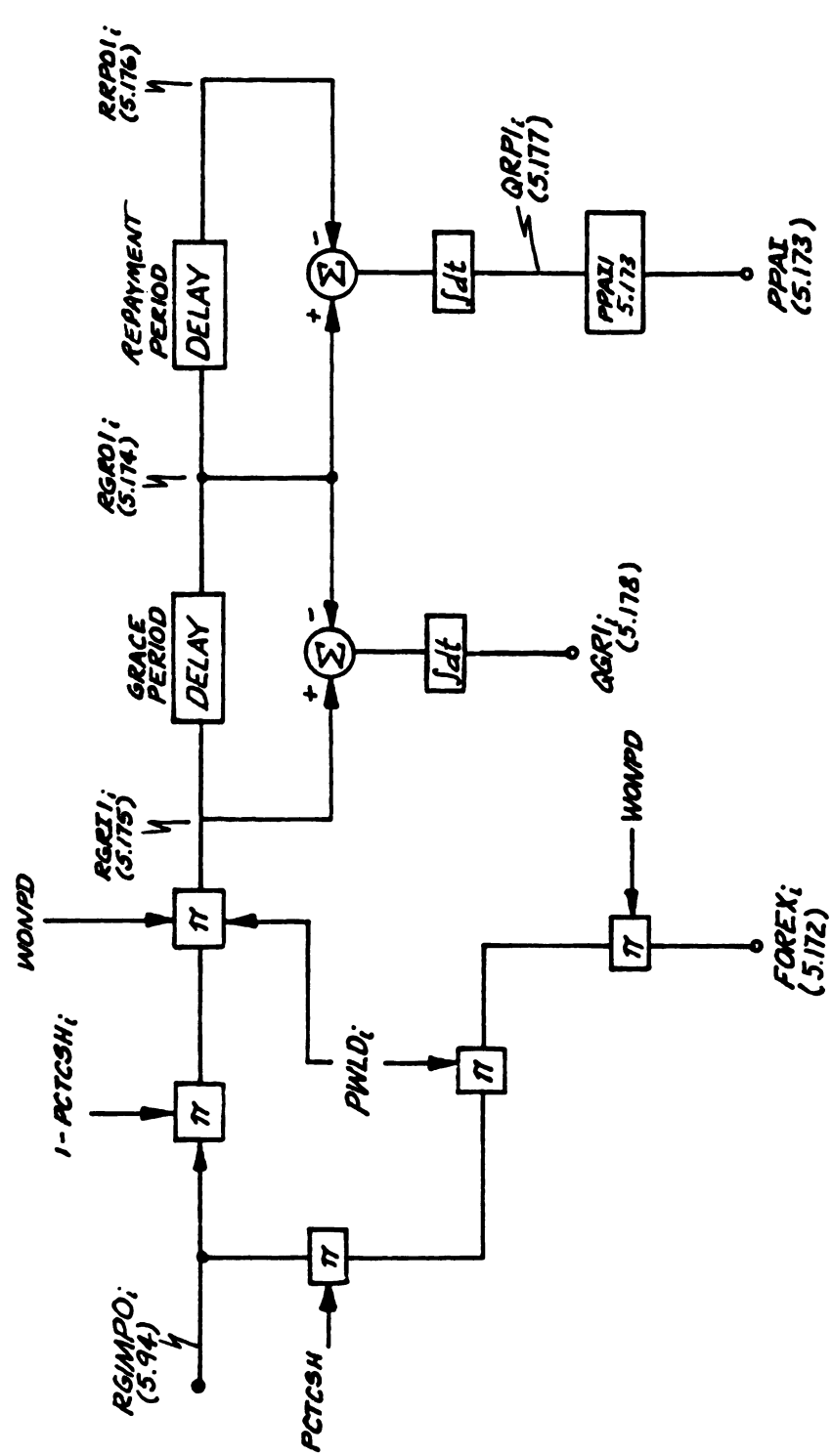


Figure 5.7. System Diagram--Cash Payments and Payments to Principal and Interest on Imported Grains.

(Cash payments)

$$FOREX_i(t) = RGIMPO_i(t)PCTCSH_i(t)PWLD_i(t)WONPD_i(t) \quad (5.172)$$

where:

FOREX = foreign exchange cost flow for cash payments for imported grains--won/yr

RGIMPO = rate at which imported grains arrive at port facilities (see Equation 5.94)--MT/yr

PCTCSH = proportion of government grain imports paid for in cash ($0 \leq PCTCSH \leq 1$)--proportion

PWLD = world price for imported grains--$/MT (U.S. dollars)

WONPD = won to U.S. dollars conversion factor--won/$

Equation 5.172 above indicates the model assumption that cash payments for imports are made upon delivery to port facilities. Although not completely accurate in reality, this simplifying assumption has negligible impact on accounting results. The reader should note the time-varying nature of the three factors PCTCSH, PWLD, and WONPD in Equation 5.172. This enables accurate historical tracking by providing actual values of these factors for past periods and also allows model users to investigate impacts of various import payment plans.

Payments to principal and interest on noncash grain import programs are calculated by the following equation.

(Payments to principal and interest)

$$PPAI1_i(t) = -\frac{AIRP1*QRP1_i(t)e^{AIRP1*DELRP1}}{1 - e^{AIRP1*DELRP1}} \quad (5.173)$$

[8]

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[8]Given a loan with a face value (before payment) of BAL(0), let BAL(t) be the unpaid balance at time t on this loan which is generating interest charges at a compounded rate of AIRP1 per annum. Further

where:

PPAI1 = payments to principal and interest on noncash imported grains--won/yr

AIRP1 = annual interest rate for long-term import repayment agreements--proportion/yr

QRP1 = total outstanding principal on import loans currently in repayment phase--won

e = natural base e (e = 2.71828...)--no units

DELRP1 = average term of repayment programs--yrs.

Although the derivation of Equation 5.173 is given in a footnote, some further explanation is necessary to relate the equation to the real world situation. (Figure 5.7 should be a particularly useful reference during this discussion.) Typically, and in harmony with current situation, all new long-term grain loans enter a grace period before repayment becomes necessary. This grace period is simulated

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assume that this loan is paid off at a fixed annual rate of X dollars per year. The following differential equation describes this repayment process.

$$\frac{d}{dt} BAL(t) = - X + AIRP1*BAL(t). \qquad (5.173A)$$

Using Laplace transformation techniques, the following calculations indicate the solution to this equation given in Equation 5.173B below.

$$SBAL(S) - BAL(0) = -\frac{X}{S} + AIRP1*BAL(S)$$

$$(S-AIRP1)BAL(S) = BAL(0) - \frac{X}{S}$$

$$BAL(S) = \frac{BAL(0)}{S-AIRP1} - \frac{X}{S(S-AIRP1)},$$

or,

$$BAL(S) = \frac{BAL(0)}{S-AIRP1} + \frac{X/AIRP1}{S} - \frac{X/AIRP1}{S-AIRP1}.$$

Therefore,

$$BAL(t) = BAL(0)e^{AIRP1*t} + \frac{X}{AIRP1}\left[1 - e^{AIRP1*t}\right]. \qquad (5.173B)$$

Letting the unpaid balance at the end of repayment period be zero, we have

by a distributed delay function represented by the following differential equation.

$$a_k \frac{d^k}{dt^k} RGRO1_i(t) + a_{k-1} \frac{d^{k-1}}{dt^{k-1}} RGRO1_i(t) + \ldots = RGRI1_i(t) \quad (5.174)$$

where:

a_j = coefficients of distributed delay function,

$$a_j = \binom{k}{j}\left[\frac{DELGR1}{k}\right]^j, \; j = 0, \ldots, k$$

DELGR1 = delay parameter representing average grace period--yrs

RGRO1 = rate at which past loans "leave" grace period and enter repayment phase--won/yr

RGRI1 = rate at which new import loans are acquired and "enter" the grace period--won/yr.

The input variable RGRI1 of Equation 5.174 above is calculated as follows.

$$RGRI1_i(t) = RGIMPQ_i(t)\,[1\text{-}PCTCSH_i(t)]\,PWLD_i(t)*WONPD(t) \quad (5.175)$$

where, variable definitions are given under Equation 5.172.

BAL(DELRP1)=0. Substituting this condition into Equation 5.173B, we have

$$BAL(0)e^{AIRP1*DELRP1} + \frac{X}{AIRP1}\left[1 - e^{AIRP1*DELRP1}\right] = 0 \quad (5.173C)$$

or,

$$X = \frac{-BAL(0)*AIRP1*e^{AIRP1*DELRP1}}{1 - e^{AIRP1*DELRP1}}. \quad (5.173D)$$

Suppose now we have many outstanding loans (the total face value before repayment equal to QRP1) which have the same interest rate and terms of repayment as above. Using the results of Equation 5.173D, the payments to principal and interest (PPAI1) on this bundle of loans are

$$PPAI1_i(t) = -\frac{AIRP1*QRP1_i(t)e^{AIRP1*DELRP1}}{1 - e^{AIRP1*DELRP1}}. \quad (5.173) \text{ repeated}$$

The movement of principal through the repayment phase of long-term grain loan repayment agreements is calculated by the following differential equation.

$$a_k \frac{d^k}{dt^k} RRPO1_i(t) + a_{k-1} \frac{d^{k-1}}{dt^{k-1}} RRPO1_i(t) + \ldots = RGRO1_i(t) \quad (5.176)$$

where:

a_j = coefficients of distributed delay function,

$$a_j = \binom{k}{j}\left[\frac{DELRP1}{k}\right]^j, \; j = 0, \ldots, k$$

DELRP1 = delay parameter representing average repayment period--yrs

k = order of delay equation

RRPO1 = rate at which grain import loan principal is paid off--won/yr

RGRO1 = rate at which grain import loans enter repayment phase (see Equation 5.174)--won/yr.

Now, the total outstanding principal on import loans, $QRP1_i(t)$, of Equation 5.173 above is calculated by the following integration.

$$QRP1_i(t) = QRP1_i(t_o) + \int_{t_o}^{t} [RGRO1_i(\tau) - RRPO1_i(\tau)]d\tau \quad (5.177)$$

where, $RGRO1_i(t)$ and $RRPO1_i(t)$ are the rates at which grain import loans enter and leave the repayment period, respectively.

New import loans usually enter a grace period in which interest payments only are required. Interest rates during this period are generally quite low, compared to interest rates charged during the principal repayment phase. The total amount of import loans currently in their grace period is calculated by Equation 5.178 below.

$$QGR1_i(t) = QGR1_i(t_o) + \int_{t_o}^{t} [RGRI1_i(\tau)-RGRO1_i(\tau)]d\tau \qquad (5.178)$$

where:

QGR1 = total value of import loans currently in their grace period--won

RGRI1 = rate at which new import loans are acquired and "enter" the grace period--won/yr

RGRO1 = rate at which past loans "leave" grace period and enter repayment phase--won/yr.

Given the total value of import loans in their grace period, grace period interest payments are calculated by the following simple equation.

(Grace period interest payments)

$$GRIP1_i(t) = AIGR1*QGR1_i(t) \qquad (5.179)$$

where:

GRIP1 = grace period interest payments--won/yr

AIGR1 = annual grace period interest rate--proportion/yr

QGR1 = total value of import loans currently in their grace period--won.

Total expenditures on foreign grain imports are then given by the following summation equation.

$$EXIMP_i(t) = FOREX_i(t) + PPAI1_i(t) + GRIP1_i(t). \qquad (5.180)$$

(5.172) (5.173) (5.179)

This concludes the discussion of model calculation of government expenditures for imported grain purchases. It might further be mentioned that summary table entries for these expenditures can be

generated by simply integrating (accumulating) the cost flows for cash payments (Equation 5.172), payments to principal and interest (Equation 5.173), and grace period interest payments (Equation 5.179) over the applicable accounting period.

Grain Storage, Processing, and Handling Costs

Grain handling and processing cost calculations are very significant in studying the impacts of various government grain management programs. These costs can vary greatly, depending on the amount of handling involved, length of storage, and policies for processing government grains. The detail of the government grain operations model enables a fairly realistic analysis of these costs, therefore, giving the model the capability of accurately reflecting grain handling and processing costs associated with particular grain management policies and programs under study.

Storage Costs

Storage costs vary significantly according to position, form, and kinds of grains being held. The storage cost accounting mechanism of the GMP model takes advantage of the level of detail built into the government grain operations model and places accurate storage cost parameters on government grains being stored throughout the grain marketing system. The following equations describe the grain storage cost calculations of the government subsector model.

(Production area storage cost)

$$CGSP_i(t) = C103A_i(t)*QGPX_i(t) + C103B_i(t)\ [QGPY_i(t)+QGPZ_i(t)] \qquad (5.181)$$

(Consumption area storage cost)

$$CGSC_i(t) = C103C_i(t)\ [QGCY_i(t)+QGCZ_i(t)] \quad (5.182)$$

(Seaport storage cost)

$$CGSS_i(t) = C103C_i(t)*QGSY_i(t) \quad (5.183)$$

(Total storage cost)

$$CGS_i(t) = CGSP_i(t) + CGSC_i(t) + CGSS_i(t) \quad (5.184)$$

where:

CGSP, C, S = storage costs for government grains located at production area P, consumption area C, and seaport S positions, respectively--won/yr

C103A, B, C = storage charge parameters--won/MT-yr

QGPX, Y, Z = quantity of government grains located at production area positions in rough X, hulled Y, and polished Z forms, respectively--MT

QGCY, Z = quantity of government grains located at consumption area positions in hulled Y and polished Z forms, respectively--MT

QGSY = quantity of government (imported) grains located at seaport positions--MT.

The total storage cost equation shown above assumes that all government storage is leased. To obtain a more accurate calculation of actual government grain storage costs, certain assumptions must be made regarding the utilization of government-owned storage facilities. These assumptions should be consistent with current grain management policy (i.e., utilizing government-owned warehousing at a certain percentage of capacity over the year, etc.). Once these assumptions are made, they can be incorporated into the model, and the storage cost of government grains stored in government-owned warehousing can be calculated and incorporated into the total storage cost equation.

The following equation is a modification to Equation 5.182 which makes the following assumptions: (1) all government-owned warehousing is located at consumption area positions, (2) government-owned warehousing is utilized at an average of UT_i proportion of capacity (whenever possible) for commodity i, and (3) storage cost for government-owned warehousing consists of fixed costs independent of the size of grain inventories and variable costs which increase as the size of grain inventories increases.

$$CGSC_i(t) = C103C_i(t)\ \max[0, QGCY_i(t)+QGCZ_i(t)-UT_i*QGOW(t)]$$

(amount in leased warehousing)

$$+\ C103D_i(t)\ \min[UT_i*QGOW(t), QGCY_i(t)+QGCZ_i(t)]$$

(amount in government-owned warehousing)

$$+\ C103E_i(t)*QGOW(t) \qquad (5.185)$$

(5.182) modified

where:

CGSC = storage cost for government grains located at consumption area positions--won/yr

C103C = unit storage cost parameter for government-leased grain storage--won/MT-yr

QGCY, Z = quantity of government grains located at consumption area positions in hulled Y and polished Z forms, respectively--MT

UT = average utilization rate of government-owned warehousing--proportion/yr

QGOW = capacity of government-owned warehousing (located at consumption area positions)--MT

C103D = variable cost parameter associated with operating government-owned warehousing--won/MT-yr

C103E = fixed cost parameter associated with operating government-owned warehousing--won/MT-yr

max = maximum function

min = minimum function.

Milling Costs

Government grains are processed both at production area and consumption area positions. Past and current Korean grain management policy, for the most part, has domestic grains processed at production area positions and imported grains processed at consumption area positions. Different milling charges are associated with milling operations at these two positions. The following equations describe milling (processing) cost calculations made in the GMP model.

(Milling costs)

$$CGM_i(t) = \underbrace{C104A_i(t)*RGPYZ_i(t)}_{\text{(production areas)}} + \underbrace{C104B_i(t)*RGCYZO_i(t)*EYZ_i}_{\text{(consumption areas)}} \quad (5.186)$$

where:

CGM = cost flow associated with the processing of government-controlled grains--won/yr

C104A, B = processing cost parameters associated with milling government grains in production areas A and consumption areas B, respectively--won/MT

RGPYZ = rate of product output from government milling operations in production area positions--MT/yr

RGCYZO = rate of total output (product and by-product) from government milling operations in consumption area positions--MT/yr

EYZ = hulled to polished form conversion factor--proportion.

It should be noted that Equation 5.186 is reflective of past and current government grain milling policies in Korea. If the model were to be used for investigating alternatives to current policy, such as two-stage milling (e.g., hulling a portion of domestic grains and then finishing the milling process at a later time, either at

production area positions or at consumption area positions), Equation 5.186 would have to be replaced by a more detailed equation. Most important would be cost parameters reflecting separate hulling and polishing charges, it being unlikely that these charges would sum to the single processing operation charge, C104A of Equation 5.186.

Handling Costs

Every time grain is handled, charges accumulate. Estimates are that government grains are handled in some manner fifteen to twenty times before they arrive at consumer households. The GMP model attempts to reflect significant handling charges on government grains in a manner that can distinguish various handling costs associated with alternative grain management programs and policies. The following equations describe the calculation of some of these important handling costs.

(Acquisition costs)

$$CGPUR_i(t) = C101(t)*GPUR_i(t). \qquad (5.187)$$

Equation 5.187 above reflects all significant costs associated with the acquisition of government domestic grains. Included are the costs of bagging materials, bagging and/or rebagging (if necessary), buying-point management costs, loading, transportation to production area storage facilities (if necessary), unloading, grading and inspection charges, and carry-in charges--all of which accumulate up to the time government grains are first placed into storage.

(Intrachannel handling costs)

$$CGICH_i(t) = C105A(t)*RGPXYO_i(t)+C105B(t)\{abs[RGPY_i(t)]+abs[RGPZ_i(t)]\} \qquad (5.188)$$

where:

CGICH = handling costs associated with handling government grains located at production area positions--won/yr

€105A = handling charge parameter associated with production area hulling operations--won/MT

RGPXYO = rate of hulling operations in production areas--MT/yr

C105B = handling charge parameter associated with moving government grains in and out of production area storage facilities--won/MT

abs = absolute function

RGPY = rate of change of government hulled grain stocks located at production area positions--MT/yr

RGPZ = rate of change of government polished grain stocks located at production area positions--MT/yr.

Equation 5.188 accounts for the handling costs associated with hulling operations on government domestic grains. It also gives some measure of the charges accumulated on government grains associated with moving hulled and polished grain into and out of storage facilities in production areas. The following equation indicates the major transportation costs accounted for by the government subsector accounting mechanism.

(Transportation costs)

$$CGT_i(t) = C106A(t)*RGPCZO_i(t)+C106B(t)*RGSCYO_i(t) \quad (5.189)$$

where:

CGT = major transportation cost associated with moving government-controlled grains between production area and consumption area positions, and between seaport and consumption area positions--won/yr

C106A, B = appropriate average transportation charge parameters--won/MT

RGPCZO = rate at which government grains move from production area to consumption area positions--MT/yr

RGSCYO = rate at which government imported grains move from seaports to consumption area positions--MT/yr

Seaport handling costs on imported grains are also reflected in the government accounting equations.

(Seaport handling costs)

$$CGD_i(t) = C107(t)*RGDO_i(t)/EYZ_i \quad (5.190)$$

where:

CGD = cost of discharge operations associated with imported grains--won/yr

C107 = cost parameter reflecting the charges associated with seaport discharge operations--won/MT

RGDO = rate at which government imported grains are discharged from vessels (see Equation 5.97)--MT/yr .

Finally, there are costs associated with the handling of government-processed grains located at consumption area positions. These costs include bagging, distribution to retail sales stores, and other operations on government grains prior to sale to the consumer. For convenience these are referred to as selling costs.

(Selling costs)

$$CGSLS_i(t) = C102(t)*GSLS_i(t) \quad (5.191)$$

where:

CGSLS = cost associated with selling government-controlled grains--won/yr

C102 = selling cost parameter--won/MT

GSLS = rate of government grain releases--MT/yr .

This concludes the description of the various handling and processing cost calculations performed by the government subsector accounting mechanism. These costs are all pulled together by the

following summation which generates the rate of total storage, processing, and handling costs of government grain operations.

(Total storage, processing, and handling costs)

$$CGHAP_i(t) = \underbrace{CGPUR_i(t)}_{\text{(acquisition)}} + \underbrace{CGSLS_i(t)}_{\text{(selling)}} + \underbrace{CGS_i(t)}_{\text{(storage)}} + \underbrace{CGM_i(t)}_{\text{(milling)}} + \underbrace{CGICH_i(t)}_{\text{(intra-channel)}} + \underbrace{CGT_i(t)}_{\text{(trans-portation)}} + \underbrace{CGD_i(t)}_{\text{(discharge)}}. \quad (5.192)$$

Warehouse Construction Costs

Construction costs for government-owned warehousing are calculated in the GMP model. The method used for calculating this cost flow is very similar to the method used for calculating repayment of long-term foreign grain import loans already described. For this reason, the same amount of detailed explanation of these equations will not be given here. Instead, the reader will be referred to similar equations for import loan repayments, where he can find a more detailed discussion.

The calculation of government warehouse construction financing made in the GMP model assumes that payments to principal and interest begin immediately upon initialization of warehouse construction. No grace period is assumed before repayment of construction loans begins. The following equation computes the principal flow of new government warehouse construction loans into the repayment phase.

$$RRPI2(t) = C111(t)*RGWUCI(t) \quad (5.193)$$

where:

RRPI2 = rate at which new warehouse construction loans enter repayment phase--won/yr

C111 = unit cost parameter for the construction of government warehouses (units are won per metric ton of polished rice equivalent capacity)--won/MT

RGWUCI = rate at which government warehouse construction projects are begun (see Equation 5.101)--MT/yr.

Next, the following distributed delay function simulates the retirement of warehouse construction loan principal over time.

$$a_k \frac{d^k}{dt^k} RRPO2(t) + a_{k-1} \frac{d^{k-1}}{dt^{k-1}} RRPO2(t) + \cdots = RRPI2(t) \qquad (5.194)$$

where:

a_j = coefficients of distributed delay function,

$$a_j = \binom{k}{j}\left[\frac{DELRP2}{k}\right]^j, \quad j = 0, \ldots, k$$

k = order of delay equation

RRPO2 = rate at which loan principal is retired over time--won/yr

RRPI2 = rate at which new warehouse construction loans enter repayment phase--won/yr.

The current amount of unpaid principal on warehouse construction loans is calculated by the following integration.

$$QRP2(t) = QRP2(t_o) + \int_{t_o}^{t} [RRPI2(\tau)-RRPO2(\tau)]\, d\tau \qquad (5.195)$$

Finally, payments to principal and interest on government warehouse construction loans are calculated by the following equation (see Equation 5.173 and accompanying footnote for more explanation).

$$PPAI2(t) = \frac{-AIRP2*QRP2(t)e^{AIRP2*DELRP2}}{1 - e^{AIRP2*DELRP2}} \qquad (5.196)$$

where:

PPAI2 = payments to principal and interest on government warehouse construction loans--won/yr

AIRP2 = annual interest rate for government warehouse construction loans--proportion/yr

QRP2 = current amount of unpaid principal on warehouse construction loans--won

e = natural base e (e = 2.71828...)--no units

DELRP1 = average loan repayment period--yrs.

Profits and Losses

Several combinations of the above revenues and expenditures are made to generate meaningful measurements of the grain management special account and grain management fund net cash flows, account changes, and balances.[9] The following equation describes the computation of net profit (cash flow) of the grain management special account.

$$RGMSA_i(t) = RVSLS_i(t) + RVBPS_i(t) - EXPUR_i(t) - EXIMP_i(t) - CGHAP_i(t) \quad (5.197)$$

where:

RGMSA = rate of change of grain management special account--won/yr

RVSLS = revenue flow from government grain sales (see Equation 5.169)--won/yr

RVBPS = revenue flow from government grain by-product sales (see Equation 5.170)--won/yr

EXPUR = expenditures flow of government domestic grain purchases (see Equation 5.171)--won/yr

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[9]The nomenclature terms "Grain Management Special Account" and "Grain Management Fund" are official names used by the Korean government to refer to specific grain management laws and accounts [22]. Although the GMP variables using these same nomenclature attempt to represent their real world counterparts, the complexity and flexibility of the real world grain management accounting system precludes the attainment of a precise one-to-one relationship.

EXIMP = expenditure flow of government foreign grain purchases (see Equation 5.180)--won/yr

CGHAP = expenditure flow for handling, storing, and processing government grains (see Equation 5.192--won/yr.

Another cash flow calculation which also includes grain warehouse construction costs, grain management administration costs, wheat subsidies, and the cost of funds borrowed from the Bank of Korea is given below.

$$RTGMF(t) = \sum_{i=1}^{2} RGMSA_i(t) - PPAI2(t) - C113(t) - EXDP(t) - GWSUB(t)*35.*RWSLSO(t) \quad (5.198)$$

$$QTGMF(t) = QTGMF(t_o) + \int_{t_o}^{t} RTGMF(\tau)d\tau \quad (5.199)$$

$$EXDP(t) = AIDP(t)*abs\ \{min[0,QTGMF(t)]\} \quad (5.200)$$

where:

RTGMF = rate of change of grain management fund--won/yr

RGMSA = rate of change of grain management special account--won/yr

PPAI2 = rate of payments to principal and interest on government warehouse construction loans--won/yr

C113 = grain management administration cost--won/yr

EXDP = cost of grain management operating funds borrowed from BOK--won/yr

GWSUB = wheat flour subsidy payments paid to flour millers--won/22-kg bag

35 = whole wheat to flour conversion factor (assuming 77% extraction rate)--22-kg bags/MT

RWSLSO = rate of wheat flour wholesales by millers (in wheat grain equivalent)--MT/yr

QTGMF = accumulation (or deficit) in grain management fund--won

AIDP = rate of interest for borrowed grain management operating funds--proportion/yr

abs = absolute function

min = minimum function.

This concludes the mathematical description of the government subsector model. The previous two chapters have been used to describe the GMP model structure for simulating the Korean grain marketing system (private and government). In the next chapter, the urban subsector model, used to simulate nonfarm consumer consumption, urban market demand, and urban household storage behavior, will be described.

CHAPTER 6

URBAN SUBSECTOR MODEL

Introduction

The urban subsector model simulates approximately 97 percent of the nonfarm demand and consumption of food grains in Korea.[1] Over three million individual household units make up the urban subsector which purchases and consumes over four million metric tons of food grains annually--or roughly 60 percent of the total annual supply.

The model *does not* disaggregate nonfarm demand for food grains in household and nonhousehold (diners, restaurants, etc.) demand, since the difference in demand, storage, and consumption behavior of these two components does not warrant the necessary additional model complexity of the disaggregation. Government food grain policies for restaurants, such as "riceless days," requirements to serve mixed grains, etc., can be adequately reflected in the aggregate urban subsector model.

The urban subsector model identifies nonfarm consumer (household) decisions regarding market price speculation, market demand, and related household food grain storage adjustments. Urban food grain consumption is modelled based on income, food grain prices, and

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[1]Each year approximately 190,000 MT (three percent of annual supply) of food grains are used by the Korean government for military use, government institutions, prisoners, relief, and welfare. The supply of these grains comes from government-owned stocks. This component of nonfarm disappearance of food grains is reflected in the government subsector model.

household food grain stock levels. The phenomenon of suppressed consumption rates due to critically low household stock levels, brought about by food grain shortages, is also reflected in the model. A detailed set of performance criteria which measure and summarize the impacts of various grain management policies and programs on the urban subsector is provided by the model. In this chapter, the mathematical details of the urban subsector model will be described. The system diagram of Figure 6.1 depicts many of the mathematical interrelationships of the model in symbolic form. The diagram should be a useful reference throughout much of the following discussion.

Urban Household Storage

Recent urban consumption survey data indicate that urban households store an average of about 125,000 metric tons of rice and 75,000 metric tons of barley throughout the year. This amount represents roughly a three-week supply for urban consumption at average consumption rates. Although the magnitude of these average household stock levels appears trivial compared to the average stock levels of farm, government, and private market sectors (i.e., about five percent), it is important to reflect urban household storage behavior and especially stock level adjustments in the model. If urban household stock levels remained constant throughout the year, there would be little need to reflect this storable behavior in the model. However, survey data indicate that urban household rice stocks alone have varied as much as 65,000 metric tons in one month's time.[2] This size

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[2]This addition to urban storage is equivalent to approximately 22 kilograms of rice (or slightly over one-quarter bag) per urban household.

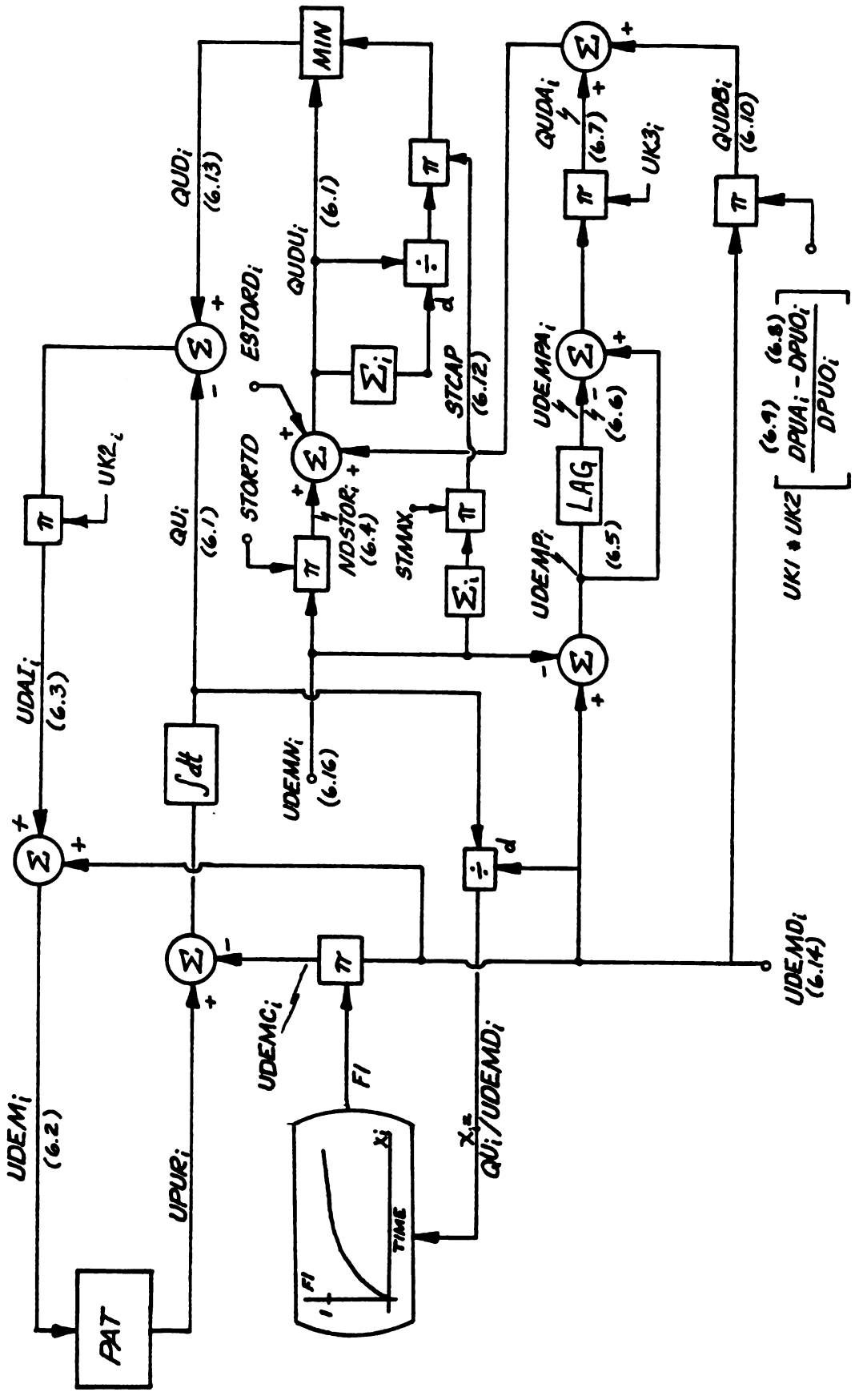


Figure 6.1. System Diagram--Urban Subsector Operations.

of stock level adjustment requires that household purchases differ from actual consumption rates by nearly 800,000 metric tons per year. These changes in urban market demand can have drastic effects on food grain prices, especially if market supplies do not (or cannot) respond accordingly.

Equation 6.1 describes the dynamics of urban household food grain inventories.

$$\frac{d}{dt} QU_i(t) = UPUR_i(t) - UDEMC_i(t) \qquad (6.1)$$

where:

QU = urban household inventory levels--MT

UPUR = rate of urban consumer purchases--MT/yr

UDEMC = rate of urban food grain consumption--MT/yr.

The rate of urban purchases, $UPUR_i(t)$ in Equation 6.1, is the variable by which adjustments to urban household inventories are made. Actual purchases are calculated in the price and transaction mechanism which interfaces total available urban market supply (private market and government) with urban subsector demand.

Household Inventory Management

Automatic feedback control techniques are used to calculate adjustments to urban subsector demand aimed at bringing about changes in household inventory levels. The following equations describe the components of urban market demand.

$$UDEM_i(t) = UDEMD_i(t) + UDAI_i(t) \qquad (6.2)$$

$$UDAI_i(t) = [QUD_i(t)-QU_i(t)]/UK2_i \qquad (6.3)$$

where:

UDEM = urban subsector market demand--MT/yr

UDEMD = current rate of urban food grain consumption demand--MT/yr

UDAI = component of urban market demand to adjust household inventory levels--MT/yr

QUD = current desired household stock levels--MT

QU = current actual household stock levels--MT

$1/UK2_i$ = control gain parameter reflecting the demand response rate for adjusting household stock levels toward desired levels--proportion/yr.

We will now develop the motivation and underlying mathematical relationships which go into the generation of desired household stock levels.

Desired Household Stock Levels

Four signals go into the generation of the desired household stock levels, $QUD_i(t)$ of Equation 6.3. These components are listed below:

(1) normal storage,

(2) emergency storage,

(3) adjustment in storage level due to price level effect, and

(4) adjustment in storage level due to price changes.

Normal Storage

The concept of a normal desired stock level of food grains is provided in the model. This represents the amount of household inventory desired under normal consumption and price conditions, without concern for emergency stocks or future price speculation. The important parameter in generating this signal is the amount of time (number of

days) household food grain stocks should sustain normal consumption rates. In Korea this parameter appears to be between ten and twenty days' supply (i.e., .03 to .06 year). The normal storage component of the desired household inventory levels is generated throughout the model run by the following equation.

$$NDSTOR_i(t) = STORTD_i * UDEMN_i(t) \qquad (6.4)$$

where:

NDSTOR = normal household storage level desired--MT

STORTD = desired sustaining time of normal storage level--yrs

UDEMN = normal consumption rate at fixed prices equal to base period prices used in model run (see Equation 6.16)--MT/yr.

Emergency Storage

The emergency storage component of the urban subsector model introduces an increase in desired household stock levels as an emergency measure in the event of a possible food shortage. It can be used as a policy variable to determine the market and other consequences of increasing consumer supplies. A variety of time profiles for establishing this emergency stock level can be investigated by the model. An example of one such profile is illustrated in Figure 6.2.

Price Level Effect

This component of desired household stock levels simulates the effect of changes in relative market price levels (from normal) on the amount of desired household inventories. When relative market price levels are higher than average, a decrease in desired storage is introduced; and, vice versa, when relative market prices are lower

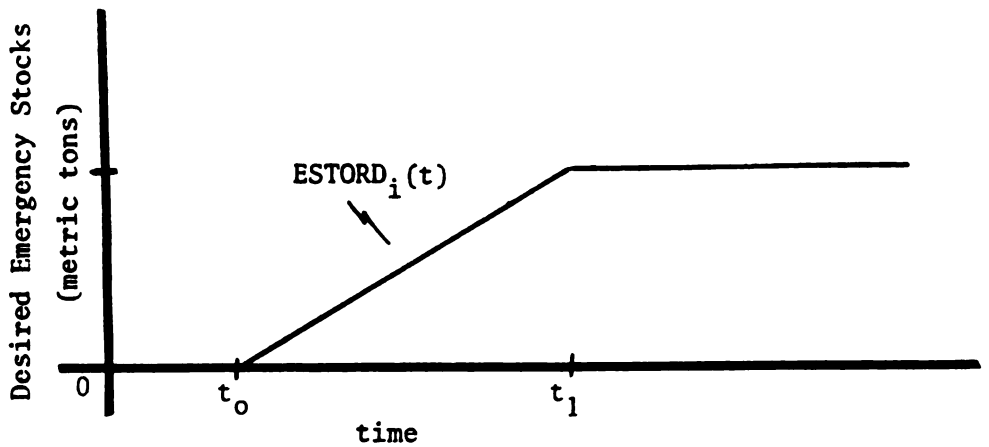


Figure 6.2. Experimental Emergency Stock Profile.

than average, an increase in desired storage results. The equations used to introduce price level effects are given below.

$$UDEMP_i(t) = UDEMD_i(t) - UDEMN_i(t) \tag{6.5}$$

$$\frac{d}{dt} UDEMPA_i(t) + UDEMPA_i(t) = UDEMP_i(t) \tag{6.6}$$

$$QUDA_i(t) = UK3_i * [UDEMP_i(t) - UDEMPA_i(t)] \tag{6.7}$$

where:

UDEMP = change in expected consumption level from normal due to current price levels--MT/yr

UDEMD = current rate of consumption, assuming adequate household stocks are available (see Equation 6.14)--MT/yr

UDEMN = normal consumption rate at fixed prices equal to base period prices used in model run (see Equation 6.16)--MT/yr

UDEMPA = exponential average (smoothed version of $UDEMP_i(t)$--MT/yr

QUDA = component of desired urban storage level due to price level effects--MT

UK3 = sustaining time parameter, used to reflect actual changes in desired storage level due to price level effects--yrs.

The price level effect is designed to reflect price level speculation on urban storage behavior. Urban consumers storing more grain because of "lower" relative prices expect prices to become "higher" in the future, and vice versa. Therefore, the smoothing term $UDEMPA_i(t)$ is used in Equation 6.7 above to eliminate any price level effect which might be caused by general changes in average price levels during the model run.

Price Change Effect

When market food grain prices are observed to be increasing at a rate higher than the cost of holding additional stocks, there is an incentive to increase household stock levels (the reverse being true if prices are not increasing at a rate adequate to cover storage costs). The cost of holding urban household stocks is assumed equal to the commodity price times current interest rate.

$$DPUO_i(t) = RI(t)*PU_i(t) \tag{6.8}$$

where:

DPUO = cost of holding household grain stocks--won/bag-yr

RI = real interest rate--proportion/yr

PU = urban market price--won/bag.

The model calculates the rates of change in urban market prices, $\frac{d}{dt} PU_i(t)$, throughout time. These rates of change can be quite erratic, so they are smoothed to better indicate trends by the following equation.

$$UK5 \frac{d}{dt} DPUA_i(t) + DUPA_i(t) = \frac{d}{dt} PU_i(t) \tag{6.9}$$

where:

DUPA = smoothed version of rates of change in food grain prices, $\frac{d}{dt} PU_i(t)$--won/bag-yr

PU = current urban market prices--won/bag

UK5 = time constant parameter--yrs.

Given the current cost of holding household grain stocks and rate of change in market prices from Equations 6.8 and 6.9, the following calculation is used to generate the amount in which desired household stock levels are adjusted due to price change effects.

$$QUDB_i(t) = UK1*UK2 \left[\frac{DPUA_i(t)-DPUO_i(t)}{DPUO_i(t)} \right] UDEMD_i(t) \qquad (6.10)$$

where:

QUDB = component of desired urban storage level due to price change effects--MT

DPUA = average rate of change in market price--won/bag-yr

DPUO = cost of holding household grain stocks (i.e., threshold price change to account for holding costs)--won/bag-yr

UDEMD = current rate of consumption, assuming adequate household stocks are available (see Equation 6.14)--MT/yr

UK1 = response parameter, indicating percent change in demand per percent rate of price change--no units

UK2 = parameter, the reciprocal of which, 1/UK2, reflects the urban demand response rate for adjusting household stock levels toward desired levels (see Equation 6.3)--yrs.

The net desired urban household storage level (without regard to maximum storage capacity) is then generated by the following equation.

$$QUDU_i(t) = NSTORD_i(t) + ESTORD_i(t) + QUDA_i(t) + QUDB_i(t). \qquad (6.11)$$

(total) = (normal) + (emergency) + (price level) + (price change)

Maximum total household storage capacity is calculated over time by the following equation.

$$STCAP(t) = STMAX * \sum_i UDEMN_i(t) \qquad (6.12)$$

where:

STCAP = maximum capacity of urban household food grain storage--MT

STMAX = parameter used to specify maximum storage capacity--yrs

UDEMN = normal consumption rate at fixed prices equal to base period prices used in model run (see Equation 6.16)--MT/yr.

Finally, the following equation constrains the total desired storage level for all commodities to be less than, or equal to, maximum household storage capacity.

$$QUD_i(t) = \min \left\{ QUDU_i(t),\ STCAP * \left[\frac{QUDU_i(t)}{\sum_i WUDU_i(t)} \right] \right\} \qquad (6.13)$$

where:

QUD = constrained net desired household storage level--MT

QUDU = unconstrained net desired household storage level--MT

min = minimum function.

This completes the mathematical description of urban household storage, and household inventory management simulated by the urban subsector model. Next, the mathematical relationships used to generate urban consumption will be described.

Urban Consumption

A Cobb-Douglas type demand function is used to simulate urban food grain consumption.

$$UDEMD_i(t) = AUO_i(t) * \prod_{j=1}^{3} \left\{ PU_j(t)^{EUCP_{ij}(t)} \right\} \left[\frac{CONSU(t)}{UPOP(t)} \right]^{EUCI_i} * UPOP(t) \quad (6.14)$$

where:

UDEMD = current rate of urban food grain consumption demand--MT/yr

PU = urban market price--won/bag

EUCP = seasonal price elasticities of urban food grain consumption[3]

CONSU = total urban income--won/yr

UPOP = urban population--people

EUCI = income elasticity of consumption

AUO = constant term of Cobb-Douglas function.

The value of AUO_i of Equation 6.14 above is calculated at the beginning of the model run as follows.

$$AUO_i = UDEMN_i(t_o) \Big/ \left\{ \prod_{j=1}^{3} \left[PUA_j(t_o)^{EUCP_{ij}(t_o)} \right] \left[\frac{CONSU(t_o)}{UPOP(t_o)} \right]^{EUCI_i} * UPOP(t_o) \right\} \quad (6.15)$$

where, $UDEMN_i(t_o)$ and $PUA_j(t_o)$ are base period consumption and prices. With initial values specified for all the variables on the right-hand side of the above equation, this value of AUO_i forces the demand curve for each commodity through base period consumption rate and prices.

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[3]The reader will note urban price elasticities are indicated as functions of time. The same argument applies to these time-varying elasticities as that given for farm consumption elasticities. The reader can refer to the description of farm household consumption in Chapter 3 for a detailed discussion of time-varying elasticities used in the model.

As indicated in the description of urban household storage, the model calculates a "normal" consumption rate for use in generating the desired level of urban stock levels. The following equation indicates how this variable is calculated.

$$UDEMN_i(t) = AUO_i * \prod_{j=1}^{3} \left[PUA_j(t_o)^{EUCP_{ij}}\right]^{(t_o)} \left[\frac{CONSU(t)}{UPOP(t)}\right]^{EUCI_i} * UPOP(t) \quad (6.16)$$

where:

UDEMN = "normal" consumption rate at fixed prices equal to base prices used in model run--MT/yr

AUO = constant term of Cobb-Douglas function (see Equation 6.15)

PUA = base prices used for model initialization (annual average prices)--won/bag.

and the other variables in Equation 6.16 are defined earlier.

The reader will note that the normal consumption rate, $UDEMN_i(t)$ of Equation 6.16, varies only with changes in income and population. Urban (and farm) population levels are input to the model over time through table look-up functions. The value of consumer income, CONSU(t), is generated over time assuming user-specified rates of growth.

$$CONSU(t) = CONSU(t_o)\ EXP[RIG*t] \quad (6.17)$$

where:

CONSU = total urban consumer income--won/yr

EXP = exponential function (e=2.71828...)

RIG = assumed rate of income growth (user specified)--proportion/yr

t = simulation time clock--yrs.

An additional consumption behavior characteristic included in the design of the urban subsector model is the phenomenon of suppressed consumption due to low household food grain stock levels. Situations may arise where sufficient food grain supplies are not available (at any price) to urban households. In such a situation, when household stock levels are dwindling to critically low levels and cannot be replenished with additional purchases, it is reasonable to assume household consumption levels would be curtailed, even though market prices for food grain may not bring about such a reduction in consumption demand. Therefore, the concept of actual food grain consumption (along with food grain consumption demand of Equation 6.14) based on household inventory stock levels is expressed in the model. The function used for suppressing consumption demand is illustrated in Figure 6.3. The ordinate value of the function ranges from zero

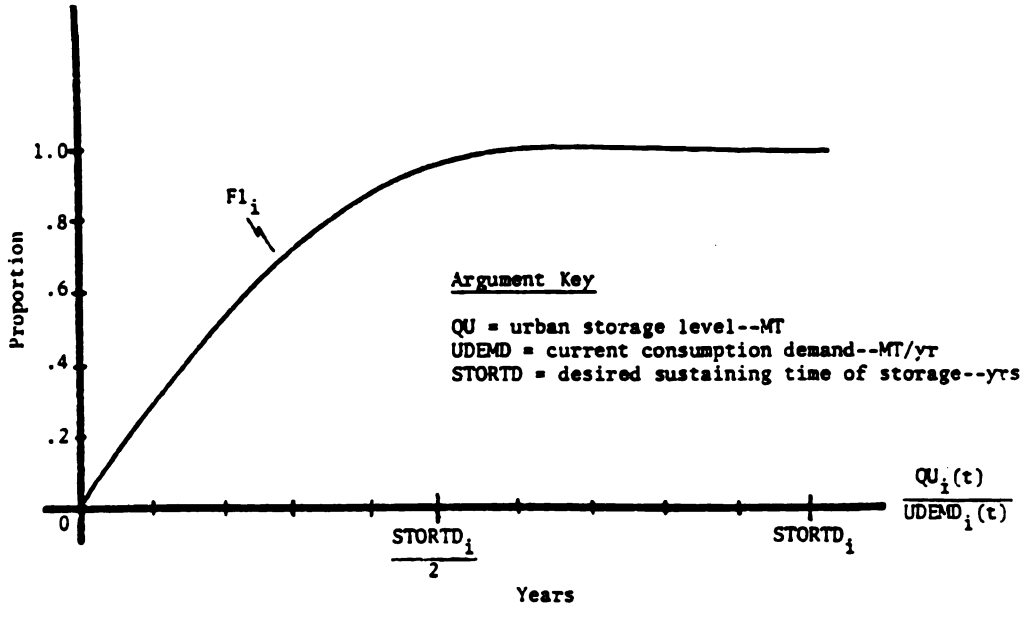


Figure 6.3. Urban Household Consumption Constraint Function.

to one. The argument of the function expresses the length of time current urban household inventory level could sustain current normal urban consumption demand. The actual values of the function are, of course, unknown. Values indicated in the figure represent starting "guestimates" used in the model. Sensitivity testing can indicate the importance of accurate values of this function on model results and, thus, the need for further research in determining its true character.

Using the constraining function of Figure 6.3 on the current rate of consumption demand from Equation 6.14, we have

$$UDEMC_i(t) = Fl_i(t)*UDEMD_i(t) \qquad (6.18)$$

where:

UDEMC = current actual rate of urban food grain consumption--MT/yr

Fl = urban consumption constraining function--proportion

UDEMD = current rate of urban food grain consumption demand (see Equation 6.14)--MT/yr.

Urban Nutrition

Urban nutrition and nutritional deficits are calculated in the urban subsector model. These outputs may be of interest to decision makers in analyzing the impacts of various grain management programs, but become of critical importance when using the model to study problems arising from acute food grain shortages. Concepts and equations used in the urban subsector nutrition component described here are based heavily on recent work by Manetsch [33].

Required food grain intake is computed as follows.

$$RUNUT(t) = GRPP*UPOP(t)*1000 \tag{6.19}$$

where:

RUNUT = required urban food grain consumption--MT/yr

GRPP = total food grain required per person (rice, barley, and wheat)--kg/capita-yr

UPOP = urban population--persons.

Total food grain consumption is calculated by the following summation.

$$TGC_i(t) = \sum_{i=1}^{3} UDEMC_i(t) \tag{6.20}$$

where:

TGC = total food grain consumption--MT/yr

UDEMC = current actual rate of food grain consumption (see Equations 6.18 and 6.14)--MT/yr.

Rice, barley, and wheat all have nearly the same nutritional value; therefore, discounting factors are not required in calculating total food grain consumption.

The accumulated nutritional deficit is calculated as

$$ANUTDP(t) = 1000 \int_{t_o}^{t} \left[\frac{RUNUT(\tau) - TGC(\tau)}{UPOP(\tau)} \right] d\tau \tag{6.21}$$

where:

ANUTDP = accumulated urban nutritional deficit per capita--kg/capita-yr[4]

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[4] It should be pointed out that this model of malnutrition and resultant expected death rates is based on the assumption of an increasing food shortage (ANUTDP increasing); therefore, it simulates a once-only food crisis. The model becomes invalid if food supplies become abundant and ANUTDP begins to decrease.

RUNUT = required urban food grain consumption--MT/yr

TGC = total food grain consumption--MT/yr

UPOP = urban population--people.

Deaths due to malnutrition in the event of an acute food shortage can be related to the accumulated food grain deficit per capita. One formulation that makes sense from a physiological point of view is to relate the probability of death by malnutrition to the variable ANUTDP. A cumulative distribution function relating these variables is illustrated in Figure 6.4.

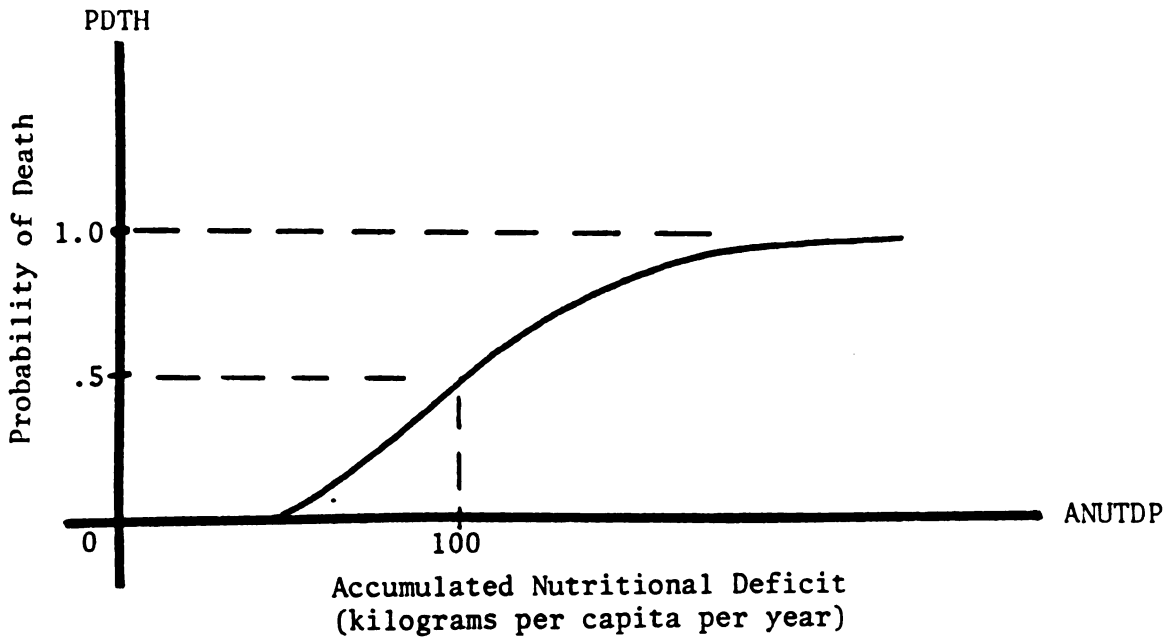


Figure 6.4. Death Probability Vs. Accumulated Nutritional Deficit.

The probability distribution function indicated in Figure 6.4 represents only an experimental "guestimate." If serious studies were undertaken in this area, concentrated efforts would be required to develop a more accurate estimate of the actual death probability distribution for Korea. Past studies in the area of human malnutrition do indicate that such a probability function can be estimated [21].

Assuming that ANUTDP is monotonically increasing, we can write the following relationships.

$$\Pr\{\text{Death} \mid A<\text{ANUTDP}<A+a\} = \text{PDTH}(A+a) - \text{PDTH}(A) \tag{6.22}$$

or,

$$\Pr\{\text{Death} \mid t_o < t < t_o + \Delta t\} = \text{PDTH}[\text{ANUTDP}(t_o+\Delta t)] - \text{PDTH}[\text{ANUTDP}(t_o)] \tag{6.23}$$

and, therefore,

$$\text{DTHS}(t) = \{\text{PDTH}[\text{ANUTDP}(t)] - \text{PDTH}[\text{ANUTDP}(t_o)]\}\text{POPU}(t) \tag{6.24}$$

where:

DTHS = deaths in period (t_o,t) due to malnutrition--people

PDTH = probability of death as function of accumulated nutritional deficit (Figure 6.4)

ANUTDP = average nutritional deficit per capita--kg/capita-yr

UPOP = urban population--people.

Since urban population is input into the model exogenously throughout the model run, the following adjustments must be made in population data, if using the model to study food crisis situations.

$$\underset{\text{(model)}}{\text{UPOP}(t)} = \underset{\text{(data)}}{\text{UPOP}(t)} - \text{DTHS}(t). \tag{6.25}$$

Migration out of urban areas due to malnutrition can also be reflected in the model, representing people moving to rural areas to seek food.

This concludes the mathematical description of the urban subsector component of the GMP model. All four subsector models (farm, private market, government, and urban) have now been described in

mathematical terms. The following chapter will describe precisely how these components are linked together to operate as an integrated system model.

CHAPTER 7

PRICE AND TRANSACTION MECHANISM (PAT)

Introduction

The price and transaction (PAT) mechanism of the GMP model performs two major functions: (1) the generation of farm and urban market prices, and (2) the calculation of actual food grain transactions occurring in farm and urban markets over time. In performing these two functions, the PAT mechainsm serves as the primary linkage among the four subsector models (farm, urban, private market, and government), tying them together into an integrated system model.

A general description of the PAT mechanism was provided in Chapter 2 under the section titles Subsector Linkage and Market Prices. To avoid repetition, the reader is referred to those sections of Chapter 2. In this chapter, the mathematical details of the PAT mechanism will be described.

Market Price Dynamics

Farm and urban market price dynamics are generated by comparing food grain demand and supply in each market over time. Excess market demand over market supply causes an upward pressure on market prices, whereas excess market supply over market demand causes a downward pressure on market prices. The mathematical relationships used to generate market food grain demand and supply coming from each subsector have already been described in the previous four chapters. To ease reference, Table 7.1 will direct the reader to the specific equations

Table 7.1. Market Supply and Demand Equation References.

		Description	Variable Name	Reference Equation
Market	Farm	Farm market supply	$FMKTS_i(t)$	3.32, 3.33, 3.36, 3.37
		Government demand	$GDEM_i(t)$	5.28, 5.37, 5.42
		Private market demand	$PDEM_i(t)$	4.1, 4.3
	Urban	Government supply	$GMKTS_i(t)$	5.29, 5.41, 5.43
		Private market supply	$PMKTS_i(t)$	4.2, 4.4
		Urban consumer demand	$UDEM_i(t)$	6.2

used to generate market supplies and demands from each subsector.

The following equations describe the dynamics of farm and urban market prices generated by the GMP model.

(Farm prices)

$$\frac{d}{dt} PF_i(t) = A10_i + F11_i(t)\left[\frac{TDEM_i(t)-FMKTS_i(t)}{TDEM_i}\right] PF_i(t) \tag{7.1}$$

$$TDEM_i(t) = PDEM_i(t)+GDEM_i(t) \tag{7.2}$$

$$F11_i(t) = \left[\frac{A11_i*PDEM_i(t)+(1-A11_i)GDEM_i(t)}{TDEM_i(t)}\right] *A12_i \tag{7.3}$$

(Urban prices)

$$\frac{d}{dt} PU_i(t) = A20_i + F21_i(t)[UDEM_i(t)-TMKTS_i(t)]PU_i(t) \tag{7.4}$$

$$TMKTS_i(t) = PMKTS_i(t)+GMKTS_i(t) \tag{7.5}$$

$$F21_i(t) = \left[\frac{A21_i * PMKTS_i(t) + (1-A21_i)GMKTS_i(t)}{TMKTS_i(t)}\right] * A22_i \qquad (7.6)$$

where, for the farm price equations:

PF = farm market price--won/bag

TDEM = sum of private market and government demands for domestic food grains--MT/yr

PDEM = private market food grain demand--MT/yr

GDEM = government demand for domestic food grains--MT/yr

FMKTS = farm marketings, farm market supply--MT/yr

F11 = time-varying parameter that determines farm market price response to market demand and supply disequilibrium--$\frac{\text{proportion/yr}}{\text{proportion}}$

A10 = constant term used to incorporate general price change trends into farm market price equation--won/bag-yr

A11 = weighting term that reflects the relative influence of private market demand and government demand in farm market price dynamics ($0 \leq A11 \leq 1$)--no units

A12 = tuning parameter for farm market price dynamics--appropriate units

and, for the urban price equations:

PU = urban market retail prices--won/bag

TMKTS = sum of private market and government urban market supply--MT/yr

GMKTS = government marketings (releases)--MT/yr

PMKTS = private marketings--MT/yr

UDEM = urban market consumer demand--MT/yr

F21 = time-varying parameter that determines urban market price response to market demand and supply disequilibrium--$\frac{\text{proportion/yr}}{\text{proportion}}$

A20 = constant term used to incorporate general price change trends into urban market price equation--won/bag-yr

A21 = weighting term that reflects the relative influence of private market demand and government demand in urban market price dynamics ($0 \leq A21 \leq 1$)--no units

A22 = tuning parameter for urban price dynamics--appropriate units.

The reader will note the similarity between the farm and urban market price equations. Because of this, the following discussion will deal primarily with the farm price equations only; a similar discussion can be deduced for the urban price equations.

Price Trends

With the exception of accounting calculations, the GMP model works with real prices rather than money prices. Farm price series are adjusted by the wholesale price index excluding grains, and urban price series are adjusted by the consumer price index excluding cereals. A large portion of the inflationary trend of money prices has been removed by these price series adjustments; however, inflation due to food grain prices is still inherent in the adjusted price series. The trend terms A10 and A20 are provided in Equations 7.1 and 7.4, respectively, to account for general price trend in whatever series is being simulated.

Price Adjustments

The second term on the right-hand side of Equation 7.1 (and 7.4) indicates how market price adjusts to disequilibrium between market demand and supply. Noting that the time-varying parameter F11 (and F21) is always non-negative, it can be seen that excess market demand causes an upward influence on prices, while excess market supply causes a downward influence on prices. The bracketed term $[1-FMKTS_i(t)/TDEM_i(t)]$ of Equation 7.1 represents the proportional

difference between market demand and supply. Given the structure of the equation, $F11_i(t)$ can therefore be defined as a 'dynamic' elasticity (or flexibility) of market price to net market demand. That is, $F11 = \frac{\Delta PF/\Delta t}{PF} \frac{\Delta Q}{Q}$, where $\Delta Q/Q$ is defined as the bracketed term $[1-FMKTS_i(t)/TDEM_i(t)]$ of Equation 7.1.

The model recognizes the possibility that demand and supply from government and private subsectors may have different degrees of influence on market price dynamics. That is, in Equation 7.1 private demand may have a greater effect on farm prices than an equal amount of government demand, or vice versa. The bracketed terms in Equations 7.3 and 7.6 for $F11_i(t)$ and $F21_i(t)$, respectively, give this weighting influence to government and private market demand and supplies. The range of these terms may vary from zero to one. For convenience these terms will be called market price flexibility dampers. Table 7.2 below gives some values of the bracketed term of Equation 7.3 for various combinations of private demand (PDEM), government demand (GDEM), and the weighting factor (A11).

Table 7.2. Farm Market Price Flexibility Damping Term -- Sample Values.

PDEM	GDEM	A11				
		0	.2	.5	.8	1.0
		$[A11_i*PDEM_i+(1-A11)*GDEM_i]/TDEM_i$				
0	100	1.0	.8	.5	.2	0
20	80	.8	.68	.5	.32	.2
50	50	.5	.5	.5	.5	.5
80	20	.2	.32	.5	.68	.8
100	0	0	.2	.5	.8	1.0

Finally, the parameters $A12_i$ and $A22_i$ of Equations 7.3 and 7.6, respectively, can be defined as the unadjusted 'dynamic' market price flexibilities; that is, the proportional change in market price (per unit time) per unit of proportional difference (disequilibrium) between market demand and supply.

Grain Market Transactions

The grain market transaction mechanism operates in the farm and urban consumer markets. On the farm market side, government and private market demands for grains are interfaced with farm marketings. Free market decisions of farmers to market into either the private or government sectors are reflected in the mechanism. These choices depend on the relative levels of government and private market demands, the relative buying prices being paid by the government and private market subsectors, and the relative convenience to the farmer in marketing into each of these subsectors. Actual grain transactions then occur so that total farm sales during any period of time are equal to total government and private market domestic grain purchases.

On the urban consumer market side, grain marketings from the private and government subsectors are interfaced with urban consumer market demands for grains. Free market decisions of urban consumers to buy from either the private or government subsectors are reflected in the mechanism. These choices depend on the relative levels of government and private grain marketings, the relative selling prices of government and private market grains, and also on the relative quality of government and private market grains. Actual grain transactions then occur so that total government and private grain

sales during any period of time are always equal to total urban consumer purchases.

The transaction mechanism contains parameters which can be altered to reflect government countermeasure policies designed to suppress normal free market decisions of farmers and urban consumers in choosing between private and government markets.

Farm Market Transactions

The equations which describe grain transactions in the farm and consumer markets are fairly straightforward. On the farm market side, private market purchases, government purchases, and farm sales are given by the following three equations.

$$PPUR_i(t) = \min[PDEM_i(t), GFMCMP_i(t)*PFMP_i(t)*FMKTS_i(t)] \quad (7.7)$$

$$GPUR_i(t) = \min\{GDEM_i(t), [1-GFMCMP_i(t)*PFMP_i(t)]*FMKTS_i(t)\} \quad (7.8)$$

$$FSLS_i(t) \triangleq PPUR_i(t) + GPUR_i(t) \quad (7.9)$$

where:

PPUR = private market grain purchases--MT/yr

PDEM = private market grain demand--MT/yr

GFMCMP = government farm marketing countermeasure policy parameters ($0 \leq GFMCMP \leq 1$)--no units

PFMP = propensity of farmers to market into the private market subsector under existing market conditions ($0 \leq PFMP \leq 1$)--no units

FMKTS = farm commercial grain marketings--MT/yr

GPUR = government grain purchases--MT/yr

GDEM = government demand for domestic grains--MT/yr

FSLS = farm sales of grains--MT/yr.

Equation 7.7 above indicates that actual private market grain purchases are calculated as the minimum of either private market demand for grains *or* the portion of total farm marketings offered to the private market subsector. The natural propensity for farmers to market their grains into the private subsector is described by the parameter PFMP. This parameter varies between zero and one and is influenced by relative prices paid to farmers by the private and government subsectors, relative levels of demands, etc. PFMP will be discussed later in more detail. The parameter GFMCMP is included in the above transaction equations to reflect government policies which are designed to influence free market choices by farmers. For example, in certain emergency situations, it may be thought necessary for the government to prohibit farm grain dealings with the private market altogether. In such cases GFMCMP would be set to zero and all farm marketings would enter into the government subsector. The impacts of such policies could then be measured by the model. Normally, GFMCMP is set equal to one, reflecting no action by the government to influence farmers' free market choices. The explanation of Equation 7.8 above follows directly from that of Equation 7.7. Equation 7.9 is an identity which assures that total farm grain sales are always equal to private market and government domestic grain purchases.

The farm market transaction equations so far have reflected free market choices by farmers to market into the private and government subsectors. However, after the initial transactions are finished, the possibility of secondary transactions may exist. Such a situation occurs whenever farm marketings exceed farm sales *and* an excess demand

exists (after the initial transactions) from either the private *or* government subsectors. These secondary transactions are reflected by the following equations for the government and private subsectors, respectively.

$$GPUR_i'(t) = GPUR_i(t) + \min[EGD_i(t), FMKTS_i(t)-PPUR_i(t)-GPUR_i(t)] \quad (7.10)$$

$$PPUR_i'(t) = PPUR_i(t) + \min[EDP_i(t), FMKTS_i(t)-PPUR_i(t)-GPUR_i(t)]. \quad (7.11)$$

In these secondary farm market transaction equations, the excess demands existing in the government or private subsectors are calculated after the initial transactions simply as follows.

$$EGD_i(t) = GDEM_i(t)-GPUR_i(t) \quad (7.12)$$

$$EPD_i(t) = PDEM_i(t)-PPUR_i(t). \quad (7.13)$$

Note that the second argument in the minimum functions in Equations 7.10 and 7.11 is the expression for excess farm marketings after the initial transactions are completed. The identity of Equation 7.9 must also hold after secondary transactions are completed.

Urban Market Transactions

On the urban consumer market side, the government and private subsectors are competing for grain sales. In this market, the urban consumer household normally enjoys the free market option of buying either government or private market grains. Initial transactions reflecting this free market choice pattern are given by the following equations.

$$PSLS_i(t) = \min[PMKTS_i(t), GUDCMP_i(t)*PUDP_i(t)*UDEM_i(t)] \quad (7.14)$$

$$GSLS_i(t) = \min\{GMKTS_i(t), [1-GUDCMP_i(t)*PUDP_i(t)]*UDEM_i(t)\} \quad (7.15)$$

$$UPUR_i(t) \triangleq PSLS_i(t)+GSLS_i(t) \quad (7.16)$$

where:

PSLS = private market grain sales--MT/yr

PMKTS = private market grain marketings--MT/yr

GUDCMP = government urban consumer market countermeasure policy parameter ($0 \leq GUDCMP \leq 1$)--no units

PUDP = propensity of urban households to buy grains from the private subsector under existing conditions ($0 \leq PUDP \leq 1$)--no units

UDEM = urban market demand for grains--MT/yr

GSLS = government grain sales--MT/yr

GMKTS = government grain marketings (releases)--MT/yr

UPUR = urban consumer purchases of grains--MT/yr.

Equation 7.14 above indicates that actual private market grain sales are calculated as the minimum of either private marketings *or* the portion of urban demand for grains from the private marketing subsector. The natural propensity for urban households to buy grains from the private market is described by the parameter PUDP. This parameter varies between zero and one and is influenced by relative selling prices of private and government grains, the relative marketings (availability) from each of the subsectors, relative grain qualities, etc. PUDP will be discussed later in more detail. The parameter GUDCMP is included in the urban market initial transaction equations to reflect government policies which are designed to influence the free market choices of urban households. For example, the requirement that school children carry mixed grains (rice and barley) in their lunches is such a countermeasure policy because it encourages urban

households to buy more government (mixed) grains. Normally GUDCMP is set to one, reflecting no extraordinary action by the government to influence free market choices of urban consumers. Government grain sales transactions in Equation 7.15 above follow from the same concepts as private grain sales just described. Equation 7.16 is an identity which assures that total urban grain purchases are equal to private and government grain sales.

The possibility of secondary transactions in the urban consumer market exists whenever urban grain demand is not fully satisfied *and* there exists an excess of (intended) marketings in either the private *or* government grain channels. These secondary transactions are indicated by the following equations for government and private market sales, respectively.

$$GSLS_i'(t) = GSLS_i(t) + \min[GMKTS_i(t)-GSLS_i(t),EUDP_i(t)] \quad (7.17)$$

$$PSLS_i'(t) = PSLS_i(t) + \min[PMKTS_i(t)-PSLS_i(t),EUDG_i(t)]. \quad (7.18)$$

In these secondary transaction equations, the first arguments in the minimum functions are the excess government and private grain marketings. The second arguments in the minimum functions are the excess urban demands remaining for government and private grains after the initial transactions are completed.

$$EUDP_i(t) = GUDCMP_i(t)*PUDP_i(t)*UDEM_i(t) - PSLS_i(t) \quad (7.19)$$

$$EUDG_i(t) = [1-GUDCMP_i(t)*PUDP_i(t)]*UDEM_i(t) - GSLS_i(t). \quad (7.20)$$

Equation 7.16 must still hold after secondary transactions are completed.

This completes the discussion of the "mechanics" of the farm and urban consumer market transaction mechanism. As can be seen from the mathematical description, the mechanism functions only to account for the actual amount of grain changing hands in the farm and urban marketplaces. Less evident from the above equations are the (internal) parameters which describe free market choices of farmers and urban consumers, i.e., $PFMP_i(t)$ and $PUDP_i(t)$. These parameters will now be described in more detail.

Free Market Choice Patterns (PFMP and PUDP)

Normally farmers and urban consumers are free to choose between private and government channels in their grain dealings. Two endogenously determined parameters are incorporated into the GMP model which reflect these free market choice patterns. In the farm marketplace, PFMP is the proportion of total farm marketings available to the private market subsector, and 1-PFMP is the proportion of total farm marketings available to the government subsector. In the urban consumer marketplace, PUDP is the proportion of total urban demand for grains from the private market, and 1-PUDP is the proportion of total urban demand for grains from the government subsector.

When the government is not active in either the farm or urban markets, the corresponding PFMP or PUDP are equal to one. That is, if the government is not buying grain, all farm marketings will go to the private subsector. Similarly, if the government is not selling grain, all urban demand will be for private market grains. Of course, the government can change the level of its grain market activities very rapidly. It is unrealistic to assume that farmer and consumer choice patterns can always change as rapidly; therefore, PFMP and PUDP

should reflect a somewhat delayed response to changing market situations. Mathematically, the situations in which the government is inactive in either the farm or urban markets are represented by the following equations.

$$PFMPU_i(t) = 1 \quad , \text{ if } GDEM_i(t) = 0 \tag{7.21}$$

$$PUDPU_i(t) = 1 \quad , \text{ if } GMKTS_i(t) = 0 \tag{7.22}$$

The more realistic lagged versions of these equations are given as follows.

$$\frac{d}{dt} PFMP_i(t) = \frac{1}{DEL41} [PFMPU_i(t)-PFMP_i(t)] \tag{7.23}$$

$$\frac{d}{dt} PUDP_i(t) = \frac{1}{DEL42} [PUDPU_i(t)-PUDP_i(t)]. \tag{7.24}$$

where:

PFMP,U = lagged and unlagged propensity for farmers to market grains into the private subsector--no units

PUDP,U = lagged and unlagged propensity for urban consumers to buy private market grains--no units

DEL. = delay parameters--yrs.

When the government is active in the marketplaces, the private and government subsectors are competing for farm marketings and urban demands. Some of the important factors which influence farmer and urban consumer free market choices (excluding government special countermeasure policies) are listed below.

(Farm market)

F1) Relative levels of government and private market demands for domestic food grains.

F2) Relative differences in government and private market buying prices.

F3) Relative convenience to farmers of marketing into government versus private market channels.

(Urban market)

U1) Relative levels of government and private grain marketings (availability).

U2) Relative selling prices of government and private grains.

U3) Relative differences in quality between government and private grains.

The mathematical forms used to represent the combination of these factors in influencing farmer and urban consumer free market choices are indicated below.

$$PFMPU_i(t) = B41A_i * F1_i(t) * F2_i(t) \tag{7.25}$$

$$PUDPU_i(t) = B42A_i * U1_i(t) * U2_i(t) * U3_i(t) . \tag{7.26}$$

This product form of combining the farmer and urban consumer free market choice factors enables the model designers to make use of a good deal of intuition in the initial specifications of these choice patterns. Of course, rigorous optimization techniques can be used in parameterizing these equations when time permits, but much can be done to reflect reality before the more formal tuning techniques are applied.

Basic to each of the free market choice equations are the factors $F1_i(t)$ and $U1_i(t)$ reflecting the relative levels of market activities of the government and private market subsectors in the farm and urban marketplaces. Bearing in mind that these factors are by definition isolated from other influences on market choices (such as

price differences, relative conveniences of the markets, quality differences, and so forth), the following direct relationships make a lot of sense for these two factors.

$$Fl_i(t) = PDEM_i(t)/(PDEM_i(t)+GDEM_i(t)) \quad (7.27)$$

$$Ul_i(t) = PMKTS_i(t)/(PMKTS_i(t)+GMKTS_i(t)) \quad (7.28)$$

where:

PDEM = private market grain demand--MT/yr

GDEM = government grain demand--MT/yr

PMKTS = private market grain marketings--MT/yr

GMKTS = government grain marketings--MT/yr.

It can be seen that $Fl_i(t)$ and $Ul_i(t)$ take on values over a range from zero to one. Equal levels of marketing activities in the private and government subsectors would result in values of .5 for these factors, meaning that farm marketings and urban demands would be split evenly between the two markets. As market activity of one subsector begins to outweigh that of the other, farmer and urban consumer choices are shifted toward the more active market. In the case where a government grain buying program ends abruptly, say, on a specific date, $Fl_i(t)$ becomes one immediately, reflecting a sudden shift in farm marketing patterns. Of course, as mentioned earlier, distributed lags are utilized in calculating these free market choice patterns to lend more realism to what actually occurs.

In the case of relative differences between private market and government buying and selling prices, the following rationale is used. Given an existing market situation in which other non-price related

choice factors are considered, equal government and private market prices should bring about no changes in free market choice patterns. This assumption is reflected in the following equations for the factors $F2_i(t)$ and $U2_i(t)$ of Equations 7.25 and 7.26.

$$F2_i(t) = 1 + B41B_i * [PF_i(t)/PB_i(t)-1] \quad (7.29)$$

$$U2_i(t) = 1 + B42B_i * [PS_i(t)/PU_i(t)-1] \quad (7.30)$$

where:

PF = private market price received by farmers--won/bag

PB = government buying price--won/bag

PU = private market retail price--won/bag

PS = government selling price--won/bag.

Each of these expressions for $F2_i(t)$ and $U2_i(t)$ is equal to one when private market and government prices are equal. Thus the values for free market choices, $PFMPU_i(t)$ and $PUDPU_i(t)$ of Equations 7.25 and 7.26, remain unchanged under these conditions. The two parameters $B41B_i$ and $B42B_i$ in the equations describe how free market choices change with relative differences in market prices. Values close to one for these parameters seem a logical starting point for tuning and testing these relationships.

The relative convenience to farmers of marketing into the government and private market channels is reflected implicitly in Equation 7.25 by the parameter B41A. This parameter not only contains the relative convenience factor, but also any other factors which have not been included explicitly into the farm free market choice

equation. A value of one for this parameter is a logical starting point for tuning and testing purposes.

Finally, the relative differences in quality between government and private market grains can be included as a factor influencing urban consumer free market choices. The relative amounts of Tongil rice varieties in government and private market inventories can be used as such an indicator of quality differences. The following relationship holds with it the assumption that equal mix ratios of ordinary and Tongil varieties in each market result in no changes in consumer free market choice patterns.

$$U3_1(t) = B42C_1[QTG(t)/QG_1(t)-QTPM(t)/QPM_1(t)] + 1 \qquad (7.31)$$

where:

$U3_1$ = urban consumer free market choice factor reflecting the effect of quality differences of private market and government grains (rice only)

QTG = amount of Tongil rice in government inventory--MT

QG_1 = total government rice inventory--MT

QTPM = amount of Tongil rice in private market inventory--MT

QPM_1 = total private market rice inventory--MT

$B42C_1$ = parameter which describes how urban consumer free market choices are influenced by relative quality differences.

In the area of quality differences such as with $U3_1(t)$ above, some extra caution must be used since so little is known about the relationship. This constraint on current knowledge, however, should not preclude its representation in the model. Much can be learned about the importance of grain quality differences through sensitivity testing.

CHAPTER 8

CREDIBILITY

Introduction

Confidence in a system simulation model such as the GMP does not manifest itself automatically but, rather, is the product of concerted efforts throughout the system design process and beyond. Testing is the word used widely to describe efforts to determine and demonstrate the presence of model quality, and testing is the means by which the system design process is perpetuated. All forms of scrutiny, review, and examination of the model throughout its history can be interpreted as testing--from examining the basic assumptions underlying the model design to determining the effectiveness of the operational model after it is incorporated into the real world decision-making process.

Much has been written in the literature regarding the philosophy of model testing, providing grounds upon which both optimistic and pessimistic viewpoints can be founded [38, 39]. The purpose of this chapter is neither to argue a particular philosophical viewpoint on model testing nor to produce rhetoric in an attempt to "sell" the integrity of the GMP model. This chapter will attempt to give an objective review of some of the actual credibility testing to which the GMP model has been subjected throughout its development, leaving each reader free to form his or her own opinions. Let it be said

again before we begin that model improvement is perpetuated by criticism, not by compliment.

Credibility testing of the GMP model has generally followed the approach described in the final KASS report [41]. Certain qualities are desirable in system simulation models such as KASS and GMP models, and credibility of a model can largely be established by evidence of the presence of these qualities. Four popular qualities are coherence, correspondence, clarity, and workability. Coherence is demonstrated by the presence of logical consistency in the model concept, in the mathematical relationships defining the model concept, and in the computerized program used to calculate solutions to the mathematical model. Correspondence is evidenced by the ability of the model to accurately reflect the real world situation or phenomena it is intended to represent. Validation and verification, respectively, are often used as descriptives for efforts (tests) aimed at establishing the qualities of coherence and correspondence of a model. Clarity is a desirable model quality because models must be used in conjunction with human intellect. Credibility or confidence in a model cannot be established if model concepts or results cannot be explained and understood by model users. Hocus-pocus model results are not likely to gain much credibility with responsible decision makers if the results cannot be explained or, if explained, cannot be comprehended. Workability is the ultimate quality desired in a model such as the GMP. This quality is evidenced when use of the model in the decision-making process results in better and more effective management of food grains than would be realized without the model.

This chapter will be devoted mainly to documentation of some of the more important validation, parameterization, and verification efforts performed on the GMP model. Evidence will be given that the GMP model is a computable simulation model. Selected computer results from test runs of the model will be used to verify this fact and to exhibit the kinds and forms of information supplied by the current operational GMP model. The qualities of clarity and workability are difficult to document but will be given some comment in Chapter 9.

Validation

Tests of logical consistency are basic requirements throughout the model development process and cover a broad range of considerations. The term validation is often used to describe efforts to establish model credibility in terms of logical consistency (or coherence). Since the computerized system simulation model is the end product of (1) the basic system conceptualization, (2) the mathematical model used to precisely define the system concept, and (3) the computer program used to approximate solutions to the mathematical model, all three of these iterative stages of model design must be subjected to validation tests. Full treatment of all aspects of validation testing undergone during GMP development would be superfluous and require an unwarranted quantity of text. The discussion here must be limited to a general description of some of the important efforts made during the various stages of model development. Selected examples will be given to bring realism to the discussion and keep the focus on the GMP model.

System Concept

The basic conceptualization of the GMP model was presented in Chapter 2, with little or no mention of mathematics or computerization required. Chapter 1 was devoted to describing the general need for the GMP model by reviewing the grain management problem in Korea, and Chapter 2 was devoted to a general nonmathematical description of the GMP model concept, proposed as an approach to solving (or at least reducing) the grain management problem. It should be evident upon reviewing these first two chapters that the design of the GMP is not what might be expected on a first pass at a system simulation model of this type but, rather, the product of many iterations of the system design process [4]. Every aspect of the model concept--from the underlying assumptions, the statement of model objectives, and identification of relevant problem issues--to decisions regarding the level of system disaggregation, variables to be included, output design, and methodology used--has been subjected to intense scrutiny through the interaction of model designers, grain management specialists, and potential model users.

Several examples could be cited in which the basic model concept has been formally and informally subjected to validation testing of this type. The results of these tests have been the identification of logical inconsistencies (in the form of basic design, omissions of detail, or presence of unwarranted detail) resulting in design changes or refinements. As the iterative process continued, more acceptance and understanding of model concepts was established, resulting in improved model credibility at the basic levels of design. A formal evaluation of the GMP model [40] completed in 1974 by the Food and

Feed Grain Institute at Kansas State University provides a good example of formal validation testing of the GMP model at the system conceptualization level. By reviewing the development status of the GMP model and its components, as documented in the above report and in others [15, 16] at that time, noting the criticisms given as a result of the evaluation, and comparing this with the current version of the GMP model being documented in this dissertation, the evolutionary process of GMP model design is clearly evidenced.

Mathematical Model

The mathematical equations and relationships used to structure the GMP model concept have also been subject to rigorous validation testing throughout development. These tests generally consist of critical reviews and consultations with systems specialists. System diagrams have proved to be a very effective means of communicating model concepts and mathematical relationships. These diagrams depict the GMP system in symbolic form, much like schematic diagrams of physical systems. Some of the system diagrams presented in earlier chapters may be fifth or sixth generations of the original component designs, again reflecting the evolutionary nature of the model design through validation testing. Figure 8.1 represents an early system diagram of the government operations subsector taken from an early status report of the model [16]. Comparison of this diagram with Figure 5.4, which is a system diagram of the same subsector, gives concrete evidence of the changes in conceptualization and mathematical structure which have occurred in the GMP model due to validation testing. Validation of the mathematical structure of the model can proceed only so far, however, without computerization.

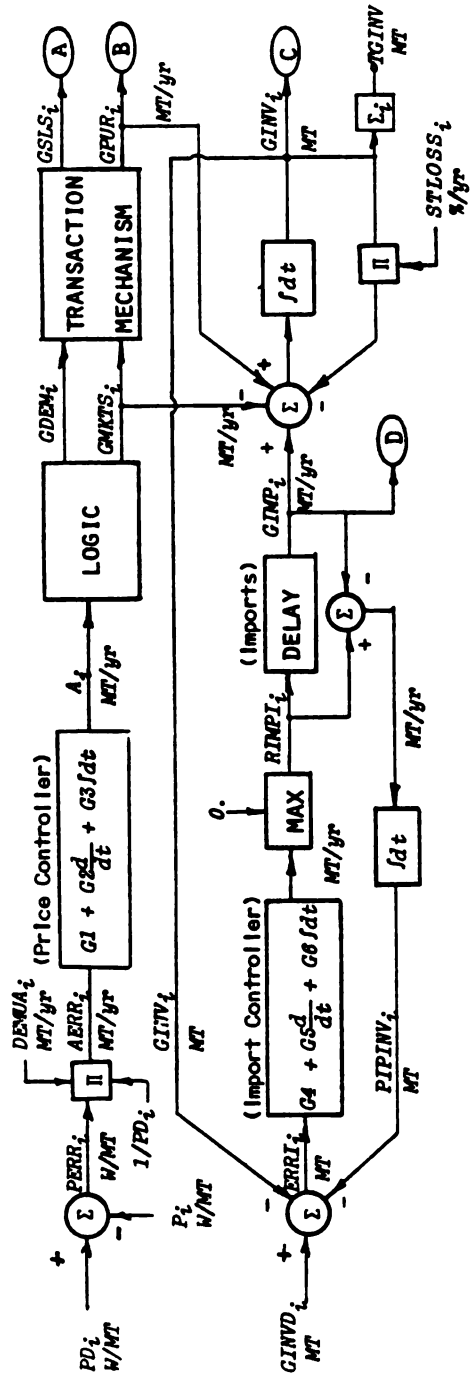


Figure 8.1. Early System Diagram--Government Operations.

Computer Model

The mathematical model must be programmed for solution on a digital computer. Since the model is dynamic, numerical integration techniques must be employed to arrive at solutions for the many differential equations. Choices of a particular numerical integration technique and size of the solution increment must be validated for required accuracy and stability. Euler integration and a solution increment DT of .005 (1/200) year have proven to be valid choices for the GMP model in most instances [30].

Debugging activity on a computer model the size of the GMP is not a trivial task. The general approach was to computerize and debug (validate) each component of the computer model separately, providing internal linkage variables among components exogenously to the individual component. Considerable verification testing was also accomplished on each component using this approach. For example, providing empirical market prices to the consumption models of the farm and urban subsector components greatly eased the validation and verification efforts on the computer model. Later, as the individual subsectors were brought into operation, the entire model was linked through internally generated prices and grain transactions.

The computer model not only is responsible for providing solutions to the mathematical model, but is also responsible for presenting model solutions in useful and convenient forms. Output design is an integral part of the computer model and must be validated through interaction with potential model users. Numerous samples of model output design are illustrated in this chapter and in Appendix A.

Many inconsistencies in the mathematical relationships of the model, oftentimes very subtle in nature, are uncovered as the model is tested on the computer. System stability, for example, is affected by a number of factors, including mathematical structure. Many instability problems with the GMP model were evidenced only after computer testing of the model. Changes in mathematical structure played an important part in solving many of these instability problems. A concrete example of where changes in mathematical structure have aided in stability can be found in the inventory control mechanisms. The superposition of a mean flow signal on inventory controller outputs (as documented in Chapters 4 and 5) precludes physical logic constraints (i.e., nonreversed flows, etc.) from interfering with the acceptable range of control signals. This structural refinement proved very effective in arriving at model stability.

Logical consistency checks are made on the computer program and mathematical structure on nearly all computer runs. During initial testing phases, virtually all variables (including internal variables) are monitored and validated for logical consistency. Special test experiments are often purposely programmed into the computer model to check for valid behavior of the system. Forcing inventories to go to zero, placing impulse and step functions on controller reference signals, and many other radical measures to "shake" the system prove very effective in identifying logical inconsistencies. Conservation of flow checks, made by eliminating all losses in the system, can also reveal many inconsistencies and structural errors. Table 8.1 gives test results over a one-year period of a model run and demonstrates some important logical consistency checks on food grain

Table 8.1. Logical Validation--Inventories and Flow (Rice CY1975).

Subsector	Inventories*		Inventory Change†	Flow Accumulations§				
	Carry-in (-)	Carry-out (+)	(=)	Domestic Purchases (+)	Imports (+)	Domestic Sales (-)	Consumption¶ (-)	Production** (+)
	1000 metric tons							
Farm	3374	3449	75			[2142]	1861	4078
Private	653	490	-163	[1621		[1784		
Government	890	1376	486	521]	483	518]		
Urban	38	48	10	[2302]			2292	
Total	4955	5363	408	[4444]	483	[4444]	4153	4078

* Inventories for each subsector are calculated from the summation of inventories at all positions of the subsector.

† Inventory changes in this column are arrived from inventory and accumulated flow data. Slight descrepancies are due to delay storages not accounted for and numerical computation errors.

§ Accumulative flows are calculated by numerical integration of flow signals.

¶ Farm consumption data reflect human, animal, and seed consumption.

** Production amount reflects a deflator factor to account for all subsystem losses, since all other losses are assumed zero for test purposes.

flows and inventory changes made as part of system validation exercises. This table is on a macro-subsector level; however, consistency here implies consistency at deeper levels of the model structure. The reader will note that the four major subsectors of the GMP model are represented by the first four rows of the table. The bottom line of the table represents the total system model. Logical consistency of inventory changes and grain flows is indicated for each subsector as well as for the total system model. Inventories for each subsector are calculated as the summation of inventories at all position points of the subsector (refer to Figure 2.4.). Flow accumulations are calculated by numerical integration of relevant flow signals from each of the subsectors. The signs presented at the top of each column indicate how the flow signals (and inventories) are combined to calculate the elements in the "inventory change" column. Farm consumption flow data reflect human, animal, and seed consumption. The amount shown in the "production" column of the table reflects a deflator factor to account for all subsystem losses, since all other losses are assumed zero for test purposes. The logical consistency of the transaction mechanism of the model is also indicated by the bracketed and linked elements of the table, i.e., total domestic purchases equal total domestic sales over the period represented by the table.

Oftentimes anomalies in a model run will reveal logical inconsistencies which would otherwise go undetected. On the other hand, anomalies can also be used to verify logical system behavior. Figures 8.2, 8.3, and 8.4 are computer plots of several marketing activity and inventory variables for three different validation runs. Each of these figures presents evidence of flow consistency throughout

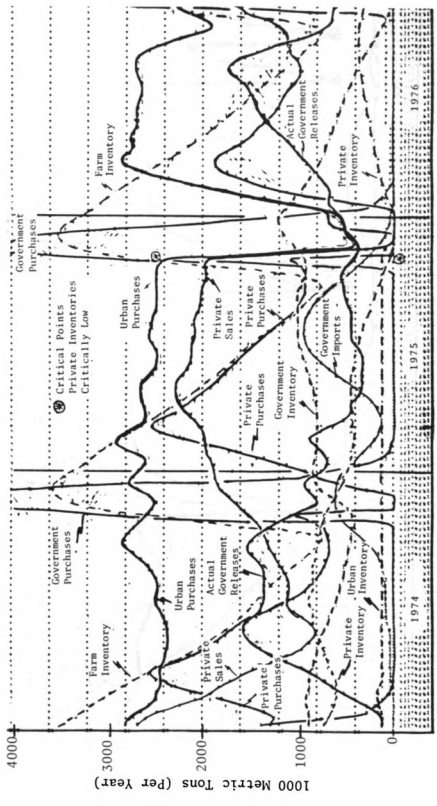


Figure 8.2. Validation Test--Marketing Activities (Historical Tracking).

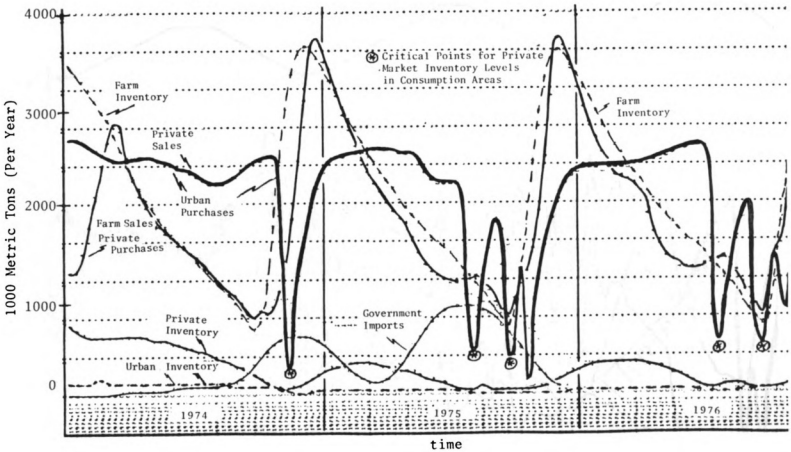


Figure 8.3. Validation Test--Marketing Activities (No Government Activities).

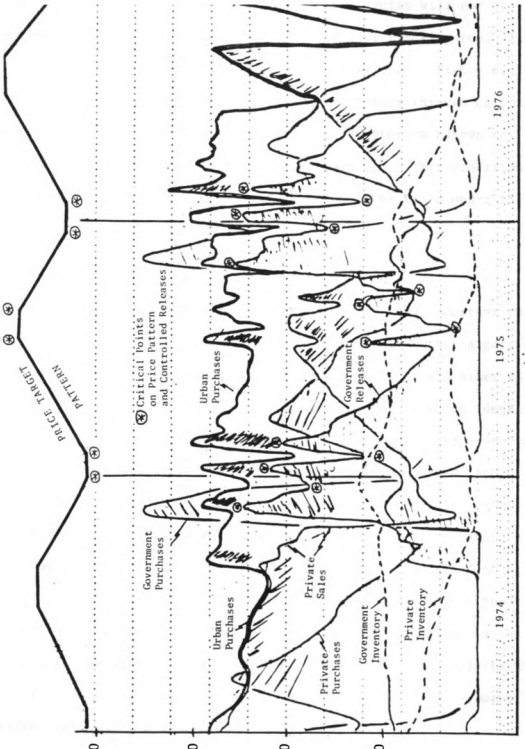


Figure 8.4. Validation Test--Marketing Activities (Urban Price Control).

the model runs, and each also demonstrates valid system behavior under anomalous situations. Details of the figures will not be discussed. Figure 8.2 represents an historical tracking run. Figure 8.3 represents a policy of no government activities. Figure 8.4 represents a policy to control urban market prices through calculated government marketing activities. Private inventories happen to decline to zero at various times during each run. This condition causes extreme system responses which prove to be valid under the conditions of each run.

Parameterization

Model parameterization (or tuning) is no less important than mathematical structure, logical consistency, or any other aspect of the system design. Given that the model is valid in all other respects, it must also contain a valid set of parameter values which identify a unique system out of an infinite family of functions represented by the nonparameterized model structure. We say a 'valid' set of parameter values, rather than a 'correct' set of parameter values, since the latter implies rejection of the model with anything less than an optimal set of parameter values. Choosing a set of model parameter values which will suffice in identifying a system function 'acceptably close' to the real world system being modelled is challenge enough for designers and enables measurements of model validity throughout the tuning and design process. The aim is model improvement rather than model perfection.

As evidenced throughout the mathematical description, scores of parameters can be found in the GMP model. Although no deliberate attempt has been made to classify every model parameter, the majority

of parameters can be placed in one or more of the following categories: (1) delay parameters, (2) control parameters, (3) technical coefficients, (4) behavioral response parameters, and (5) time-varying parameters. The values placed on model parameters are determined from available data, information, and knowledge about the real world system, as well as from an intimate familiarity with the system model itself. Oftentimes parameter values have a one-to-one relationship with real world system parameters (e.g., storage and milling capacities, milling extraction rates, crop maturing periods, unit accounting costs, expected delay times, etc.) which can be determined directly from available statistics, or from knowledgeable individuals. Other parameters, such as demand and supply elasticities, have implicit values inherent in real world time-series (or cross-sectional) statistical data on prices, consumption levels, incomes, marketings, inventory levels, and other relevant factors. Data accuracy, availability, and consistency problems create a sizeable challenge in the search for values of these types of parameters. Still other model parameters have no counterpart values to be found, either explicitly or implicitly, in the real world system. Such parameters come into being due to the abstract nature of the model and are not measurable (or even existent) in the real world system. Knowledge of the system model, as well as the objective at hand, is required to assign valid numbers to these parameters.

In this section, a selective discussion will be given to describe the process of GMP model parameterization. This discussion is not intended to give full treatment to model parameterization,

but is presented here to convey some of the important model tuning efforts made throughout the development and refinement stages.

System Delays

Time delays are an inherent characteristic of the real world system which must be captured in the mathematical model if the *dynamic* nature of the real world system is to be represented. For the most part, system delays provide the information storage (memory) about past history of the system needed to determine future system responses, given future system inputs. Grain storage integrators are themselves inherent delay functions, but for the purpose of this discussion we will limit ourselves to those system delays which can be represented by ordinary linear differential equations. Listed below are several examples of such delays found in the GMP model.

- importation delays
- port discharge delays
- transportation delays
- grain processing delays
- production process delays
- debt repayment delays
- warehouse construction delays
- information smoothing delays

For distributed delay functions, two parameters must be specified: the mean time of the delay (DEL), and the order of the delay (k). Extensive treatment of the theory of distributed delays is covered by Manetsch and others [1, 30]; however, some basic discussion will be given here in order to convey the general technique used in selecting valid delay parameters.

It can be shown that the impulse response of a distributed delay function is identical to the Erlang density function given below.

$$X(t) = \frac{(k/DEL)^k \; t^{k-1} \; e^{-(k/DEL)t}}{(k-1)!} \tag{8.1}$$

where:

$$E\,(t) = DEL \qquad \text{(mean)} \tag{8.1A}$$

$$Var\,(t) = \frac{DEL^2}{k} \qquad \text{(variance)} \tag{8.1B}$$

$$m(t) = \left[\frac{k-1}{k}\right] DEL \qquad \text{(mode)} \tag{8.1C}$$

From these expressions for the mean, variance, and mode (most likely) values of the Erlang distribution, considerable insight can be made into the relationship between the parameters DEL and k, and the characteristics of the distributed delay functions used in the model. The linear qualities of the delay functions enable use of the superposition principle to gain insight into the delay characteristics when the input is a sequence of impulses.

It is important to note that a value of k=1 results in an exponential distribution, and as k increases, the impulse response approaches a normal distribution. Where adequate data exist, a fair approximation can be made to determine appropriate values of k and DEL to use in the distributed delay equations.

A rough test of non-negative data can be made by computing the coefficient of variation (CV) of measured data, defined as $CV = \frac{\sigma}{\mu}$ where σ and μ are the measured standard deviation and mean of the data. If the coefficient of variation of data is found to be close to 1, it is reasonable to suppose that an exponential distribution

will fit the data, since the mean μ and standard deviation σ for the exponential distribution are identical.

The coefficient of variation for the general Erlang function of Equation 8.1 is

$$CV = \frac{DEL}{k^{1/2}} \Big/ DEL = 1/\sqrt{k} \tag{8.2}$$

Therefore, we see that $CV \leq 1$ and decreases as k increases. When measured data are significantly less than 1, it is reasonable to suppose that the data may be represented by the Erlang distribution for which k is closest to the measured value of $(\mu/\sigma)^2$.

Example:

If = 5 weeks (measured mean)

= 2 weeks (measured standard deviation)

then,

$$CV = \frac{2}{5} = 1/\sqrt{k}$$

and $k = \left(\frac{5}{2}\right)^2 = \frac{25}{4}$ $\qquad k = 6$

Control Parameters

Several automatic feedback control mechanisms can be found throughout the GMP model. These controls are used for a number of purposes, e.g.,

- position inventory management
- subsector inventory management (price speculation)
- import scheduling and management
- market price control
- warehouse management

General proportional-plus-derivative-plus-integral control designs with unity feedback were indicated in the mathematical descriptions of the controllers and also programmed into the computer model. This generalization in the system structure allows full flexibility in controller designs (through gain parameterization) to shape the system response to desired performance specifications (PS). These specifications are not set at severe levels, but do require realistic system behavior, e.g.,

- stability (stable mode desired)
- realistic time response
- small final error for step input
- small overshoots, if any.

Because these PS are set lightly, the difficulty of controller parameterization was eased considerably. Each controller required individual attention, but the basic similarity of system structure in the vicinity of many control points enables several controllers to be parameterized in a similar manner.

Trial-and-error control systems synthesis techniques were used in selecting valid parameter values for the control mechanisms of the model [11]. This does not imply that parameter values were pulled from a hat and tried until a valid set was obtained. Choices were made based on judgement, intuition, and experience. Root locus techniques and other aids to control systems design were employed to keep track and help position dominant system eigenvalues (poles) and serve as guides to choices of control parameter values. As choices were made and the model was tested with computer runs, the process converged to an acceptable design set of control parameters.

Table 8.2 indicates the current value choices of several of the control parameters used in the GMP model. These values represent a suboptimal set, but do result in system behavior which is quite acceptable for the purpose at hand. It might be noted that a proportional-plus-derivative control strategy proved to be most effective after testing several attempts to include integral control for zero steady state error. The tendency for system instability caused by integral control eventually resulted in zero values being chosen for most of these gain parameters.

Technical Coefficients

Technical coefficients are used throughout the GMP model as scaling factors for model variables, and for setting realistic boundaries on model functions. Conversion factors, product extraction rates from milling operations, storage capacities, milling capacities, limits to changes in prices, unit costs of production operations, limits to import discharge rates and unit costs of grain storage and handling are some examples of technical coefficients used in the model. Delay and smoothing function parameters can also be considered technical coefficients.

Values of model technical coefficients are rarely found published in statistical data. Since the mathematical model is absolutely precise, it calls for precise technical coefficients in precise units. Efforts are made to design the model considering available technical information, but such a design criterion cannot be adhered to in many instances. Oftentimes no reliable information exists on the values of technical coefficients, but omission from the model cannot be tolerated. Other times, a vast amount of information is available,

Table 8.2. Control Parameters.

Controller Symbol	Reference Equation	Element Parameter Values			Controller Description	
		Proportional A	Derivative B	Integral C	Subsector	Type
G21.	3.22	100	5	1	FARM	Inventory
G22.	3.26	40	0	--	FARM	"
G31.	4.37	0	0	0	PM	Inventory
G32.	4.41	100	10	0	"	"
G33.	4.59	100	10	0	"	"
G34.	4.67	100	10	0	"	"
G35.	4.26	.1E-5	0	0	"	"(Speculation)
G51	4.101	40	--	--	PM (Flour)	Import
G52.	4.108	25	15	0	"	Inventory
G53.	4.115	25	2.5	0	"	
1/UK2	6.3	.5	--	--	URBAN	Inventory
G10.	5.25	15	2	0	GOV	Import
G13.	5.80	100	10	0	"	Inventory
G14.	5.62	100	10	0	"	"
G15	5.65	40	--	--	"	"
G16	5.75	40	--	--		"
$GF11_{11}$.*	5.37	3000	500	0	GOV	Farm Price
$GF11_{12}$.	"	0	0	0	"	"
$GF11_{21}$.	"	0	0	0	"	"
$GF11_{22}$.	"	200	100	0	"	"
$GU11_{11}$.	5.41	4000	400	0	GOV	Urban Price
$GU11_{12}$.	"	0	0	0	"	"
$GU11_{21}$.	"	0	0	0	"	"
$GU11_{22}$.	"	100	50	0	"	"
G15A	5.107	15	--	--	GOV	Warehousing
G15B	5.119	1	--	--	"	"
G16	5.101	7	--	--	"	"

* For notational convenience, GF11. and GU11. parameters are denoted differently in Equations 5.37 and 5.41.

usually conflicting, and in much more analytical detail than called for by the model. In these instances, large amounts of data must be analyzed and aggregated to come up with the precise parameter called for by the model. When little or no information exists on parameter values, designers must seek the required values through surveys, interviews with knowledgeable individuals, or--if no recourse is left--attempt an intelligent guess as to the correct value. Strange as it may seem, knowledgeable people sometimes refuse to guess the value of a parameter needed in the model, leaving the task to model designers. Generally, the model requires *some* value for all parameters to operate. Sensitivity tests after the model is operational help to disclose the sensitivity of model outputs to changes in parameter values. These tests help to identify critical parameters whose values significantly affect model results. Once they are identified, more effort can be expended in researching and estimating more credible values. More will be said about sensitivity testing in a subsequent section of this chapter.

It will not serve the purpose of this dissertation to make an attempt at describing how all technical coefficients were assigned values. A brief discussion of a few selected technical coefficients will disclose the general approach.

Conversion factors are important technical coefficients which must be provided for the model. Extraction rates, that is, the weight conversion between grain forms, must be handled carefully, both in the model structure and through the values of the conversion factors themselves. Government policy can set extraction rates but, in reality, these rates vary considerably. Model sensitivity to these technical

coefficients is obvious, as is the real world system. Table 8.3 describes some of the important conversion factors used in the model. These values should be known at all times to model users, should they wish to adjust them to what they feel are more accurate values.

Table 8.3. Grain Form Weight Conversion Factors.

Conversion	Symbol	Rice	Barley	Wheat
Rough to polished	EXZ_i	.720	.630	.770
Rough to hulled	EXY_i	.780	.960	1.0
Hulled to polished (flour)	EYZ_i	.923	.656	.770

Values are shown for all conversions in the above table; however, the reader should note that the following relationship should be rigidly held in assigning new values for any conversion factor.

$$EXZ_i = EXY_i * EYZ_i \tag{8.3}$$

Different extraction rates often exist for foreign grains, so these technical coefficients are slightly different for processing in consumption areas. The barley conversion factors are a weighted average for common and naked barley conversions. These commodities are not disaggregated in the model, so the technical coefficient must carry the aggregate information. Rice varieties also exhibit different extraction and product characteristics. For example, Tongil varieties have a larger cracking factor than ordinary varieties. This information must also be carried in the technical coefficients. The sensitivity of extraction rates is demonstrated by the fact that 1 percent variation in the parameters would produce approximately 100,000 metric tons

variation in annual processed supplies. This is approximately ten shiploads of grain.

Weight-to-volume conversions are also necessary in the model to calculate storage space utilization. Table 8.4 below indicates the basic volume to weight conversion factors used in the model.

Many technical coefficients vary greatly over time. Sometimes it is necessary to enter certain model parameters into the model as empirical functions of time. Examples of such model parameters are listed below.

. unit storage and handling costs
. seasonal demand elasticities (described later)
. seasonal desired inventory sustaining times
. seasonal storage loss rates
. world prices
. won-to-dollar conversions
. system capacities

Behavioral Response Parameters

Econometric techniques are used to model some of the basic behavioral response processes of the grain system. Food grain consumption, farm marketings, and domestic production decisions are processes which have lent themselves to this modelling approach. Other processes, such as private market demand and supply functions, have required other modelling techniques. In this section, a brief description of the methods employed to estimate behavioral response parameters for consumption and marketing equations will be given. Parameterization and testing of farm production decision processes have already been described in Chapter 3.

Table 8.4. Weight to Volume Conversion Factors.

Form	Symbol	Rice	Barley	Wheat
		- 100-Liter Bags Per Metric Ton -		
Rough	BPMTX	17.86	18.19	12.99
Hulled	BPMTY	16.66	--	--
Polished	BPMTZ	12.5	13.07	13.16
		- Kilograms Per 100-Liter Bag -		
Rough	$1000/BPMTX_i$	56	55	77
Hulled	$1000/BPMTY_i$	60	--	--
Polished	$1000/BPMTZ_i$	80	76.5	76
		- Volume Reduction Factors (Percent) -		
Rough	--	100	100	100
Hulled	--	55	--	--
Polished	--	50	55	--

Food Grain Consumption

The reader will recall that both annual and seasonal food grain consumption models are contained in the GMP model. Calculation of annual food plans through the generalized demand-price analyzer (Chapters 2 and 5) requires an annual demand model for farm and urban populations. Simulation of actual food grain consumption demand patterns throughout the year requires seasonal demand models for farm and urban populations. Parameterization of each of these models will be described below.

Annual Consumption Demand

Recall from Equation 5.7 that the basic model structure for the annual demand models is given as follows.

$$\begin{bmatrix} Q_1 \\ Q_2 \\ Q_3 \end{bmatrix} = \begin{bmatrix} C_1 \\ C_2 \\ C_3 \end{bmatrix} + \begin{bmatrix} \varepsilon_{11} & \varepsilon_{12} & \varepsilon_{13} \\ \varepsilon_{21} & \varepsilon_{22} & \varepsilon_{23} \\ \varepsilon_{31} & \varepsilon_{32} & \varepsilon_{33} \end{bmatrix} \begin{bmatrix} P_1 \\ P_2 \\ P_3 \end{bmatrix} + \begin{bmatrix} m_1 \\ m_2 \\ m_3 \end{bmatrix} I \qquad \begin{matrix} (8.4) \\ (5.7 \\ \text{repeated}) \end{matrix}$$

or,

$$Q = C + EP + MI$$

where, this represents the log-form of the Cobb-Douglas functions (Equations 5.1 and 5.2). Recall also that the constant matrix C is calculated at model initialization to place the demand curve through base values of consumption, prices, and income, so that consideration here shall be determination of the values for parameters in the E and M matrices. The elements of these matrices may be called the price and income elasticities of consumption, respectively. However, sign

discrepencies in some of the elements preclude calling these values elasticities in a strictly economic sense.

Table 8.5 indicates the values of the parameters used for the E and M matrices in the farm and urban annual consumption demand models.

Table 8.5. Annual Demand Model Parameters.

		Prices			Income	
		Rice	Barley	Wheat		$\bar{R}^2$
		- Farm Sector -				
Quantities	Rice	-.88	.64	-.12	-.41	.65
	Barley	.74	-.44	-.30	-.49	.76
	Wheat	-1.49	-.59	-.20	-.42	.91
		- Urban Sector -				
Quantities	Rice	-1.1	.28	-.16	-.15	.78
	Barley	4.6	-.79	.34	.72	.82
	Wheat	.28	0	.58	1.71	.81

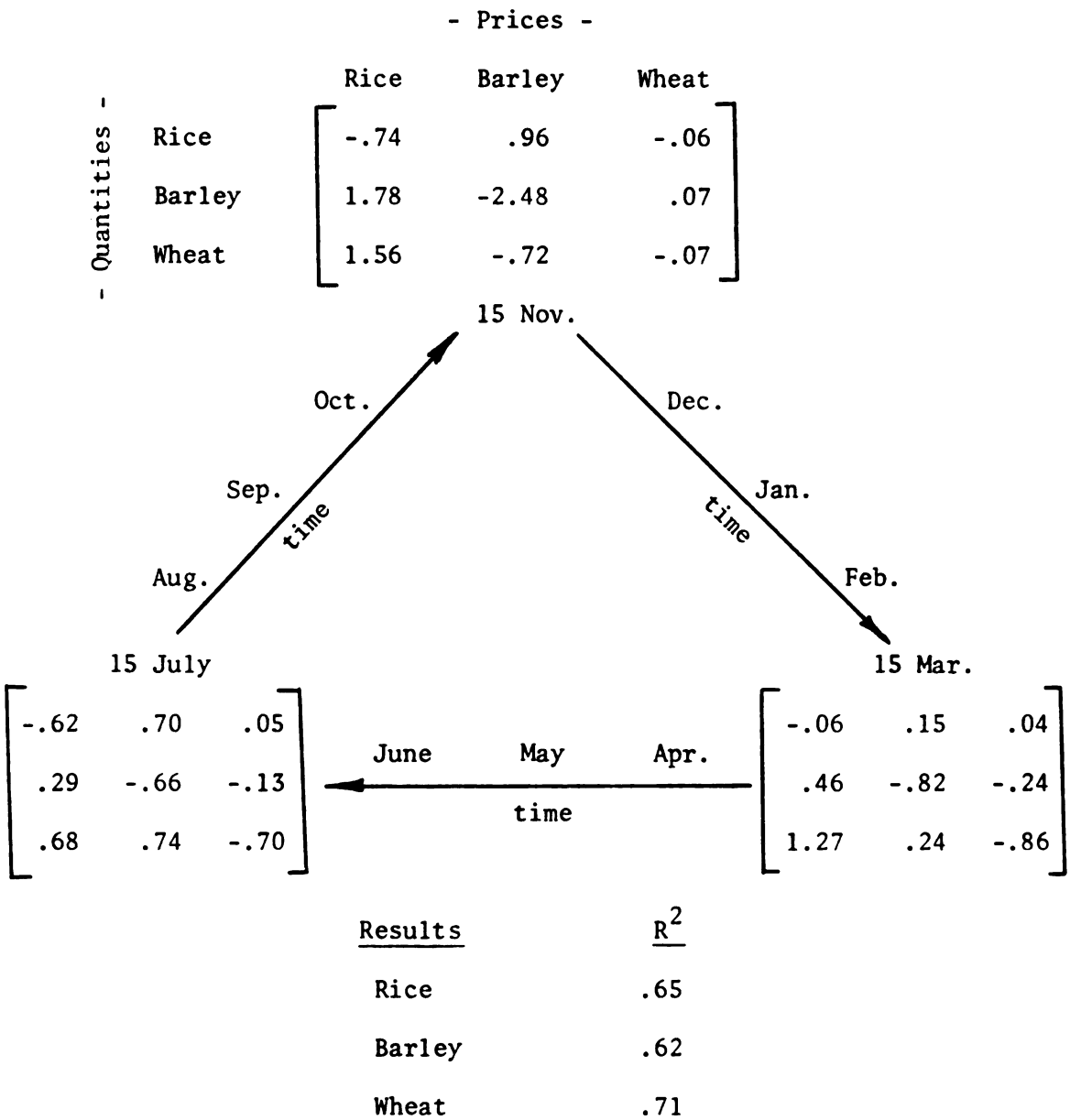
The parameter values presented in the above table represent the results of much off-line analysis of statistical data. Annual consumption, price, and income data were used from 1965 to 1974 (ten years' data). Over thirty ordinary least squares (OLSQ) regression estimates were made, using various functional forms, weighted prices, and trend terms. The above values represent what system designers felt yielded the most valid results for GMP model purposes. The sign difficulties in wheat and barley cross parameters have consistently plagued researchers in Korea. The reason for these difficulties is

due to the fact that several other factors besides price and income are affecting consumption demand in Korea. Nonprice countermeasures to curb rice consumption and stimulate barley consumption (such as dual price system for barley, riceless days, and government mixing of rice and barley) are all factors not reflected in the demand equations.

Seasonal Consumption Demand

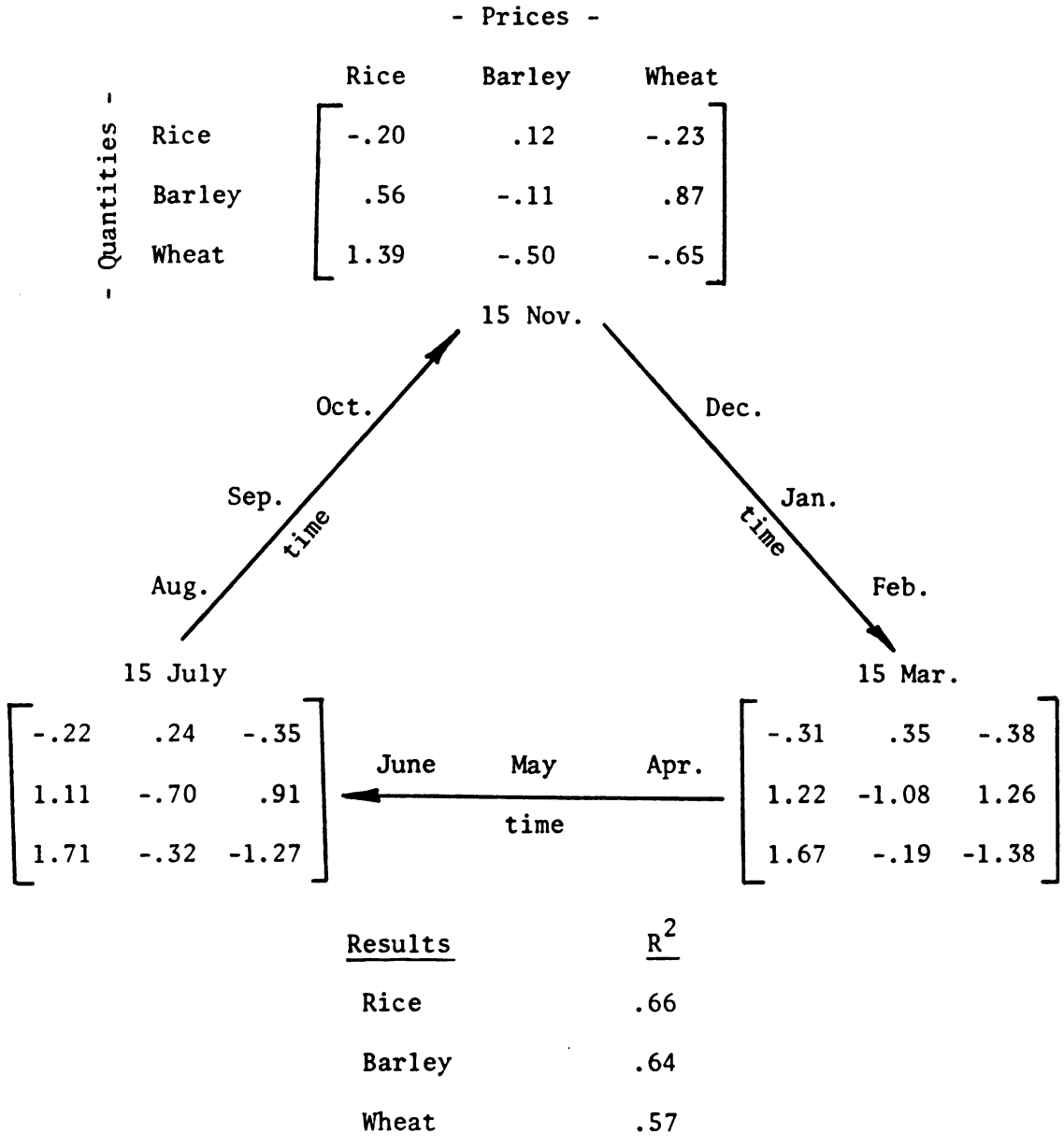
The structure of farm and urban seasonal consumption models is described in Chapters 3 and 6, respectively. The reader will recall that a Cobb-Douglas form is used in both models. The unique feature of the models is that it is necessary to use time-varying parameters (price elasticities of consumption) to obtain valid seasonal consumption responses. Coefficients of Determination ($\bar{R}^2$) in the order of .25 and below were the best that could be obtained in regression estimates, assuming constant parameters throughout the year.

Consumption parameters were estimated for three seasons of the year for both models: (1) October through January, (2) February through May, and (3) June through September. Figures 8.5 and 8.6 illustrate the values of the seasonal demand parameters used in the GMP model for farm and urban subsectors, respectively. Values given in the figures represent parameter estimates at the midpoints of the three periods of the year: (1) November 15, (2) March 15, and (3) July 15. Table functions are used during the model run to provide interpolation and continuity between succeeding sets of parameters [3].



Results	R^2
Rice	.65
Barley	.62
Wheat	.71

Figure 8.5. Time-Varying Parameters of Farm Consumption Model.



Results	R^2
Rice	.66
Barley	.64
Wheat	.57

Figure 8.6. Time-Varying Parameters of Urban Consumption Model.

Farm Marketing

Several farm marketing functions have been designed for use in the GMP model. Three of these functions are discussed in Chapter 3 and revealed in Equations 3.32, 3.33, and 3.34. Other functions for farm marketing behavior have been borrowed from other research studies [34], modified for use in the GMP model [15, 16], and tested. The three functions given in the above three equations, however, proved to be most adequate for GMP model purposes.

The reader will note the quantity of farm stocks available for sale, $QFSAS_i(t)$, calculated in Equation 3.31, is present in all three forms of the farm marketing equations. This is an example of data which are not available in statistical data series. Furthermore, it would be very difficult to measure by survey, because it involves management attitudes over time. A time series for this variable was generated by use of the GMP model itself; empirical data on farm production, consumption, and marketings were processed in the farm subsector component on a special computer run. The result was a time series for $QFSAS_i(t)$ which was fashioned to the GMP model structure. Estimates of marketing function parameters were then done off-line by regression analysis. $\bar{R}^2$ values in the range of .80 to .90 were obtained.

Sensitivity Testing

Sensitivity testing is an important part of the model testing and tuning process and can be carried out both formally and informally. In general, sensitivity tests consist of changing values of model parameters significantly (usually one at a time when done formally) between model runs and noting the effect these changes have on model

results. The result of these tests is the identification of sensitive model parameters whose values have significant effect on model output variables. With this information at hand, researchers and model designers can establish relative priorities to the accuracy requirements of the several scores of parameters found in the model. Parameterization efforts can then be allocated more effectively to sensitive parameters where the credibility of the values being used is questioned. Sensitivity tests can often be used to justify special survey designs when statistical data are not available for establishing credible values for sensitive parameters. Policy variables can also be subject to sensitivity testing. Like parameter sensitivity testing, the result is to establish the extent to which model outputs are affected by the values of policy variables. Connectedness of policy variables to model output variables is also determined through these sensitivity tests.

In many cases, better model results can be expected by getting better estimates of real world parameters--but this is not necessarily always true. Since there is not always a one-to-one correspondence between real world and model parameters, true values of parameters in the real world will not necessarily yield best results in the model. Inadequacies in model structure, omission of real world detail, and causal factors will forever be present in any abstract model. Therefore, the true goal should be to find parameter values which optimize model tracking performance rather than true values which determine the real world system performance. Advanced techniques such as computer optimization packages can be applied to effectively explore the parameter surface of the model to attain improved performance [7, 8, 27]. These packages are also expensive to apply, with cost proportional to

the number of parameters being optimized. Considerable insight into parameter sensitivities was gained informally through the computer testing and tuning process of model development. Drawing on this experience with the model, it is possible to select sets of parameters as candidates for costly sensitivity tests and/or application of computer optimization packages. Table 8.6 gives a selected set of parameters which, if optimized, would undoubtedly greatly improve model tracking performance. Table 8.7 indicates important model output variables which should be entered into the objective function. Equation 8.4 below describes one possible criterion measurement (sum of square errors) which could be used for such an objective function.

$$\min \sum_{i=1}^{3} \sum_{j=1}^{6} \sum_{k=1}^{m} \left(\frac{X_{ijk} - \hat{X}_{ijk}}{\hat{X}_{ijk}} \right)^2 wt_{ij} \qquad (8.4)$$

- X_{ijk}: empirical data value of output variable
- $\hat{X}_{ijk}$: model-generated value of output variable
- wt_{ij}: weight given to output criterion variable (optional)
- k: sample index (say, monthly over run duration)
- j: output criterion variable index (see Table 8.7)
- i: commodity index (rice = 1, barley = 2, wheat = 3)

Of course, subsets of the criterion variables (j) and commodity indices (i) might be used to relax the objective function requirements for initial optimization efforts.

Verification

Model verification generally consists of ascertaining the model's ability to reflect accurately the real world situation or phenomena it is intended to represent. Since the end product of

Table 8.6. Selected Parameters for Computer Optimization Tuning.

Parameter	Priority	Current Value		Reference Equation	Brief Description
		Rice	Barley		
A10	C	0	0	7.1	Price dynamics (farm)
A11	A	.8	.5	7.3	" " "
A12	A	12E-7*	30E-7	7.3	" " "
A20	C	2000	2000	7.4	Price dynamics (urban)
A21	A	.5	.5	7.6	" " "
A22	A	7.5E-7	15E-7	7.26	Price dynamics (urban)
ELAS35	A	.3	.3	4.7	PM supply/demand response (margin)
G35A	B	1E-6	1E-6	4.26,4.1 4.2	PM inventory control
G35B	B	0	0	4.26,4.1 4.2	" " "
C35	C	1.1	1.1	4.7	Normal profit margin
UK1	A	.02	.02	6.10	Urban demand response (price changes)
UK2	A	.5	.5	6.3,6.10	Urban demand response
UK3	B	.1	.1	6.7	Urban demand response (price level)
A	A	3.	3.	3.32	Farm marketings
EAP	A	1.	1.	3.33	Farm marketings (price)
B41A	B	1	1	7.25	Market choice (farm)
B41B	B	1	1	7.29	Market choice (farm price)
B42A	B	1	1	7.26	Market choice (urban)
B42B	B	1	1	7.30	Market choice (urban price)
B42C	C	.1	0	7.31	Market choice (urban quality)

* 1E-n $\triangleq$ $1X10^{-n}$; used for ease in presentation.

Table 8.7. Selected Output Variables for Performance Criterion Measurements.

Reference Symbol	Output Variable	Suggested Weights	Description
(Equation 8.4)			
X_{i1}	PU_i	1	Urban price
X_{i2}	PF_i	1	Farm price
X_{i3}	$PCCF_i$	.5	Farm consumption
X_{i4}	$PCCUD_i$	.5	Urban consumption
X_{i5}	$FMKTS_i$	.5	Farm marketings

the model is the computerized program, most verification testing of the model is done with the computer model. Verification is another testing exercise which perpetuates the iterative process of model design, bringing about refinements and innovative changes in the model concept, mathematical structure, model parameterization, and in the computer program itself. Model verification is more than testing for correspondence between the model's output and real world measurements. Model output design is also subject to validation and verification testing to assure model users are receiving the kinds of information required in useful and convenient forms.

Historical tracking experiments are basic to model tuning and verification exercises. The normal procedure followed in these tests is to operate the model over some past period of time and compare model output with real world empirical data. State variables of the model are initialized as closely as possible to those values which can be determined to have existed in the real world system at the

beginning of the simulation period.[1] Table 2.7 describes the contents of the GMP data bank, which is an integral part of the system model for testing purposes. Some 3855 statistical data points from 1966 through late 1976 are available on program files for automatic model initialization and to provide ready access to real world historical data for model tracking verification. Since the model design is oriented toward investigating alternative government grain management programs and policies, historical tracking runs use past time series of government grain operations and policies (e.g., domestic purchases and sales, foreign imports, government buying and selling prices, etc.) as model inputs. Domestic grain production, consumption, farm marketings, private market operations, storage, and market prices are then generated by the model.

It is more difficult to verify the model's predictive and prescriptive capabilities than its historical tracking capabilities, since no data exist for comparison with the real world. Judgement, intuition, and experience of grain system experts must be relied upon to provide a basis for establishing model credibility in these areas. "What if" tests of the model are run similar to historical tracking tests, except model inputs are changed from those which actually occurred in reality. These tests attempt to ascertain the model's predictive capability.[2] For example, alternative purchase and release programs may be addressed to the model over a past time

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[1]Since state variables contain all necessary information about the system, initial values of all other (nonstate) variables are calculated internally at the beginning of each run.

[2]Predictive capability can also be tested by forecasting into the future.

period to measure the "what if" implications. Alternative government purchase and/or release price policies can be addressed to the model or past import schedules can be altered to determine the model implications of various levels of self-sufficiency for past periods in history. These model results are usually compared with historical tracking base runs over the same period, since many model deficiencies and inaccuracies are cancelled in the comparisons. Human judgement and experience must then be used to verify the credibility of model results.

The GMP model is also designed to provide prescriptive information on government grain activities required to meet specific grain management policy objectives. For example, the model can prescribe the timing and intensity of government purchase and/or release programs to obtain desired seasonal market price behavior. The model can also prescribe foreign import scheduling and government domestic grain activities required to obtain prespecified annual food grain consumption and/or market price targets. Run in this mode, government grain operations and policies are generated within the model and become system outputs. Again, human judgement and experience must be used to determine the credibility of the model in these exercises.

Model Testing

The purpose of this section will be to demonstrate some verification test exercises performed on the GMP model. Due to the size and scope of the model, nothing close to full verification of the model can be demonstrated. Rather, two test runs of the model will be used to illustrate the general nature of verification testing undergone by the GMP model. The *first* run will be used to demonstrate the historical

tracking capabilities of the model. The *second* run will be used to demonstrate the prescriptive capabilities of the model for urban market price control and import scheduling. Comparison of these runs can then be used to imply some "what if" consequences of alternative grain management policies, these implications also being subject to verification efforts. Model output from these two runs must be severely limited in the text so that the discussion can proceed without becoming muddled in detail and confusion. Appendix A supplies additional model output from the two test runs. This appendix serves to demonstrate the type and forms of information which can be provided by the GMP model.

The time period under investigation for both runs is the three-year period beginning 1 January 1974 and ending 31 December 1976. Although this is now an historical period, the reader should note that absolutely no information regarding market prices, consumption rates, or any other endogenous model variables beyond the initial starting conditions on 1 January 1974 has been provided to the model. This includes model parameter estimates such as consumption elasticities which were based on time series data available before 1974.

Historical Tracking

The first run tests the GMP model's ability to replicate the real world grain system operations and provides a base to which other run results can be compared. The model is initialized (automatically) at the beginning of the run from data pulled from the data bank representing consumption levels, market prices, food grain stock levels, etc., prevailing on 1 January 1974. The model then proceeds to step through time, calculating all system variables at increments of 1/200 year (1.8 day) intervals for three years. Government policies

and grain activities such as buying and release prices, imports, domestic purchases, and releases are input to the model from the data bank and represent actual real world values (according to available data) for these variables throughout the model run.

Grain Management Policy Alternative

Judging from what has already been said about the scope of the GMP model for investigating a wide range of grain management issues, the reader should realize that it is impossible to test and demonstrate all aspects of the model in a single alternative run. We choose here a very simple example.

> Suppose the government wishes to investigate the consequences (good and bad) of undertaking an active urban rice price control program to attempt to influence urban rice price to move along a prespecified seasonal pattern. The government also requires some prescriptive guidelines as to just how it should manage its release program to achieve this seasonal price pattern. To sweeten the example a little further, suppose the government also undertakes an import policy to replenish its stocks of rice from foreign imports only to the extent of maintaining its rice stock levels at a minimum of 400,000 metric tons. The government requires guidelines for scheduling import orders to maintain this minimum stock level.

For a sound comparison between model results of the baseline run and this policy alternative run, all other government policies and grain activities (other than rice releases and imports) are identical in the two runs; government purchase programs remain the same, and government buying and release prices remain the same.

Historical Tracking Results

Figures 8.7 through 8.10 illustrate a limited set of the system time series variables generated in the baseline (historical tracking)

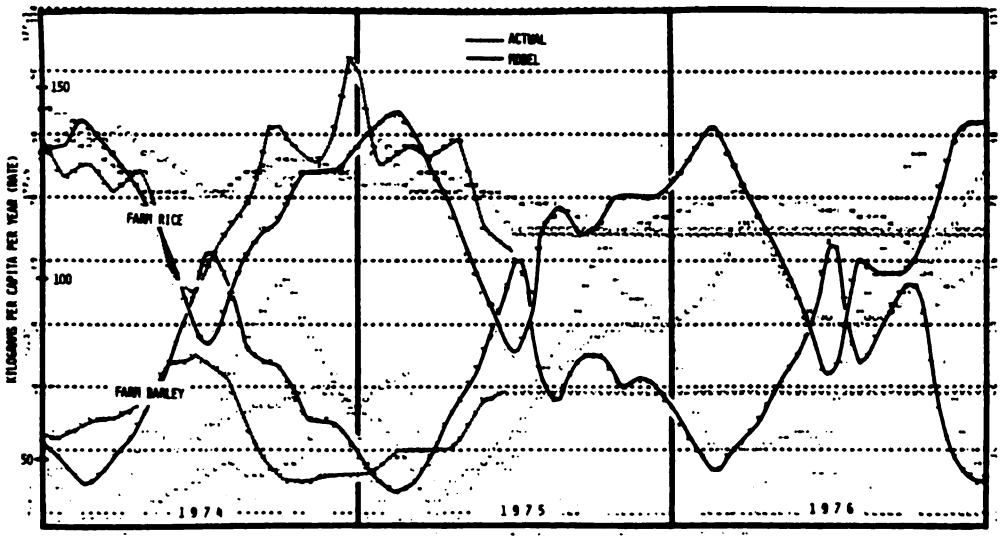


Figure 8.7. Food Grain Consumption Tracking.

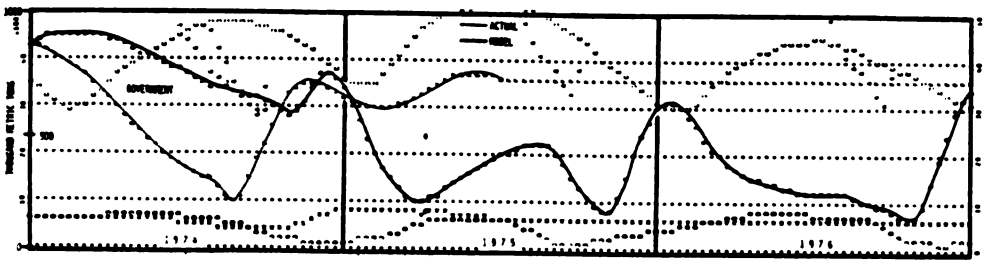


Figure 8.8. Rice Inventory Tracking.

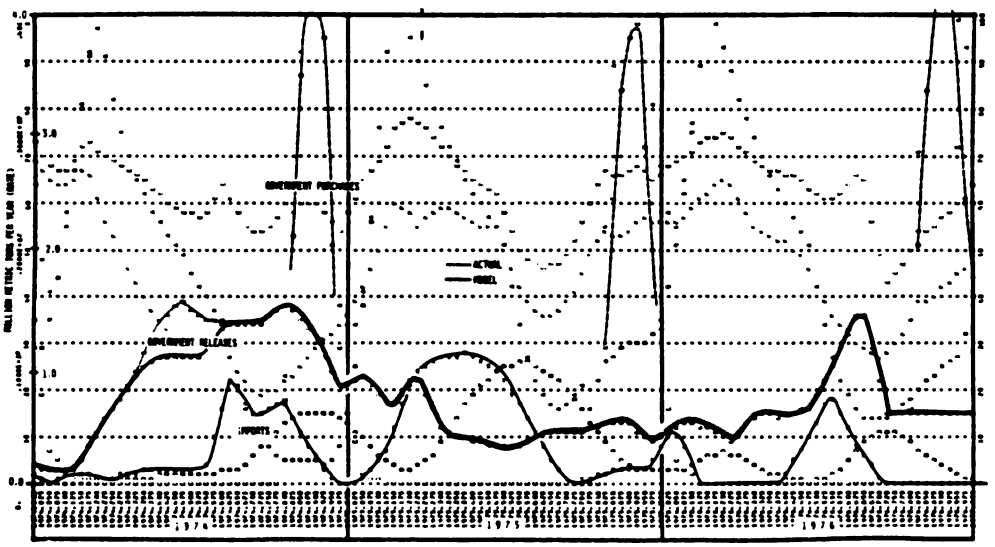


Figure 8.9. Rice Marketing Activities.

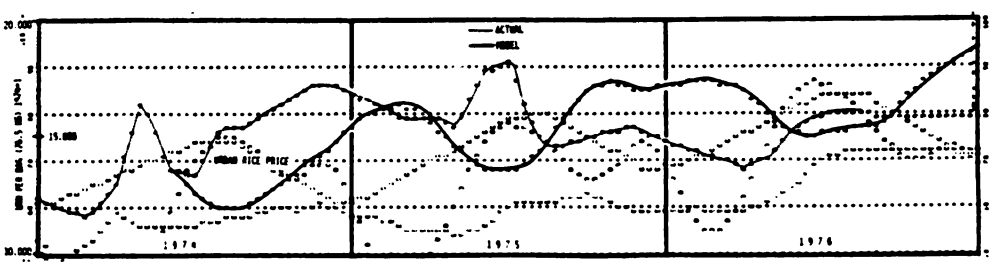


Figure 8.10. Urban Rice Price Tracking.

run of the model.[3] Data from the GMP data bank are plotted along with model-generated variables so that the reader has a clear view of just how well the model performed during this test run. Tracking performance is also measured quantitatively through the use of various statistical measurements (see Table 8.8). Figure 8.7 illustrates the consumption of rice and barley by the farm population. These series were chosen to demonstrate the ability of the model to represent the substitution effect between rice and barley consumption, especially in the farm population where it is normally more prevalent. Although these results appear good, other tests of the model indicate the consumption behavior equations used in the model perform much better when provided actual farm and urban market prices. The reader must recall that these functions are driven by model-generated prices.

Figure 8.8 illustrates government rice inventories (modelled and actual) throughout the period of the baseline run. Other system inventories such as farm, private market, and urban household inventories could also be illustrated, but are not in order to simplify the illustration. The seemingly poor performance of the model in reproducing government inventories during the period points out another potentially useful aspect of the model: data inconsistency verification. In this run, all government grain activities were taken from historical data, i.e., government purchases, government releases, and imports. The government rice inventory level generated is merely an accounting of government grain accumulations from these data, indicating an

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[3]The number of variables illustrated must be severely limited to avoid confusion to the reader, and to avoid the ever-present hazard of too much detail for the purpose at hand. Appendix A contains additional model output from the two runs.

Table 8.8 Historical Tracking Performance.

Key Variable	Rice			Barley*		
	Measurement of Performance			Measurement of Performance		
	SSE†	B-coef§	R^2¶	SSE	B-coef	R^2
Farm price	.255 (12%)	1.88	.325	.248 (12%)	.231	.082
Urban price	.213 (11%)	.409	.385	.212 (11%)	-.333	-.467
Farm consumption	.271 (12%)	.517	.522	.593 (18%)	.412	.091
Urban consumption	.037 (5%)	.359	.388	.534 (17%)	.283	.628
Farm inventories	.113 (8%)	.994	.975	1.509 (29%)	1.345	.895
Farm sales	NA**	.800	.654	NA	.499	.387

* Poor performance in barley is indicated because most model-tuning effort at time of run had been devoted to rice. Much improvement in performance can be expected.

† Sum of square errors (number in parentheses is percent error).

§ B-coefficient of regression equation when model results are regressed on actual data (should be one).

¶ Coefficient of determination with sign (should be one).

** Not available.

inconsistency in official government data--either in grain activities reported, inventory levels, or both.[4]

Figure 8.9 illustrates rice marketing activities during the period of the historical tracking run. Government rice purchases, releases, and imports are shown. Private market purchases and sales, as well as farm sales and urban purchases that equal the sum of government and private purchases and sales, respectively, could also be shown; but this would make the figure much too difficult to follow. The reader will later be asked to refer back to this figure to compare the changes in government grain activities (releases and imports) prescribed in the policy alternative run.

Figure 8.10 illustrates the greatest challenge to the GMP model--simulating market prices. The figure displays actual versus model urban market rice price during the period of the run.[5] These results represent the culmination of much hand tuning of the model (the process of assigning values to model parameters affecting the pricing function). In all, close to ten major parameters (tuning knobs) are involved in the performance of the pricing functions. This is far

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[4]Discrepancies between actual and model-generated government activities (purchases and sales) will be indicated in later summary tables. This is a subtlety of this particular test run, which has the farm and urban market choice mechanism operating. Government *demand* and *supply* throughout the run correspond to data bank values of government *purchases* and *sales*, respectively. Therefore, model-generated government activities will be somewhat different than actual. Other tests of the model indicate that what has been said about the inconsistency of official government data is true; discrepancies in government activities from actual in this run make some differences in the final results, but the inconsistencies are still evident in runs which produce exact values of government purchases and sales.

[5]The food grain system in Korea in early 1974 was in a state of much flux. Price tracking has proven to be very difficult through this period and, therefore, was not started until early May 1974 in this particular run.

too many parameters to adjust simultaneously by hand to achieve maximum model performance--it is like tuning an engine carburator with ten needle valves without the aid of a machine. Nevertheless, model designers are pleased with the level of performance indicated. Model prices are not bounded in any way, precluding the situation present in many simulation models where model variables, more often than not, *ride the bounds*. Hand tuning of the pricing function indicates that the GMP has the parameters and model construct to alter the behavior of the pricing functions in virtually any conceivable manner. All that is needed is some automatic assistance in finding the proper value of these parameters to maximize model performance. As mentioned earlier, computerized optimization packages suitable for such tasks are available and can be applied to efficiently explore the parameter space of the model to attain (undoubtedly) more accuracy [7, 8].

As mentioned in Chapter 2, the GMP model provides various measurements of its own performance in tracking key variables. Some of these measurements are given in Table 8.8 for the key variables discussed above and others not discussed.

Policy Alternative Results

We have now established a baseline for making judgements regarding the outcomes of alternative grain management policies. Although it has been made clearly evident that the model is far from perfect in accurately reproducing past grain system performance, it is important to note that whatever deficiencies the model has in the baseline run are also present in alternative runs. If the model has invalid initialization data, invalid input variables, or invalid accounting coefficients in the baseline run, then the same information and

parameters are present in the second run. If these model deficiencies cause errors in model results, these errors should run in the same directions in both runs, tending to cancel when comparisons are made between run results.

Figures 8.11 through 8.14 illustrate the same time series variables that were illustrated from the historical tracking (baseline) run. The reader is free to view the two sets of plots and make any comparisons he wishes. Of most interest, however, is to note the changes in government imports, government stock levels, and government releases of rice indicated between the two runs (Figures 8.8, 8.9, 8.12, 8.13). Figure 8.14 illustrates the targeted seasonal urban rice price policy under investigation along with actual (simulated) urban rice price realized by undertaking the government releases indicated in Figure 8.13. The figure indicates that the strategy used in the model for observing actual and desired price behavior and issuing release orders was quite successful in achieving the desired results. This strategy will not be discussed here in detail except for one point: the reader's attention is called to the early warning capability of the urban rice price control strategy. Sizeable government releases are called for long in advance of the time urban prices move above target levels. This can be seen by noting the position of the arrow on Figure 8.14 which indicates the time at which government releases are begun in order to turn urban prices downward.

Comparisons of Results

Thus far we have presented some of the highlights of the results of both the baseline (historical tracking) run and the policy alternative (urban rice price plus rice import control) run. The plots and

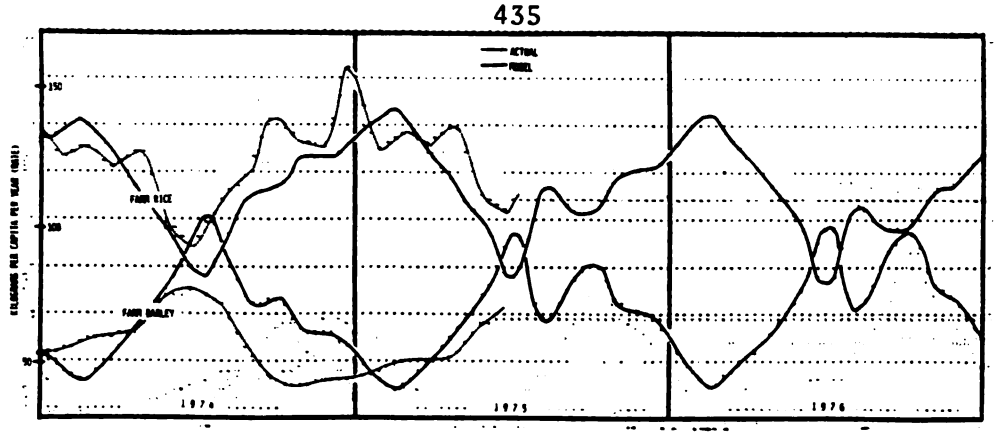


Figure 8.11. Food Grain Consumption Policy Alternative.

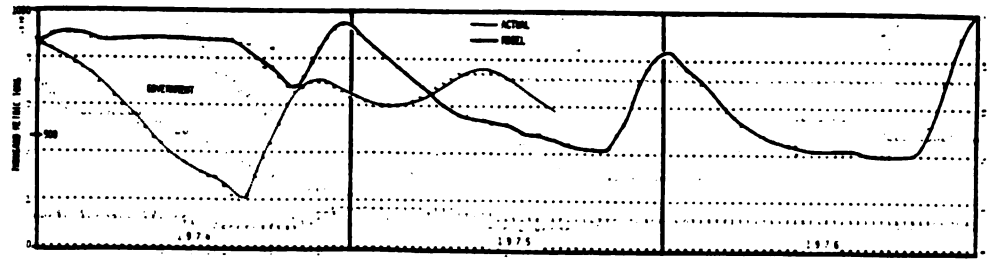


Figure 8.12. Rice Inventory Policy Alternative.

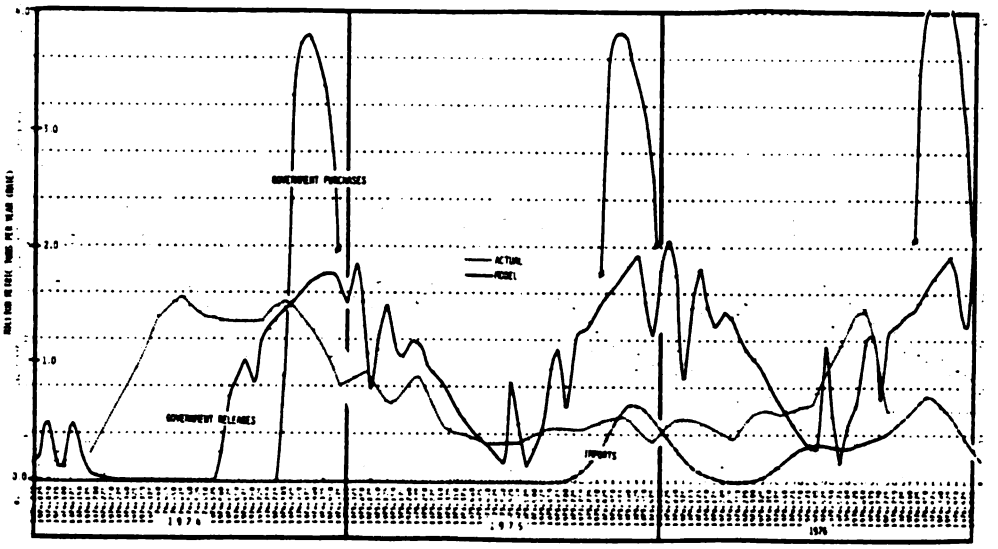


Figure 8.13. Marketing Activity Policy Alternative.

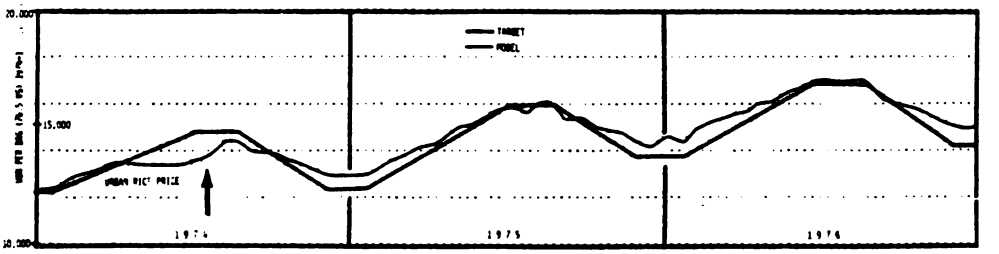


Figure 8.14. Urban Rice Price Control.

performance tables serve a useful purpose but give little information as to which of the two runs indicated the *best* results. Many comparisons can be made to make this determination depending on the objectives of the grain management policy under consideration. Oftentimes both good and bad consequences will be indicated for particular policy alternatives under study; however, it is up to the decision maker to weigh these results and make the final determination.

The basic question here is this: would Korea's food grain situation be better (or worse) off today if the government had undertaken the grain management policy alternative studied in the second run of the example? As has been done throughout this example, we must severely limit ourselves in the comparisons and analyses made between the two test runs under consideration.

Table 8.9 enables the reader to compare selected items, such as imports, farm commercial sales of food grains, government share in the market, food grain consumption, etc., between the two test runs. The table also provides information on actual data on these selected items for 1974, 1975, and 1976. Comparisons between actual data and baseline results will (with the other information already given) help to establish the level of credibility the reader wishes to give the model for this particular test. The table is self-explanatory and will not be discussed here.

Table 8.10 presents the impact of both runs on a psuedo grain management special account. Baseline and policy alternative run results are given in the table (along with a comparison of run results) for calendar years 1974, 1975, and 1976. The table gives an abbreviated analysis for 1974 and 1976 and a more detailed analysis for 1975.

Table 8.9. Comparison of Selected Items for Model Test Runs.

Unit: 1000 metric tons or kilograms per capita per year*

Selected Items	Actual Data	Baseline Run Results	Policy Run Results	Actual Data	Baseline Run Results	Policy Run Results	Actual Data	Baseline Run Results	Policy Run Results
	CY 1975			CY 1975			CY 1976		
Imports	252	253	0	480	483	153	165	160	278
Farm Sales	1805	2192	2230	2095	2429	2294	NA	2497	2427
. Government	756	623	641	780	524	654	789	672	779
. Private	1049	1569	1589	1315	1905	1640	NA	1825	1648
Urban Purchases	2781	2534	2643	2567	2563	2585	2621	2395	2624
. Government	1092	937	572	484	523	1021	687	484	1160
. Private	1689	1597	2071	2083	2040	2564	1934	1911	1464
Human Consumption	4390	4180	4152	4354	4113	4215	4391	3962	4185
. Average per-capita*	127	121	120	123	116	119	121	110	116
- Urban Consumption	2757	2617	2610	2567	2522	2619	2621	2427	2634
. Average per-capita*	130	125	125	119	117	122	117	108	118
- Farm Consumption	1665	1563	1542	1787	1591	1596	1770	1535	1551
. Average per-capita*	123	115	114	129	114	115	128	111	112

Table 8.10. Grain Management Special Accounts.

Unit: billion won

Line Item	Baseline Run Results				Policy alternative Results				Comparison of Run Results			
	A Rice	B Barley	C Wheat	D Total	E Rice	F Barley	G Wheat	H Total	E-A Rice	F-B Barley	G-C Wheat	H-D Total
	Results for Calendar Year 1974 (Abbreviated Analysis)											
Revenues	141	43	-	184	93	43	-	136	-48	0	-	-48
Expenditures	172	50	61	283	139	51	61	251	-33	1	0	-32
Stock Changes*	-16	21	-	5	12	21	-	33	28	0	-	28
Account Changes	-47	14	-61	-94	-34	13	-61	-82	13	-1	-	12
	Results for Calendar Year 1975 (Detailed Analysis)											
Revenues	101	45	-	146	199	45	-	244	98	0	-	98
- by-product sales	1	2	-	3	1	2	-	3	0	0	0	0
- product sales	100	43	-	143	198	43	-	241	98	0	-	98
Expenditures	202	75	18	295	190	75	20	285	-12	0	2	-10
- domestic purchases	117	47	-	164	159	47	-	206	42	0	-	42
- foreign purchases	70	14	-	84	15	14	-	29	-55	0	-	-55
- subsidies†	-	-	18	18	-	-	20	20	-	-	2	2
- grain operations	15	14	-	29	16	14	-	30	1	0	-	1
(handling)	(11)	(10)	(-)	(21)	(13)	(10)	(-)	(23)	(2)	(0)	(-)	(2)
(processing)	(2)	(1)	(-)	(3)	(1)	(1)	(-)	(2)	(-1)	(0)	(-)	(-1)
(storage)	(2)	(3)	(-)	(5)	(2)	(3)	(-)	(5)	(0)	(0)	(-)	(0)
Stock Changes	-44	48	-	4	-23	48	-	25	21	0	-	21
Account Changes	-145	18	-18	-145	-14	18	-10	-16	131	0	-2	129
	Results for Calendar Year 1976 (Abbreviated Analysis)											
Revenues	114	35	-	149	269	35	-	304	155	0	-	155
Expenditures	45	74	10	129	287	76	10	373	242	2	0	244
Stock Changes	-113	12	-	-10	42	12	-	54	155	0	-	155
Account Changes	-44	-27	-10	-81	24	-29	-10	-15	68	-2	0	66
	Summary Results for 3-Year Period 1974-1976 (Abbreviated Analysis)											
Revenue	356	123	-	479	561	123	-	684	205	0	-	205
Expenditures	419	199	89	707	616	202	91	909	197	3	2	202
Stock Changes	-173	81	-	-92	31	81	-	112	204	0	-	204
Account Changes	-236	5	-89	-320	-24	2	-91	-113	212	-3	-2	207

* Difference between opening and ending inventories valued at period-end prices.

† Table does not reflect policy change in wheat subsidies made in early 1976.

Major line items in the table are (1) revenues, (2) expenditures, and (3) stock changes. Net account changes are also indicated for each year and are simply revenues minus expenditures plus the value of stock changes. The table gives run results for rice, barley, and wheat accounts. A total accounts column is also given. In 1974, the table states that the baseline run indicated a 94 billion won (approximately $US 235 million) loss in total grain accounts. The policy alternative run indicated an 82 billion won loss in total grain accounts for 1974. Comparing these results, the table states that a 12 billion won saving was indicated in the policy alternative run for 1974. Summary results are also given for the three-year time period of the test. Table 8.10 states that a 207 billion won (approximately $US 431 million) saving was indicated in the policy alternative run results for the three-year period. A 212 billion won saving (under the policy alternative) is indicated in the rice account over the three-year period, while barley and wheat accounts show three and two billion won losses, respectively.

The saving in the rice account indicated in Table 8.10 is derived from two major sources: (1) delayed sales of government grains at increased prices, and (2) differences in import levels and in changes of stock levels. Some overall savings are indicated in grain operations costs for the three-year period; but, as can be seen in the table, the policy alternative run actually resulted in greater cost of grain operations in 1975.

Credibility of Results

A brief review of the comparisons between the two test runs has been given. More analysis of the results would be necessary to

form a sound judgement regarding the credibility of the results if the model were being used in a real world decision process. Evidently, as indicated by the model, the government may have realized major savings between 1974 and 1976 by undergoing an import policy similar to the one studied in the policy alternative. There are also indications that the government may have been delinquent in making upward adjustments in rice release prices. These price increases are implied by the delayed releases that occurred after price increases were already in effect. The increased release prices did not seem to hinder the effect of government releases on urban rice price control.

The reader, no doubt, has begun forming his own opinions and questions regarding the results of this test example. If he were working with the GMP he would undoubtedly ask for more analysis or alternative runs to help substantiate his interpretations and answer questions brought to light here. Such activity is what the GMP model is all about--relieving the user of the drudgery of calculation while, at the same time, lending insight into the complexities of managing the food grain system.

This concludes the discussion on model verification. Hopefully, through the discussion and demonstration tests (and Appendix A) many of the tangible qualities of the GMP model have been shown and verified. Model accuracy in tracking historical data has been revealed in an objective manner. Much improvement can be expected through finer tuning of model parameters. However, even with this level of accuracy, the model has been shown capable of producing information that may be very useful in the real world decision-making process--right now!

CHAPTER 9

CONCLUSIONS AND RECOMMENDATIONS

Introduction

Set forth in a summary by themselves, a list of GMP model capabilities can appear quite impressive--even to model designers. But progress is not driven by satisfaction. Dag Hammarskjöld wrote in *Markings*:

> Never let success hide its emptiness from you,
> Achievement its nothingness,
> Toil its desolation.
> And so keep alive the incentive to push on further,
> that pain in the soul which drives us beyond ourselves.

In this chapter a conscious attempt will be made to " . . . keep alive the incentive to push on further, . . . " by providing an objective review of model capabilities and limitations. Further research is the means to model success, and model success is (in the end) measured by the extent to which it is used and is useful in the real world decision-making process.

Capabilities and Limitations

The generalized nature of the GMP model, enabling its use in studying a wide range of important grain management program and policy issues, is probably its most distinguishing overall feature.[1] However, since the model is an abstaction of reality, it is necessarily limited

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[1]Another positive aspect of the overall model deserving mention here is its capability of accepting unlimited user-specified policy alternatives in studying various grain management issues.

in what it can do in studying any particular grain management problem. This section will pull into perspective the major capabilities and limitations of the current GMP model by describing model strengths and shortcomings in specific terms.

Model Strengths

A list of important grain management issues which the GMP model can address was given in Chapter 2. The list is repeated below for convenience purposes.

1. The timing and quantity of government grain purchases and/or releases in order to control farm and/or urban market prices.
2. Price and, hence, government subsidy requirements of government-regulated wheat flour.
3. Location, quantity, and movement of government-controlled grain stocks.
4. Quantity and scheduling of foreign grain imports.
5. Purchase and release price policies for government grains.
6. Seasonal price pattern policy objectives.
7. Government purchase programs for domestic grains.
8. Food grain self-sufficiency.
9. Planned food grain consumption levels and diet mixes of farm and urban consumers through relative food grain price control.
10. Foreign grain loan repayment schedules.
11. Grain milling extraction rates.
12. Warehouse construction and financing programs.
13. Storage and handling losses.
14. Impacts of grain management policies and programs on domestic food grain production.

Although designed to address a wide range of grain management issues, the current GMP model (as might be expected) is stronger in some areas than in others. The following discussion will review some of the areas where the current GMP model exhibits greatest potential.

Market price stabilization and control is no doubt one of the most important grain management issues facing decision makers in Korea. By no accident, much of the development and design of the current GMP model is aimed at this area of potential use. Both annual and seasonal price stabilization and control problems are addressed by the GMP model. The *generalized* demand-price analyzer (or GMP front-end mechanism) provides a computerized means for the study and development of annual food (grain) plans which must be formulated each year under the Grain Management Law. The mechanism not only provides a means of studying various food plans, but also indicates necessary market conditions which must exist throughout the year for the actual realization of a particular food plan under study. The mechanism enables the study of plans for various degrees of self-sufficiency and will indicate annual supply and price conditions in supplement grains necessary for the achievement of these self-sufficiency goals. Import planning is an integral part of the GMP front-end mechanism.

Seasonal price stabilization and control (by assuring adequate market supplies of food grains) is the means by which annual food (grain) plans are carried out. Annual food plans indicate average prices (and supplies) necessary for the realization of a particular food plan, but say nothing about how market prices should vary throughout the year. The *generalized* GMP model provides an analytical means for investigating a continuous range of alternative seasonal market price

policies for food grains. The detail provided by the multi-commodity demand models, interrelationships among commodity prices, the private marketing subsector, and system performance measurements of the GMP model allows for rational choices among alternative seasonal market price policies under study. Given desirable seasonal market price patterns for food grains (rice and barley) the GMP model is designed to prescribe government grain market activities (buying and selling) required to influence market prices to follow seasonal price policy targets.[2] When used in close conjunction with actual government grain operations, the GMP model can become an "on-line" grain management tool.

Korean experience demonstrates very strong interrelationships among food grain prices. Wheat flour price, unlike rice and barley prices, can be closely controlled by government-legislated price policy. This is because of the centralized nature of wheat flour supplies under tight government control. Therefore, government-regulated wheat flour price can become a powerful instrument for influencing market prices (and consumer demand) for rice and barley. The GMP model can provide the computerized framework for studying the impacts of alternative wheat flour price policies--and can also be used to prescribe wheat flour prices in conjunction with the timing and quantity of government rice and barley releases required for achievement of targeted market price policies for rice and barley.

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[2]Government policy of releasing mixed grains (i.e., rice and pressed barley mixed together) for market price control greatly complicates the problem of reflecting the real world system in the computerized model. Later in this chapter, a special section is devoted to discussing the importance of reflecting mixed grains in later versions of the GMP model.

Alternatives to past government purchase programs are of great interest to Korean grain policy makers. However, because Korea has very little experience with alternatives to traditional purchase programs (i.e., fixed government purchase price for a fixed period after harvest), there is a reluctance to try new programs. The GMP model provides the analytical framework to study and develop viable alternative purchase programs and offers an opportunity for officials to learn more of the expected consequences of alternative purchasing procedures before such programs are implemented into the real world system.

Another powerful feature of the GMP model is the ability to prescribe the importation schedules of foreign grains on a seasonal basis to be consistent with annual food plans and conscientious grain reserve programs. The GMP import control mechanism can be used to control government seasonal food grain stock levels to more acceptable ranges than have been observed in the past.

Alternatives to government grain handling and logistical policies can be studied and developed through the use of the GMP model. The analytical detail used in simulating grain processing, storage, transportation, and position point inventory management, along with detailed cost accounting, makes the GMP model a potential tool for feasibility studies of alternative government grain handling procedures.

The optional production response mechanism of the GMP model can provide decision makers with valuable system performance criteria by which alternative grain management programs and policies can be judged--namely, the impacts on farm production decisions.

The government warehousing component is more applicable to longer runs of the model, but does offer detailed analysis of grain storage losses by warehouse class, forms of grains stored, and locations of types of warehousing facilities.

Model Shortcomings

The above list of important grain management issues which the GMP model can address could be countered with another list of model shortcomings for each entry, and, regrettably, this list could go on with many grain management issues which the GMP model *cannot* address. For example, the GMP model is not designed to address the following types of issues.

1. Presale mixing and mix ratios of government-controlled rice and barley.
2. Geographic differences in farm price supports and/or controlled market prices.
3. Inventory or shipping order management and accounting by individual warehouse.
4. Price differentials by grain qualities.
5. Food and feed grain commodities beyond rice, barley, and wheat, such as pulses, potatoes, maize, etc.
6. Distinctions among varieties of food grains (except in the production response mechanism).
7. Long-run food grain policies and programs (i.e., beyond two to five years).
8. Distinctions among food grain products, i.e., baked goods, noodles, alcohol, confectionaries, and other processing beyond milling and/or pressing.
9. Impact of food grain policies and programs on the remainder of agricultural sector (e.g., supply and demand of all agricultural products).

Obviously, this list can go on, depending on the level of appreciation the reader has for the diversity and complexity of the

food grain management problem in Korea. In the following section, some important and challenging topics for further research into the grain management problem in Korea will be discussed. Further work and model development in any of these areas will serve the useful purpose of enhancing the realization of the objectives of the model set forth in Chapter 2 of this dissertation. Before describing these suggested further research topics, however, it may be well to discuss some important lessons learned in Korea.

Lessons Learned

A running controversy exists between those who support the *total* system concept, subscribing to the belief (and rightly so) that a system is the product of *all* its components and the interrelationships among them; and those who are content with the *partial* system concept. The former are impressed with huge generalized models, such as the GMP and KASS models, which attempt to reflect all significant system interrelationships and address themselves to a wide range of problem issues. The latter tend to be more impressed with simpler (easier to work with) models which omit many of the detailed considerations of larger models. Credibility, in the broad sense, is easier to gain with the larger models than with the simpler models because, if rejected for omission of relevant factors and detail, the credibility gap is simply closed by adding the additional factors and detail to the model. Concerning the descriptions and complexities of large simulation models (like the GMP), it has been written [42]:

> . . . descriptions of the (GMP) model are messy, and lack what the mathematician calls "elegance" and what the theorist means when he says "a model is beautiful." Fortunately, such models are often *acceptable* to decision makers because a messy general model (1) can correspond

> to the messy real world in which decision makers operate, and (2) can utilize the wide range of information typically considered by decision makers . . .

The author of this dissertation, because of his background and orientation, subscribes more to the total system concept. However, it must be said that the huge "messy general models" of the "messy real world" have their own price. This price is paid in terms of (1) development time, (2) unforeseen problems in design, (3) need for clear and detailed documentation, and (4) a lot of foot tapping by officials waiting for some results. Admittedly, mistakes were made in the development of the GMP; mistakes, however, in which valuable lessons can be learned.

The first major mistake was made by attempting to design the GMP model as an integral component of the already large and expanding KASS computer model. This required several modifications to the KASS model and placed many restraints on the original GMP design. Problems in shakedown testing of both models (the KASS model was also undergoing major development and design changes) appeared to be unending. After approximately one year of intensive effort to develop this supermodel, the effort was abandoned without a single execution of the merged model. This was a difficult decision in the design process, because it constituted an admission that prior efforts toward the merge had been unsuccessful. Many of the inputs and outputs thought available through the KASS model then had to be developed for the GMP model, committed to operate independently. The writer believes that this willingness to back down from the *total* system approach, by pulling the GMP model out of the larger KASS model and developing it as an independent model, was truly a right decision. In retrospect, looking over the development

problems which actually occurred in both models since the pull-out of the GMP model, it is doubtful if the supermodel would ever have operated.

The second major mistake during the development of the GMP model was the ever-present tendency to push model expectations ahead of model development. Rhetoric is very easy to produce on an intangible concept. Much effort lies between an elegant concept such as that of the GMP and its realization as a computable simulation model. The author is pleased with the GMP model in its current state of development and, being one who knows best its capabilities as well as its limitations, would give it a respectable overall credibility rating--better than any other model or analytical capacity for addressing grain management problems in Korea today. The author does regret, however, what history now reveals was the path taken to bring the GMP model to its current state. An excess of rhetoric about the general system simulation approach and the impending GMP model's capability to "do it all" pushed model expectations way ahead of development. Officials who were anxious to see model results could only be furnished with what was available--more rhetoric which, in turn, pushed model expectations further ahead of development.

A KASS project evaluation instituted by USAID in 1974, including a special evaluation of the GMP model [40], proved constructive in many ways but succeeded in pushing model expectations again way ahead of current development at the time. A rudimentary GMP model version [16] was becoming operational at the time of the KASS project evaluation. After the evaluation, major design changes and much more detail were incorporated into that version of the model which (instead of becoming operational in its time) served as a nucleus for further design

expansion. This process of model development chasing model expectations continued throughout the project from mid 1972 to mid 1975 when the current version of the GMP model began to operate on the computer as a fully integrated system simulation model. Troubleshooting, validation, verification, and hand tuning of the integrated computerized model took much of the remainder of 1975. Again, exaggerated expectations for the GMP (and tremendous pressure for application of the model) kept efforts on the model pushing to close the gap between the current state of the model and the high expectations of government officials. In February 1976 pressures due to the impending departure of MSU personnel finally "forced" a formal demonstration of the GMP model and its results [18]. The demonstration did much to establish true model credibility, but, just as feared, a gap still remained between Korean officials' expectations and the current state of the model.[3] Although consensus of all project personnel was not mutual, the feeling of the author, who presented the results to Korean officials throughout the Ministry of Agriculture and Fisheries, was that the first (and only) real exposure to the total GMP model was met by an air of disappointment.

It is doubtful, had the approach to the current GMP model been different, that a "better" GMP model could have been developed. The real mistake, it seems, was the failure to create and *maintain* an operational GMP model, however crude, early in the project. Of course, such a model would not have done much, but at least it would have done something--more than the current GMP did during its development.

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[3]Model results demonstrated were much the same as those documented in this dissertation, as very little model work has taken place since departure from Korea in March 1976.

Initial credibility, expectations, and (mostly) material for rhetoric would have suffered a severe jolt, but this could have been regained as government officials became more and more familiar with an advancing *operational* GMP model. A bit of a dilemma does exist here, however. Maintenance of an operational version of a system model throughout its development would require continuing effort and resources. Spent on this, efforts toward model developments, innovations, and expansion would have to be severely compromised. The results in Korea may well have been a much cruder GMP model as a final product, but a model which was more usable because of familiarity of users, and a model that caused no surprises in the end.

Two conflicting needs displayed themselves in Korea: (1) the need for isolating creative model research, development, and refinement from pressures for premature application; and (2) the need for model operation and application to real world problems (whatever the state of development of the model). Much to the benefit of the author, whose interests were best served on the research and development side of the GMP, the first of these needs (isolation) was granted to a large extent. There were real application needs for the GMP during its development, however, which had to be satisfied. These needs largely involved recommendations for government purchase price policies for rice and barley. Several periodic studies on this recurring problem utilized portions of the GMP model (mainly the front-end mechanism) which were operationalized [45] and applied to the existing problem situations [23, 24, 25, 26]. Even with this involvement in practical application, it must be said that the former needs for model development isolation were served, at much sacrifice to the later needs for application. The author can

express regret for this, but cannot bear full responsibility. Satisfactory realization of both these needs was not possible in Korea, given qualified manpower assigned to the GMP. Both development and application are full-time tasks. With only one qualified staff member working full time with the GMP throughout the Korean project, the fact that compromises had to be made in the extent of model application should not be difficult to understand. The tasks of operationalizing, testing, interaction with users, institutionalization, and application of the GMP model (with *no* further development) could well have been a full-time job for the author (or an equally qualified person), using a much earlier version of the GMP model, say, from early 1974 [16] until his departure in 1976.

In concluding this section, it is strongly recommended that future research, development, and application of the GMP model bear in mind the lessons learned to date.

(1) Models the size and complexity of the KASS and GMP *demand respect;* they are difficult to work with, and they are difficult to keep working. Major modifications can spell unimagined difficulties for the most qualified personnel. The ideal supersimulation model (e.g., KASS/GMP) may bear "costs" in the form of problems which far outweigh their "benefits" as fully integrated system models. Simply said, supermodels may not work [6]!

(2) Specialized problems, such as those addressed by the GMP model, are better served by specialized *independent* models (such as the GMP, with respect to an integrated KASS/GMP model). This lesson can also be applied to the existing GMP model

and further specialized GMP problems. A system of independent GMP models will be discussed later.

(3) Development and application are two major research tasks. Although both are necessary, there must be some isolation between them. Development is needed to create the concept and computable model, while application is needed for problem solving and model refinement. Each of these tasks offers several challenges for future GMP research.

Suggested Research Topics

Prior to beginning the discussion of further research topics for GMP model improvement, some general comments are necessary.

Just as with the KASS model [2, 41], the GMP model denotes a problem-solving concept and approach, with no part or aspect of it considered impeccable. The true glory of the GMP model is in the eclecticism of its approach to a real world problem situation and not in the content of the model itself. It is quite certain that if vigorous work continued on GMP model development, refinement, continuing modernization, and adaptation into the decision-making process--the structural content of new-generation models would evolve into modifications totally unlike the current version of the model. Such a phenomenon has already taken place in the development of the GMP model to its current state. The current version of the GMP model is judged *best* (in terms of capabilities, accuracy, theoretical base, convenience, output design, being in tune with current grain management problem issues, and overall credibility) among all previous versions of the model. And this should be the basis of judgement of future-generation GMP models--change is inevitable and improvement is the goal.

Computer Program

The computer program of the current version of the GMP model is fully operational. That is, it has been completely debugged, validated for logical consistency, and verified as an adequate representation of its mathematical model counterpart. The program is a 36th generation updated version of the original GMP computerized model and has evolved from all model testing, refinements, and modifications to date. Of course, the program is large, containing approximately thirty common blocks of variables and over seventy subroutines. An abbreviated listing of the program (single spaced and without common blocks listed) requires over 150 pages of computer printout and contains approximately 7500 lines of print. Zymurgy's First Law of Evolving Systems Dynamics and others such as Murphy's Law[4] have held true in the GMP case. Zymurgy's Law states that:

> Once you open a can of worms, the only way to recan them is to use a bigger can.

The current GMP computer program, representing so many modifications and expansions, must be considered a bench test version of the model. Although credited with producing valid results, it might be described in computerbabble as somewhat of a kludge. It is strongly felt that a complete reprogramming of the model at this juncture, before further development continues, would pay dividends in terms of computational efficiency, reducing pressures on core limits, and easing further development modifications. This streamlining of the model should be

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[4]Murphy's Law states that if anything can go wrong, it will. Both these (unnatural) laws were taken from Arthur Block's book, *Murphy's Laws--and Other Reasons Why Things Go Wrong* (Los Angeles: Price/Stern/Sloan Publishers, 1977).

considered no trivial task, and would likely take several months for a well-qualified computer programmer intimately familiar with the GMP concept and mathematical model to complete and verify. The writer feels that completion of such a task, along with user documentation, should satisfy university requirements for a master's degree thesis.

GMP Model Application

As revealed earlier, the current operational version of the GMP model has had very limited exposure--in terms of demonstrating its capabilities and application to real world grain management problems. The reason for this was explained as the necessity for isolation between creative development and practical application. A logical sequence of events puts development before application. Manpower limitations and high model expectations have been cited as factors prohibiting more application of earlier versions of the model.

Positioning ourselves in the present moment, turning our backs on any future GMP model activities, and viewing the GMP model with hindsight only, it is not difficult (at least for the author) to pass some judgements on the "success" of the GMP model. Current GMP model development, as evidenced by the operational computer program designed and attuned to address real world grain management problem issues, should be given a relatively high "success" score. Judged in terms of actual demonstrated application to real world problem situations (for which it is designed), user familiarity, degree of institutionalization [41], and playing an active role in the real world grain management decision-making process, the current operational GMP model (viewed in retrospect only) can be given nothing more than a failing score. Since overall model success must be judged on all aspects,

should no future model activities be undertaken, the GMP model must be termed a failure--a waste of time, effort, manpower, resources, and thousands of dollars in costs. A failure--yes--but only to the extent that work is terminated on the current operational version of the model.

Much room exists for future research in model expansion, but such activity must not take precedence over current model application and refinement. The GMP model is a reality (now) in its current form. It is computerized, debugged, validated, parameterized, and verified to a large extent--it works! It must now be put to work to demonstrate its full potential as a powerful analytical tool. Many people must become *familiarized* with the GMP model, not so much in terms of its theoretical base or potential application, but in terms of what the model can actually do. Model refinement was included with model application above because all application work with the model perpetuates refinement. Most of this refinement should be limited to improving model accuracy (through improved parameterization) and providing improved user-model communications. Refinements to expand current model capabilities, detail of analysis, etc., should not be undertaken in this effort. Just as development must be isolated from practical application, application as suggested here must be isolated from new development beyond the refinements mentioned above.

To put this task of model application into a proper perspective, some further discussion is needed. Model application can proceed on several issues as described in Chapter 2, but involves much more than making a series of computer runs and documenting the results of these runs. Researchers must apply the GMP model to real issues (such as

price stabilization or control, alternative purchase programs, alternative pricing policies, alternative food plans, alternative grain management procedures, etc.) and draw credible inferences from the model results. Application research with the GMP model should produce a number of documents or study papers, all of whose titles could begin with the words "Recommendations for Alternative . . . ." Model run results can be used for the bases of these studies, to furnish the analytical framework, and provide a consistent set of criterion measurements upon which recommendations can be founded. Just as importantly, the GMP model results should raise insights and questions into the real world system (such as occurred in the test runs of the previous chapters). The "clarity" quality of the model would then have to be utilized to provide explanation, give credibility to the model results, and hopefully bring attention to many important subtleties and interrelationships of the real world grain management system which are normally overlooked.

The model application process should continue, beginning with special studies such as mentioned above, providing documented model results and recommendations. These studies, if performed by graduate students or other researchers in the university environment (outside Korea), would have to be more involved with providing substantial evidence that past grain management policies and programs could (and should) have been different for more desirable outcomes. These "what if"-type studies, even though performed on past historical periods, can (if considered credible) provide a direct influence on current grain management policy and program development. In-country applications of the GMP model are also necessary. Applications do not have

to involve huge, intriguing, or radical changes in current grain management policies and programs. Simple uses of the model, such as continuing its use for recommending government purchase and release prices, can do much to increase model exposure to decision makers. Studies of alternative food plans can provide useful inputs to this annual government decision process. Studies for alternative purchasing programs for government rice and barley would certainly generate much attention on the GMP model and probably reveal some very interesting and surprising results.

So, regardless of the type or scope of the application research with the model, it will all serve the very important requirement for increasing GMP model familiarity among potential users. Familiarity is required for model credibility among decision makers and credibility here is prerequisite to model adoption into the decision-making process. All this takes time and much concentrated effort by model researchers, but the end results should serve to "balance" the scores between model development and applications and spell great "success" for the current operating version of the GMP model. The real heroes in the GMP story will be those who *utilize* the model to bring about improvements in the real world decision-making process.

Automatic System Parameterization

Probably the biggest improvement in the current (or future) versions of the GMP model can be realized through "automatic system parameterization." Scores of 'tuning knobs' in the form of system parameters are available in the GMP model to tune the system to produce realistic outputs. As discussed in Chapter 8, model parameterization to date has proceeded on the basis of trial and error and off-line

research. Regression packages were utilized in arriving at estimates of behavioral parameters for consumptions, marketings, and production decisions, but only hand-tuning processes were used to bring the integrated system model to its present state of accuracy. As evidenced in the previous chapter, the model does demonstrate the ability to track historical data to a fair degree of accuracy. Time and trial are the instruments which can be used to determine if the level of accuracy of the model is sufficient. Model designers would hesitate strongly to say that current model accuracy, as evidenced by historical tracking, is adequate. Although even in its current state of tuning, it is felt that the GMP model can contribute to the formulation of sound grain management policies by enhancing the insights of decision makers into the complex interrelationships of the real world grain system. This is a positive viewpoint regarding current model accuracy, but the fact still remains that improved accuracy is a desirable goal and would do much in establishing model credibility, especially in the eyes of potential users and those responsible for committing resources to adopt the model into the decision-making process.

Having performed all model-tuning efforts to date, the author feels that current model parameter values represent good ballpark figures but are far from forming an optimum set of values. Furthermore, hand tuning has most likely proceeded as far as feasibly possible to improve accuracy. The process is much like punching a pillow, wherein model accuracy is gained for a few variables but lost in others as further hand-tuning attempts are made. Initial hand-tuning efforts yielded great improvements, but there seems little to be gained by further hand-tuning efforts. The author feels that the system

flexibility for improved tracking is present, but the interrelationships are too complex for additional hand tuning to yield much improvement.

The next logical step to improve GMP tracking accuracy would be to utilize an available computerized optimization package, such as that developed by Buchner [7, 8]. The general procedure would be to 'strip' the model for maximum running efficiency and then choose a priority subset of system parameters, say, ten to fifteen, to be optimized. Recall that Table 8.6 identified a selected set of model parameters (with priorities indicated) that would be good candidates for initial optimization efforts. Table 8.7 identified selected output variables which should be included in an objective function for optimization (see Equation 8.4). Seasonal market price generation, of course, represents the biggest tuning challenge and should be included in the objective function. So important are these functions that consideration should be given to optimize model tracking performance around price generation alone. Market prices are extremely sensitive to the urban subsector price elasticities of consumption. These parameters might also be considered for optimization after initial efforts are made on other parameters. Recall from Figure 8.6 that twenty-seven price elasticities are involved in the urban (and farm) consumption function.

Computer costs for automatic system parameterization efforts described in this section could be extremely high. Substantial financial support would be needed before this important research effort could be undertaken.

User-Oriented Language

Because of its size and complexity (or perceived complexity), the GMP model must overcome the difficulty of interaction with potential users with various levels of model understanding. Competent policy decisions must be based on a sound understanding of the real world grain system, but do not necessarily depend on the decision maker being intimately familiar with all the "ins and outs" of the model itself. A user-oriented Policy Analysis Language (PAL), developed as part of the KASS project [49, 50, 51, 52], would be well suited for full adaptation to the GMP model. This would greatly enhance accessibility to the model for many nontechnical people and serve to create much more user/model interaction and familiarity.

A System of Specialized GMP Models

One of the major lessons learned with the GMP model experience is that large simulation models made bigger can spawn many difficulties which bear on size alone. The current version of the GMP model is an integrated model operating under *one* computer program. The author feels that this was a 'right' approach to developing the GMP model to its current state: capable of addressing a wide range of grain management problem issues. Future research and model development may be concentrated on specific problem issues, such as market price stabilization, government warehousing problems, developing annual food plans, studying the effectiveness of government mixed grains (and various mixed grain ratios), studying longer range grain management planning (say, five years or more), etc. These 'special' interest research topics will undoubtedly require additional development of specific components of the current GMP model, or development of

brand new components, if the specific issue being considered is not currently addressed by the model.

Recall now from Figure 2.1 and the discussion surrounding that figure, that the GMP model is considered a supplementary component of the KASS model. Both models are comparable in size and complexity--the KASS model being broader in scope, but shallower in analytical detail (in grains) than the GMP model. The same type of figure can be envisioned for specialized GMP models of the future, which can be considered supplementary components of the original GMP model concept. Even with the current version of the GMP model, much of the model detail is superfluous to the study of specific grain management issues. For example, a smaller and more suitable model could be designed for studying seasonal price control policies alone, and yet yield the same pertinent information provided by the current GMP model.[5] Such a specialized model would serve as a nucleus of further model development aimed specifically at this issue. The evolutionary processes of model design would then work toward producing a *specialized* Price-Control GMP model better suited for studying price control and stabilization issues than the current *generalized* GMP model.

Many grain management issues require longer run durations than are practical with the current version of the GMP model. A specialized Long-Run GMP model could be designed which would be better suited for this purpose. Many of the longer run features of the current GMP model could be transferred to such a new model, easing its initial development. When run over longer simulation periods (i.e, five to

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[5]Initial design for such a specialized model could draw heavily on the relevant portions of the current GMP model concept and design.

ten years), these already developed features could then deliver more of their problem-solving potential than is currently realizable. Listed below are some of the transferable features of the current GMP model.

- annual demand models
- front-end mechanism
- foreign grain repayment scheduling
- production response mechanism
- concepts of private and government marketing channels
- private market demand and supply functions
- many accounting and other output features
- warehousing component
- modified dynamic pricing and transaction mechanism
- other relevant features and concepts applicable to longer run durations

Some important grain management issues that could be better addressed by a specialized long-run GMP model are listed below.

- long-range food plans
- long-range food grain price policies
- food grain considerations in the development of Five-Year Economic Development Plans
- self-sufficiency plans and implications
- warehouse construction programs
- foreign grain repayment schedules
- dynamics of private marketing channel grain handling capacity and implications

Price Control Mechanism: Mixed Grains and Decoupling

Market price stabilization and control is one of the most important food grain management issues in Korea. The current version of the GMP model addresses this issue, but further research and development of this aspect of the model would greatly enhance its credibility and usefulness as an analytical tool in dealing with this very real problem. Two important real world phenomena, related to seasonal food grain price control, are not included or are underdeveloped in the current version of the GMP model. These considerations which require further research work are (1) the phenomenon of mixed grains, and (2) price decoupling in the design of the GMP price control mechanisms. Since the early 1970's, a portion of government grain releases has been in the form of a rice/(pressed)barley mix. Various mix ratios have been used in these releases with a 70/30 (rice/barley) ratio being used during 1975-1976. The proportion of total government rice released as mixed grain has increased since the initiation of this program, and by mid 1974 all government rice releases were in the form of mixed grain. A portion of government barley releases was in the form of pure barley. Strong coupling effects are evident in market food grain prices; changes in rice (or barley) prices can result in significant changes in barley (or rice) prices through this price coupling effect.[6] It therefore stands to reason that an effective

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[6]Wheat flour prices are established through government policy, since essentially all wheat flour supplies and sales are under strict government regulation (see Chapter 4). Therefore, no price coupling exists between changes in market prices of rice or barley--and wheat flour prices. On the other hand, strong coupling effects are evident between change in wheat flour price (policy) and the market prices of rice and barley.

price control system would be one that could compensate for these price coupling effects. For example, in controlling urban rice price, the mechanism would prescribe government rice releases for control of urban rice price and, at the same time, prescribe compensating barley releases to cancel the coupling effects these rice releases had on barley price.

Recall from the description of the GMP price control mechanism in Chapter 5 that the current GMP model is structured for prescribing decoupling compensation such as described here; but as indicated in Table 8.2, the compensating gain parameters (off-diagonal elements) of the controller gain matrices are assigned zero values, thus deactivating the decoupling mechanisms. Valid parameterization of these control gain elements is an immediate challenge for further research work with the GMP model; however, the mixed grain phenomena in Korea severely complicates the problem.

Mixed grains are found in government marketing channels only and are essentially a unique food grain commodity. Consumer preference for mixed grains is somewhere between their preferences for pure rice and pure barley, depending on the mix ratio and quality of grains making up the mix. Mixed grains normally contain a relatively high portion of Tongil rice and foreign imported rice, both considered inferior to ordinary Korean rice varieties available through private marketing channels. Government price control programs using mixed-grain releases are actually using the coupling effects among food grain commodities to bring about changes in market prices--government mix is released in an attempt to control private market price of pure (ordinary) rice varieties. The mixed-grain release policy also places constraints

on the compensating releases, although, as mentioned earlier, pure barley is still released by the government.

Indeed, there is a need for more challenging research and development of the GMP price control mechanism. Evidently, mixed grains have become a permanent food grain commodity in the Korean grain system and should be included in the GMP model. The design of valid decoupling networks in the price control mechanism is also needed, since the real world system actually operates on the coupling effects. Wheat price (controllable through government policy) plays a very important role in market prices of rice and barley, and should become an optional control variable of the GMP price control mechanism. Noninteracting control of multivariable linear systems is addressed in several pieces of modern control literature [5, 11, 12, 19]. Research in this area of the GMP model could draw heavily on much of this work. Appendix B contains some notes on the derivation of demand elasticities for rice/barley mix under certain assumptions.

Further Model Disaggregation

So far, the discussion on suggested research topics has been careful to set priorities in order to capitalize on GMP development to date. Top priority must be placed on research which will not balloon the size and complexity of the current GMP model before it can be brought to its full *operating* potential.

Model disaggregation is a means of enhancing model realism, lending it more applicable to real world problems and situations. However, model complexity and size can be greatly compounded by disaggregation which must be approached with caution. Some further

disaggregation does seem warranted in the GMP model and will be discussed in this section.

Regionalization

The GMP model is disaggregated by market position points, but not by geographic region. Three major regions are identified in the KASS model and, if also identified in the GMP model, would enhance model quality considerably. Caution should be used in this disaggregation effort to make certain that regionalization occurs only in those portions of the model where it is essential. First priority for regionalization is the farm subsector component.

Farm production response can be more accurately modelled with a regionalized farm subsector component. Tongil and other new rice varieties with different production and yield characteristics can be associated with specific geographic regions. Common barley, naked barley, and domestic wheat can also be associated with specific geographic regions. Regionalization could also be extended to the other subsectors of the model with some benefit to model quality. However, the author is not able to offer a strong argument in which the additional model benefits would be worth the "costs" of such an expansion in model complexity. Regionalization of specialized GMP models, say, for addressing grain logistics problems, seems a much more reasonable approach.

Tongil Rice

Tongil rice is identified explicitly only in the production response mechanism of the GMP model. Since it is so different from native rice in expected yield, production characteristics, consumer

preferences, price, milling characteristics, etc., it should be identified as a separate commodity throughout the entire GMP model.

Wheat Flour Products

Currently, industrial (imported) wheat is handled by the GMP model under a single commodity grouping. Essentially all this wheat is milled into flour by the Korean Flour Millers Industrial Association (KOFMIA) and then moves into further processing and ends up on the (farm and urban) consumer markets as bread, cakes, noodles, condiments, household flour, makoli, and other products. To improve the performance (and credibility) of the food grain demand models representing the interrelationships between rice, barley, and "wheat" demands and their respective prices, "wheat" should be broken down into major wheat product categories.

Farm Size

Domestic production, farm storage, farm consumption, and farm marketing behavior are strongly related to farm size. Great improvement in the quality of all aspects of the farm subsector component can be expected with this additional disaggregation dimension in the model. Farm marketing functions of the model should improve greatly. Grain management policies and programs have quite different impacts on farms of various sizes. Measurement of these impacts should be of great interest to potential model users.

Optimizing Capabilities

There are areas within the current GMP model structure and dynamics in which optimizing routines could greatly enhance the quality and usefulness of the model. With such routines available,

the model could better address questions related to lowering total average costs, reducing storage losses, improving operations efficiency, etc. A great improvement to the current demand-price analyzer (front-end mechanism) would be to develop and implement a linear programming mechanism for optimizing grain importation schedules (i.e., Korean food grain diet mixes) with respect to changing relative world food grain prices. This LP model would have to be constrained by maximum 'tolerable' consumption rates (policy inputs) of inferior food grains such as barley. The effective world price of wheat also varies greatly with repayment schedules such as those under PL480 shipments. This optimization capability would provide a solid analytical linkage between domestic food plans and changing world grain prices, as well as U.S. grain surplus programs.

Overview and Comments

This dissertation has provided written documentation of the research, development, and testing underlying the design configuration of a generalized system simulation model for the management of food grains in the Republic of Korea. As indicated in Chapter 1, the need for such a model has been evident throughout the history of the Republic, and little evidence exists which supports a notion that critical grain management problems will cease being a major concern to the Korean people in the foreseeable future. In Chapter 2, the GMP model concept was introduced and described in general nonmathematical terms. The objectives of the model were carefully stated, but not in such a way as to impinge on the generalized nature of the model design. Chapters 3 through 7 were used to describe the mathematical equations and interrelationships used in the design of the GMP model. These

five chapters contain several hundred equations, accompanied by a narrative description of the real world system phenomenon being modelled by essentially every equation. This style of documentation is typical (and necessary) for models using the general system simulation approach [31]. Chapter 8 discussed credibility in terms of the GMP concept, the mathematical model used to represent the GMP concept, and the computerized GMP simulation model used to calculate solutions to the mathematical model and produce model results. In this final chapter, an attempt has been made to summarize some of the capabilities and limitations of the current GMP model, and provide some recommendations for further important and challenging research. Lessons learned in this effort were brought to light in hopes that similar efforts in the future can benefit.

Contained in these pages is a report on what has been a difficult piece of research. Difficult, not in the sense of developing any new, high-powered, or sophisticated systems theory--but difficult in the sense of application of already existent techniques in the synthesis of a system model to fit the pressing needs of a very complex *real world* problem situation. The hard reality of the problem topic undertaken by this study, and severe demands on the model design (and performance) from the beginning to keep it out of the clear blue sky and down to the "messy" real world, have presented the biggest challenges.

The real success of this dissertation will be measured by the extent it can establish credibility for the GMP model and is able to convince people that work must continue. Wherever the work continues--either in model implementation and application in Korea, or in further development and refinement--the costs of this work will be great.

Researchers interested in carrying on this work will require considerable financial support. Although accurate figures are not available to the author, total KASS project costs directly attributable to the development of the GMP model undoubtedly exceed $150,000. (This figure represents roughly 10 percent of the total KASS budget.) This is a high cost of development, but hardly measurable compared with the saving that could be realized through more effective and consistent grain management in Korea. The model has already indicated that savings in the order of $100 million per year are possible through simple alternatives to current grain management policies. So, again, the real "success" of this dissertation will be measured by the extent it is able to " . . . keep alive the incentive to push on further, . . . " and give the model the chance it deserves--to serve as an analytical tool to help decision makers in the realization of a more effective grain management system.

APPENDICES

APPENDIX A

GMP OUTPUT TABLES FOR TEST RUNS

APPENDIX A

GMP OUTPUT TABLES FOR TEST RUNS

This appendix contains supplemental GMP output tables from the two GMP verification test runs documented in Chapter 8. The primary purpose of providing this additional material is to illustrate further the kinds and types of model output information available from the current version of the GMP model. Eight output tables are provided from each of the two model runs. The historical tracking run is referred to as Run A, and the policy alternative run (urban price control, etc.) is referred to as Run B. For ease in comparison, Run A and Run B results for each output table will appear sequentially. The following is a list of the eight output tables (two each) contained in this appendix.

A.1. Grain Management Special Accounts (CY1975)

A.2. Private Market Grain Accounts (CY1975)

A.3. Farm Accounting Table (CY1975)

A.4. Farm Production Summary Table (CY1975)

A.5. Food Grain Inventory Stock Summary Table (CY1975)

A.6. Urban Grain Purchases, Consumption, and Storage Summary Table (CY1975)

A.7. Price Policy Summary Table (CY1974)

A.8. Special Transaction Summary Table

Table A.1A. Grain Management Special Accounts (CY1975)--Run A.

GRAIN MANAGEMENT SPECIAL ACCOUNTS *(1975)*

	RICE	BARLEY	TOTAL
REVENUES(WON)			
1 GRAIN SALES	199,815,589,310.	42,720,062,127.	241,535,651,437.
2 BY-PRODUCT SALES	547,759,941.	1,311,656,760.	2,059,413,701.
3 TOTAL REVENUES	199,363,349,251.	44,231,718,887.	243,595,065,138.
EXPENDITURES (WON)			
4 GRAIN PURCHASES	174,405,423,030.	60,857,760,161.	235,263,183,191.
5 (DOMESTIC)	159,074,035,891.	46,613,761,263.	205,687,797,154.
6 (IMPORTS)	15,331,387,138.	14,243,998,899.	29,575,386,037.
7 GRAIN OPERATIONS	15,752,500,064.	14,204,737,211.	29,957,237,276.
8 (HANDLING)	12,753,188,354.	9,689,039,949.	22,442,227,802.
9 (PROCESSING)	974,803,202.	1,164,230,120.	2,139,033,322.
10 (STORAGE)	2,024,506,008.	3,351,528,143.	5,376,034,151.
11 WAREHOUSE CONSTRUCTION			18,246,174,113.
12 ADMINISTRATION			25,000,000,000.
12A WHEAT FLOUR SUBSIDIES			10,294,759,300.
TOTAL EXPENDITURES			
13 (GRAIN ACCOUNTS)	190,157,923,094.	75,062,557,372.	265,220,480,467.
14 (TOTAL GMSA)			281,466,654,580.
PROFITS AND LOSSES			
15 GROSS PROFITS	24,957,926,221.	-16,626,041,274.	8,331,884,947.
16 NET PROFITS	9,205,426,157.	-30,839,934,485.	-21,625,412,324.
16A VALUE OF SLC	-21,925,131,221.	43,037,711,694.	21,172,580,473.
17 NET CHANGES IN GMSA	-12,719,705,064.	17,266,873,209.	-15,199,005,968.

Table A.1B. Grain Management Special Accounts (CY1975)--Run B.

GRAIN MANAGEMENT SPECIAL ACCOUNTS *(1975)*

		RICE	BARLEY	TOTAL
REVENUES (WON)				
1	GRAIN SALES	100 049 270 823.	42 848 988 778.	142 898 259 601.
2	BY-PRODUCT SALES	1 359 459 996.	1 526 605 093.	2 886 065 088.
3	TOTAL REVENUES	101 408 730 819.	44 372 593 860.	145 781 324 679.
EXPENDITURES (WON)				
4	GRAIN PURCHASES	197 822 632 196.	69 750 123 396.	267 572 755 592.
5	(DOMESTIC)	117 396 103 035.	46 506 124 487.	163 902 227 522.
6	(IMPORTS)	70 426 529 161.	23 243 998 899.	93 670 528 060.
7	GRAIN OPERATIONS	14 764 575 393.	14 208 030 996.	28 972 606 389.
8	(HANDLING)	10 981 920 111.	9 702 615 814.	20 691 535 925.
9	(PROCESSING)	2 082 838 723.	1 175 742 852.	3 258 581 575.
10	(STORAGE)	1 699 816 559.	3 329 672 371.	5 022 488 889.
11	WAREHOUSE CONSTRUCTION			25 755 810 272.
12	ADMINISTRATION			250 000 000 000.
12A	WHEAT FLOUR SUBSIDIES			239 316 570 096.
	TOTAL EXPENDITURES			
13	(GRAIN ACCOUNTS)	202 587 207 339.	74 958 154 383.	277 545 361 971.
14	(TOTAL GMSA)			305 300 872 243.
PROFITS AND LOSSES				
15	GROSS PROFITS	-36 413 901 377.	-16 377 529 986.	-102 791 430 803.
16	NET PROFITS	-101 178 476 770.	-30 535 560 022.	-131 764 037 292.
16A	VALUE OF SLC	-44 434 548 618.	47 833 344 827.	3 458 735 209.
17	NET CHANGES IN GMSA	-145 613 025 387.	17 297 784 805.	-156 560 751 355.

Table A.2A. Private Market Grain Accounts (CY1975)--Run A.

PRIVATE MARKET GRAIN ACCOUNTING
(FOR CY 1975)

	RICE	BARLEY	TOTAL
REVENUES (won)			
1 GRAIN SALES	527 279 063 325.	27 018 035 578.	554 297 100 903.
2 BY-PRODUCT SALES	8 442 698 000.	1 965 489 194.	10 408 187 194.
3 TOTAL REVENUES	535 721 761 325.	28 983 524 772.	564 705 286 097.
EXPENDITURES (won)			
4 GRAIN PURCHASES	464 510 297 337.	56 479 176 407.	520 989 473 245.
5 GRAIN OPERATIONS	30 275 329 333.	8 561 401 175.	38 836 731 008.
6 (HANDLING)	12 345 088 158.	2 336 916 260.	14 742 004 418.
7 (PROCESSING)	7 159 496 140.	1 579 550 902.	8 769 047 041.
8 (STORAGE)	3 436 194 762.	2 590 211 148.	6 026 405 911.
9 (CREDIT)	7 234 550 773.	1 934 722 865.	9 249 273 637.
10 TOTAL EXPENDITURES	494 785 627 670.	65 039 576 582.	559 825 204 252.
PROFITS AND LOSSES			
11 GROSS PROFITS	71 211 463 487.	-27 434 650 635.	43 776 812 852.
12 NET PROFITS	40 936 133 655.	-36 056 051 310.	4 880 081 045.

Table A.2B. Private Market Grain Accounts (CY1975)--Run B.

PRIVATE MARKET GRAIN ACCOUNTING
(FOR CY 1975)

REVENUES (won)	RICE	BARLEY	TOTAL
1 GRAIN SALES	390,114,352,159.	29,969,835,999.	420,084,688,359.
2 BY-PRODUCT SALES	6,833,739,160.	2,943,156,637.	9,826,895,797.
3 TOTAL REVENUES	396,398,591,519.	32,912,992,636.	429,911,584,156.
EXPENDITURES (won)			
4 GRAIN PURCHASES	389,625,877,394.	55,817,838,703.	445,443,716,097.
5 GRAIN OPERATIONS	22,329,433,334.	3,013,284,427.	31,342,717,761.
6 (HANDLING)	10,018,762,420.	2,435,829,834.	12,504,392,254.
7 (PROCESSING)	5,843,361,726.	2,371,096,191.	8,214,457,917.
8 (STORAGE)	2,148,624,724.	2,276,019,899.	4,424,644,623.
9 (CREDIT)	4,318,684,465.	1,830,540,503.	6,149,224,967.
10 TOTAL EXPENDITURES	411,955,310,728.	61,831,125,130.	476,786,435,859.
PROFITS AND LOSSES			
11 GROSS PROFITS	7,372,714,125.	-23,904,846,067.	-15,532,131,942.
12 NET PROFITS	-14,956,719,209.	-31,918,132,494.	-46,874,851,703.

Table A.3A. Farm Accounting Table (CY1975)--Run A.

FARM ACCOUNTING TABLE

FOR 1975.

	RICE	BARLEY	WHEAT
1. GROSS INCOME (MIL. WON)	744964.	144594.	28491.
1) FARM CONSUMPTION	189555.	54289.	2801.
2) SELLING	555409.	90305.	25690.
A. GOVERNMENT	125529.	43472.	0.
B. PRIVATE	429879.	46832.	25690.
2. COST (MIL. WON)	280355.	47967.	3317.
1) PRODUCTION	263932.	43031.	3317.
A. FIXED			
B. VARIABLE	263932.	43031.	3317.
2) MILLING	16423.	4936.	0.
3. GROSS MARGIN PER HECTOR (1000 WON/HA)	242.	55.	
4. NET FARM INCOME (MIL. WON)	464609.	96627.	25174.
5. NET FARM INCOME (1000WON/HH)	193.	40.	10.

Table A.3B. Farm Accounting Table (CY1975)--Run B.

FARM ACCOUNTING TABLE

FOR 1975.

	RICE	BARLEY	WHEAT
1. GROSS INCOME (MIL. WON)	720573.	157114.	28431.
1) FARM CONSUMPTION	189192.	56509.	2801.
2) SELLING	531381.	100606.	25630.
A. GOVERNMENT	156586.	47250.	0.
B. PRIVATE	374794.	53356.	25630.
2. COST (MIL. WON)	280106.	47933.	3317.
1) PRODUCTION	263932.	43031.	3317.
A. FIXED			
B. VARIABLE	263932.	43031.	3317.
2) MILLING	16174.	4902.	0.
3. GROSS MARGIN PER HECTOR (1000 WON/HA)	222.	67.	
4. NET FARM INCOME (MIL. WON)	440467.	100181.	25174.
5. NET FARM INCOME (1000WON/HH)	103.	45.	10.

Table A.4A. Farm Production Summary Table (CY1975)--Run A.

F A R M P R O D U C T I O N S U M M A R Y T A B L E

FOR 1975.

	RICE		BAR_EY		WHEAT		TOTAL	
PRODUCTION	4442760.		1700820.		136010.		6279590.	
AREA	1204000.		859010.		67000.		2130000.	
YIELD	3.690		1.980		2.030		2.567	
CONSUMPTION	1613778.	(1.00)	1049751.	(1.00)	85556.	(1.00)	2749084.	(1.00)
HUMAN	1577658.	(.98)	946801.	(.90)	36536.	(.43)	2560994.	(.93)
ANIMAL	0.	(0.00)	60000.	(.06)	45000.	(.53)	105000.	(.04)
SEED	36120.	(.02)	42950.	(.04)	4020.	(.05)	83090.	(.03)
SALES	2428782.	(1.00)	709238.	(1.00)	37841.	(1.00)	3175921.	(1.00)
GOVERNMENT	524617.	(.22)	305754.	(.43)	37841.	(1.00)	868212.	(.27)
PRIVATE	1904165.	(.78)	403544.	(.57)	0.	(0.00)	2307709.	(.73)
CARRY IN	3431042.		561338.		99680.		4092061.	
CARRY OUT	3365996.		560439.		137426.		4053921.	

Table A.4B. Farm Production Summary Table (CY1975)--Run B.

F A R M P R O D U C T I O N S U M M A R Y T A B L E

FOR 1975.

	RICE		BARLEY		WHEAT		TOTAL	
PRODUCTION	4442760.		1709820.		136010.		6278590.	
AREA	1204000.		959000.		67000.		2130000.	
YIELD	3.690		1.980		2.030		2.567	
CONSUMPTION	1631750.	(1.00)	1035195.	(1.00)	85556.	(1.00)	2752491.	(1.00)
HUMAN	1595630.	(.98)	932235.	(.90)	36536.	(.43)	2564401.	(.93)
ANIMAL	0.	(0.00)	60000.	(.06)	45000.	(.53)	105000.	(.04)
SEED	36120.	(.02)	42960.	(.04)	4020.	(.05)	83090.	(.03)
SALES	2300171.	(1.00)	770905.	(1.00)	37841.	(1.00)	3108917.	(1.00)
GOVERNMENT	654746.	(.28)	336748.	(.44)	37841.	(1.00)	1029335.	(.33)
PRIVATE	1645425.	(.72)	434158.	(.56)	0.	(0.00)	2079582.	(.67)
CARRY IN	3351059.		607176.		99680.		4057916.	
CARRY OUT	3394414.		557994.		137426.		4089834.	

Table A.5A. Food Grain Inventory Stock Summary Table (CY1975)--Run A.

FOOD GRAIN INVENTORY STOCK SUMMARY TABLE (UNIT: 1000MT MAX,AVE,MIN)
FOR PERIOD,75- 1- 1 TO 76- 1- 0

PRODUCTION AREA POSITIONS	RICE	BARLEY	WHEAT	TOTAL
1 FARM	3559.	1251.	161.	4467.
	2237.	694.	121.	3051.
	869.	166.	75.	1986.
2 PRIVATE MARKET	192.	431.		498.
	70.	324.		394.
	10.	262.		311.
3 GOVERNMENT	432.	360.		788.
	61.	191.		252.
	0.	34.		34.
4 SUB-TOTAL	3995.	1821.	161.	5542.
	2368.	1209.	121.	3697.
	890.	540.	75.	2511.
CONSUMPTION AND PORT AREA POSITIONS				
5 PORTS	302.	731.	15.	1031.
	58.	507.	7.	570.
	0.	86.	1.	104.
6 IMPORT PIPELINE	204.	327.	368.	704.
	93.	107.	292.	496.
	21.	0.	281.	303.
7 PRIVATE MARKET	305.	96.	496.	695.
	496.	59.	247.	554.
	315.	30.	78.	394.
8 GOVERNMENT	496.	290.		773.
	247.	277.		523.
	79.	272.		353.
9 URBAN HOUSEHOLDS	134.	32.	34.	175.
	77.	15.	29.	122.
	27.	7.	27.	70.
10 SUB-TOTAL	1331.	1125.	860.	2771.
	973.	965.	575.	2266.
	471.	516.	391.	1776.
11 TOTAL STOCKS	4775.	2944.	952.	7439.
	3341.	2173.	698.	5963.
	1590.	1493.	533.	4776.
12 GOVERNMENT TOTAL	743.	1351.		2005.
	452.	1091.		1543.
	121.	550.		1234.
13 PRIVATE TOTAL	852.	493.	832.	1592.
	566.	383.	546.	1494.
	446.	297.	360.	1247.

Table A.5B. Food Grain Inventory Stock Summary Table (CY1975)--Run B.

FOOD GRAIN INVENTORY STOCK SUMMARY TABLE (UNITS 1000MT MAX,AVE,MIN
FOR PERIOD,75- 1- 1 TO 76- 1- 0

PRODUCTION AREA POSITIONS	RICE	BARLEY	WHEAT	TOTAL
	3527.	1257.	161.	4429.
1 FARM	2215.	686.	121.	3023.
	845.	167.	75.	1935.
	138.	345.		478.
2 PRIVATE MARKET	47.	281.		327.
	12.	224.		236.
	541.	363.		900.
3 GOVERNMENT	164.	194.		358.
	0.	38.		151.
	4151.	1733.	161.	5592.
4 SUB-TOTAL	2427.	1160.	121.	3708.
	856.	524.	75.	2538.
CONSUMPTION AND PORT AREA POSITIONS				
	8.	734.	12.	741.
5 PORTS	1.	509.	5.	516.
	0.	86.	-1.	92.
	139.	327.	245.	521.
6 IMPORT PIPELINE	29.	107.	193.	328.
	0.	0.	196.	196.
	442.	151.	592.	492.
7 PRIVATE MARKET	301.	79.	403.	390.
	165.	24.	178.	219.
	592.	291.		870.
8 GOVERNMENT	403.	280.		684.
	178.	274.		459.
	156.	30.	25.	206.
9 URBAN HOUSEHOLDS	104.	17.	25.	146.
	76.	7.	25.	110.
	950.	1171.	839.	2241.
10 SUB-TOTAL	838.	991.	626.	2052.
	547.	505.	393.	1566.
	4748.	2936.	931.	7453.
11 TOTAL STOCKS	3264.	2152.	747.	5760.
	1584.	1476.	539.	4733.
	930.	1363.		2044.
12 GOVERNMENT TOTAL	596.	1091.		1687.
	407.	555.		1436.
	463.	409.	914.	1444.
13 PRIVATE TOTAL	348.	359.	601.	1309.
	217.	267.	369.	1080.

Table A.6A. Urban Grain Purchases, Consumption, and Storage Summary Table (CY1975)--Run A.

URBAN GRAIN PURCHASES, CONSUMPTION, AND STORAGE SUMMARY TABLE
(FOR THE PERIOD 75- 1- 1 THRU 76- 1- 01)

GRAIN PURCHASES	UNIT	RICE	BARLEY	WHEAT	TOTAL
1. TOTAL PURCHASES	THOUSAND MT	2562. (1.00)	600. (1.00)	1415. (1.00)	4666. (1.00)
2. (GOVERNMENT)		523. (.20)	462. (.64)		955. (.21)
3. • DOMESTIC		38. (.03)	94. (.16)		144. (.06)
4. • IMPORT		633. (.17)	369. (.51)	1415. (1.00)	2196. (.47)
5. (PRIVATE MARKET)		2048. (.80)	246. (.36)		2286. (.49)
6. (DIRECT FARM)		0. (0.00)	0. (0.00)		0. (0.00)
7. AVERAGE PER-CAPITA 1/	KG/CAPITA-YR	119.	32.	66.	217.
8. MAXIMUM PER-CAPITA	KG/CAPITA-YR	154.	31.	9.	170.
9. OCCURING ON	DATE	75- 2-10	75-11-17	75- 6-29	75- 2-10
10. MINIMUM PER-CAPITA	KG/CAPITA-YR	69.	0.	0.	67.
11. OCCURING ON	DATE	75- 1- 1	75- 5-18	75- 1- 1	75- 1- 1
GRAIN CONSUMPTION					
12. TOTAL CONSUMPTION	THOUSAND MT	2522.	789.	1411.	4641.
13. AVERAGE PER-CAPITA	KG/CAPITA-YR	117.	33.	65.	215.
14. MAXIMUM PER CAPITA	KG/CAPITA-YR	126.	38.	84.	231.
15. OCCURING ON	DATE	75- 3-26	75- 6-18	75-11-15	76- 1- 8
16. MINIMUM PER CAPITA	KG/CAPITA-YR	104.	28.	37.	195.
17. OCCURING ON	DATE	75- 9-25	75- 6- 2	75- 5- 2	75- 3- 2
GRAIN STORAGE					
18. AVERAGE STOCKS	THOUSAND MT	77.	15.	29.	122.
19. PER-HOUSEHOLD	KG/HOUSEHOLD	26.	5.	10.	41.
20. NO. DAYS SUPPLY	DAYS	11.	8.	8.	10.
21. MAXIMUM STOCKS	THOUSAND MT	134.	32.	34.	173.
22. PER-HOUSEHOLD	KG/HOUSEHOLD	45.	11.	11.	58.
23. NO. DAY SUPPLY	DAYS	19.	16.	9.	14.
24. OCCURING ON	DATE	75- 5-27	75- 1- 1	76- 1- 8	75- 1-26
25. MINIMUM STOCKS	THOUSAND MT	27.	7.	27.	70.
26. PER-HOUSEHOLD	KG/HOUSEHOLD	9.	2.	9.	23.
27. NO. DAYS SUPPLY	DAYS	4.	3.	7.	5.
28. OCCURING ON	DATE	75- 9-21	75- 6- 2	75- 1-12	75- 1-23
29. CARRY-IN	THOUSAND MT	30.	32.	27.	93.
30. CARRY-OUT	THOUSAND MT	74.	12.	34.	120.
31. CHANG IN STOCKS	THOUSAND MT	48.	-20.	7.	27.

(FOOTNOTES)

1/ AVERAGE POPULATION OF 35420. THOUSAND
13850.
21570.

Table A.6B. Urban Grain Purchases, Consumption, and Storage Summary Table (CY1975)--Run B.

GRAIN PURCHASES	UNIT	RICE	BARLEY	WHEAT	TOTAL
1. TOTAL PURCHASES	THOUSAND MT	2585.(1.00)	713.(1.00)	896.(1.00)	4194.(1.00)
2. (GOVERNMENT)		1021.(.40)	441. (.62)		1462.(.35)
3. . DOMESTIC		621.(.24)	95. (.13)		717.(.17)
4. . IMPORT		400.(.15)	345. (.48)	896. (1.00)	1642. (.39)
5. (PRIVATE MARKET)		1564.(.60)	272. (.38)		1836.(.44)
6. (DIRECT FARM)		0.(0.00)	0. (0.00)		0.(0.00)
7. AVERAGE PER-CAPITA 1/	KG/CAPITA-YR	128.	33.	42.	195.
8. MAXIMUM PER-CAPITA	KG/CAPITA-YR	130.	29.	0.	145.
9. OCCURING ON	DATE	75- 3-24	75-11-17	75- 7- 8	75- 3-24
10. MINIMUM PER-CAPITA	KG/CAPITA-YR	38.	4.	0.	63.
11. OCCURING ON	DATE	76- 1- 8	75- 5-18	75-12-16	75- 1- 1
GRAIN CONSUMPTION					
12. TOTAL CONSUMPTION	THOUSAND MT	2619.	727.	897.	4243.
13. AVERAGE PER-CAPITA	KG/CAPITA-YR	122.	34.	42.	197.
14. MAXIMUM PER CAPITA	KG/CAPITA-YR	130.	39.	52.	206.
15. OCCURING ON	DATE	75- 1- 1	75- 8- 8	75-11-15	75-11-15
16. MINIMUM PER CAPITA	KG/CAPITA-YR	116.	28.	27.	183.
17. OCCURING ON	DATE	75- 7-16	75- 6- 8	75- 4- 3	75- 3- 2
GRAIN STORAGE					
18. AVERAGE STOCKS	THOUSAND MT	84.	17.	25.	146.
19. PER-HOUSEHOLD	KG/HOUSEHOLD	35.	6.	8.	49.
20. NO. DAYS SUPPLY	DAYS	15.	8.	10.	13.
21. MAXIMUM STOCKS	THOUSAND MT	156.	30.	25.	206.
22. PER-HOUSEHOLD	KG/HOUSEHOLD	52.	10.	8.	69.
23. NO. DAY SUPPLY	DAYS	22.	15.	10.	10.
24. OCCURING ON	DATE	75- 1-16	75- 1- 1	76- 1- 8	75- 1- 1
25. MINIMUM STOCKS	THOUSAND MT	76.	7.	25.	110.
26. PER-HOUSEHOLD	KG/HOUSEHOLD	25.	2.	9.	37.
27. NO. DAYS SUPPLY	DAYS	11.	3.	10.	9.
28. OCCURING ON	DATE	75- 7- 8	75- 6- 8	76- 1- 8	75- 7- 8
29. CARRY-IN	THOUSAND MT	151.	38.	25.	206.
30. CARRY-OUT	THOUSAND MT	117.	16.	25.	159.
31. CHANG IN STOCKS	THOUSAND MT	-33.	-14.	0.	-47.

Table A.7A. Price Policy Summary Table (CY1974)--Run A.

PRICE POLICY SUMMARY TABLE

(FOR PERIOD 74- 1- 1 TO 75- 1- 1)

	FARM		URBAN	
	ACTUAL	RESULTS	ACTUAL	RESULTS
PRICE LEVELS				
(WON PER BAG)				
RICE				
1 AVERAGE	7732.05	7439.98	9813.59	9839.60
2 HIGH	8289.90	8973.56	11373.68	10394.49
3 LOW	6896.25	5571.73	7982.60	7982.60
4 RATIO (HIGH/LOW)	1.20	1.61	1.42	1.30
BARLEY				
5 AVERAGE	3671.89	3810.93	4197.13	3999.47
6 HIGH	4650.56	4307.20	4736.34	4379.09
7 LOW	3089.16	3249.10	3856.00	3699.64
8 RATIO (HIGH/LOW)	1.51	1.34	1.22	1.19
PRICE CHANGES				
(PERCENT PER YEAR)				
RICE				
9 MAXIMUM RISE				
10 MAXIMUM FALL		Output		
11 AVERAGE TREND		Not Available		
12 VARIATION (C.V.)				
BARLEY				
13 MAXIMUM RISE				
14 MAXIMUM FALL				
15 AVERAGE TREND				
16 VARIATION (C.V.)				

Table A.7B. Price Policy Summary Table (CY1974)--Run B.

PRICE LEVELS (WON PER BAG)	FARM TARGET	FARM RESULTS	URBAN TARGET	URBAN RESULTS
RICE				
1 AVERAGE	7623.13	7742.15	9114.75	9036.93
2 HIGH	8231.05	8502.28	9841.61	9632.70
3 LOW	6995.61	6651.93	8365.63	8396.99
4 RATIO (HIGH/LOW)	1.18	1.28	1.18	1.15
BARLEY				
5 AVERAGE	3671.89	3799.73	4197.13	3999.24
6 HIGH	4650.56	4320.80	4736.34	4379.99
7 LOW	3089.16	3247.96	3866.00	3698.25
8 RATIO (HIGH/LOW)	1.51	1.33	1.22	1.19
PRICE CHANGES (PERCENT PER YEAR)				
RICE				
9 MAXIMUM RISE		Output Not Available		
10 MAXIMUM FALL				
11 AVERAGE TREND				
12 VARIATION (C.V.)				
BARLEY				
13 MAXIMUM RISE				
14 MAXIMUM FALL				
15 AVERAGE TREND				
16 VARIATION (C.V.)				

Table A.8A. Special Transaction Summary Table--Run A.

YEAR	Farm Sales FSLS	Private Purchases PPUR	Government Purchases GPUR	Private Sales PSLS	Government Sales GSLS	Urban Purchases UPUR	Imports RGIMPO
1974.0							
RICE	.2192E+07	.1569E+07	.6229E+06	.1545E+07	.9311E+06	.2476E+07	.2534E+06
BARLEY	.6482E+06	.3193E+06	.3290E+05	.2059E+06	.5171E+06	.7230E+05	.3085E+05
1975.0							
RICE	.2429E+07	.1905E+07	.5237E+06	.1999E+07	.5183E+06	.2517E+07	.4833E+06
BARLEY	.7086E+06	.4028E+06	.3058E+06	.2137E+06	.4445E+06	.6581E+05	.4801E+06
1976.0							
RICE	.2497E+07	.1825E+07	.6719E+06	.1831E+07	.6751E+06	.2506E+07	.1600E+06
BARLEY	.9477E+06	.5572E+06	.3805E+06	.4738E+06	.3360E+06	.8098E+05	0.

Table A.8B. Special Transaction Summary Table--Run B.

YEAR	Farm Sales FSLS	Private Purchases PPUR	Government Purchases GPUR	Private Sales PSLS	Government Sales GSLS	Urban Purchases UPUR	Imports RGIMPO
1974.0							
RICE	.2230E+07	.1590E+07	.6409E+06	.2070E+07	.5724E+06	.2543E+07	0.
BARLEY	.6801E+06	.4038E+06	.2763E+06	.2114E+06	.5139E+06	.7253E+06	.3085E+06
1975.0							
RICE	.2293E+07	.1640E+07	.6536E+06	.1559E+07	.1014E+07	.2572E+07	.1531E+06
BARLEY	.7702E+06	.4335E+06	.3367E+06	.2715E+06	.4393E+06	.7107E+06	.4801E+06
1976.0							
RICE	.2427E+07	.1648E+07	.7790E+06	.1560E+07	.1151E+07	.2610E+07	.2793E+06
BARLEY	.9780E+06	.5911E+06	.3869E+06	.4918E+06	.3353E+06	.8171E+06	0.

APPENDIX B

DERIVATION OF DEMAND ELASTICITIES FOR RICE-BARLEY MIX UNDER CERTAIN ASSUMPTIONS

APPENDIX B

DERIVATION OF DEMAND ELASTICITIES FOR RICE-BARLEY MIX UNDER CERTAIN ASSUMPTIONS

Suppose we make the following assumptions regarding rice-barley mix.

(1) Consumers' preference for rice-barley mix, hereafter called "brice," is between their preferences for pure rice and pure barley (i.e., pure rice is preferred to brice, but brice is preferred to pure barley). Furthermore, consumers' preference for brice is determined by a linear combination of their preferences for pure rice and pure barley. The coefficients for this linear combination are determined by the mix ratio.

(2) Price of brice is determined by the current prices of pure rice and pure barley weighted by the mix ratio. No discount or value-added conditions are allowed under these assumptions.

Given the above assumptions, along with a stable per-capita total grain consumption hypothesis, it is possible to transform a 3 x 3 elasticity matrix estimated for pure rice, pure barley, and wheat flour into a 4 x 4 elasticity matrix which identifies the demand response for brice explicitly. This transformation causes no change in the original elasticity estimates and also perseveres the stable consumption hypothesis.

For clarity in notation, the 4 x 4 elasticity matrix we are considering is depicted as follows.

$$\begin{array}{l} \text{Rice} \\ \text{Barley} \\ \text{Brice} \\ \text{Wheat} \end{array} \begin{bmatrix} \varepsilon_{RR} & \varepsilon_{RB} & \varepsilon_{RM} & \varepsilon_{RW} \\ \varepsilon_{BR} & \varepsilon_{BB} & \varepsilon_{BM} & \varepsilon_{BW} \\ \varepsilon_{MR} & \varepsilon_{MB} & \varepsilon_{MM} & \varepsilon_{MW} \\ \varepsilon_{WR} & \varepsilon_{WB} & \varepsilon_{WM} & \varepsilon_{WW} \end{bmatrix} \qquad \text{(B.1)}$$

The rows correspond to quantities demanded and the columns correspond to changes in prices (e.g., ε_{RM} is the elasticity of pure rice demand with respect to changes in the price of brice). The cross elasticities of demand for pure rice, pure barley, and wheat flour with respect to changes in brice price (third column elements of matrix B.1) can be written directly from the assumptions given in the beginning of these notes.

$$\varepsilon_{RM} = R_T \ \varepsilon_{RR} + (1 - R_T) \ \varepsilon_{RB} \qquad \text{(B.2)}$$

$$\varepsilon_{BM} = R_T \ \varepsilon_{BR} + (1 - R_T) \ \varepsilon_{BB} \qquad \text{(B.3)}$$

$$\varepsilon_{WM} = R_T \ \varepsilon_{WR} + (1 - R_T) \ \varepsilon_{WB} \qquad \text{(B.4)}$$

where, R_T is the rice proportion of the mixed grains.

A stable per-capita total grain consumption hypothesis calls for the following relationships.

$$\overline{Q}_R \ \varepsilon_{RR} + \overline{Q}_B \ \varepsilon_{BR} + \overline{Q}_W \ \varepsilon_{WR} = 0 \qquad \text{(B.5)}$$

$$\overline{Q}_R \ \varepsilon_{RB} + \overline{Q}_B \ \varepsilon_{BB} + \overline{Q}_W \ \varepsilon_{WB} = 0 \qquad \text{(B.6)}$$

$$\overline{Q}_R \ \varepsilon_{RW} + \overline{Q}_B \ \varepsilon_{BW} + \overline{Q}_W \ \varepsilon_{WW} = 0 \qquad \text{(B.7)}$$

where, $\overline{Q}_R$, $\overline{Q}_B$, and $\overline{Q}_W$ are average consumption amounts. The conditions in Equations B.5 to B.7 can be written to include brice as follows.

$$\bar{Q}'_R \ \varepsilon_{RR} + \bar{Q}'_B \ \varepsilon_{BR} + \bar{Q}_M \ \varepsilon_{MR} + \bar{Q}_W \ \varepsilon_{WR} = 0 \qquad (B.8)$$

$$\bar{Q}'_R \ \varepsilon_{RB} + \bar{Q}'_B \ \varepsilon_{BB} + \bar{Q}_M \ \varepsilon_{MB} + \bar{Q}_W \ \varepsilon_{WB} = 0 \qquad (B.9)$$

$$\bar{Q}'_R \ \varepsilon_{RM} + \bar{Q}'_B \ \varepsilon_{BM} + \bar{Q}_M \ \varepsilon_{MM} + \bar{Q}_W \ \varepsilon_{WM} = 0 \qquad (B.10)$$

$$\bar{Q}'_R \ \varepsilon_{RW} + \bar{Q}'_B \ \varepsilon_{BW} + \bar{Q}_M \ \varepsilon_{MW} + \bar{Q}_W \ \varepsilon_{WW} = 0 \qquad (B.11)$$

where, the $\bar{Q}'$ (primes) signify pure rice and pure barley consumption.

Equation B.8 can also be written as

$$[\bar{Q}_R - P_M(\bar{Q}_R + \bar{Q}_B) \ R_T] \ \varepsilon_{RR} + [\bar{Q}_B - P_M(\bar{Q}_R + \bar{Q}_B) \ (1 - R_T)] \ \varepsilon_{BR} + P_M(\bar{Q}_R + \bar{Q}_B) \ \varepsilon_{MR} + \bar{Q}_W \ \varepsilon_{WR} = 0 \qquad (B.12)$$

where:

P_M = proportion of brice to total rice and barley

R_T = mix ratio, i.e., rice proportion of mix.

It is not difficult to see that the coefficient expression in front of each elasticity in Equation B.12 is the expected value of the demand for each commodity.

Equation B.12 may be rearranged as follows.

$$\bar{Q}_R \ \varepsilon_{RR} + \bar{Q}_B \ \varepsilon_{BR} + \bar{Q}_W \ \varepsilon_{WR} + P_M(\bar{Q}_R + \bar{Q}_B) \ [\varepsilon_{MR} - \varepsilon_{RR} \ R_T - \varepsilon_{BR} \ (1 - R_T)] = 0 \qquad (B.13)$$

but,

$$\bar{Q}_R \ \varepsilon_{RR} + \bar{Q}_B \ \varepsilon_{BR} + \bar{Q}_W \ \varepsilon_{WR} = 0 \qquad \text{repeat (B.5)}$$

Therefore, what remains after simplification is

$$\varepsilon_{MR} - \varepsilon_{RR} \ R_T - \varepsilon_{BR} \ (1 - R_T) = 0 \qquad (B.14)$$

or,

$$\varepsilon_{MR} = \varepsilon_{RR} \ R_T + \varepsilon_{BR} \ (1 - R_T). \qquad (B.15)$$

The same procedure can be applied to Equations B.9 through B.11 above to give

$$\varepsilon_{MB} = \varepsilon_{RB} R_T + \varepsilon_{BB} (1 - R_T) \tag{B.16}$$

$$\varepsilon_{MM} = \varepsilon_{RM} R_T + \varepsilon_{BM} (1 - R_T) \tag{B.17}$$

$$\varepsilon_{MW} = \varepsilon_{RW} R_T + \varepsilon_{BW} (1 - R_T) \tag{B.18}$$

Thus, to summarize this transformation in matrix form, we begin with the estimated 3 x 3 elasticity matrix for rice, barley, and wheat flour.

$$\begin{bmatrix} \varepsilon_{RR} & \varepsilon_{RB} & \varepsilon_{RW} \\ \varepsilon_{BR} & \varepsilon_{BB} & \varepsilon_{BW} \\ \varepsilon_{WR} & \varepsilon_{WB} & \varepsilon_{WW} \end{bmatrix} \tag{B.19}$$

Next, we generate the 3 x 4 matrix,

$$\begin{array}{c} \\ (1) \\ (2) \\ (3) \end{array} \begin{array}{c} \begin{array}{cccc} (1) & (2) & (3) & (4) \end{array} \\ \begin{bmatrix} \varepsilon_{RR} & \varepsilon_{RB} & \varepsilon_{RM} & \varepsilon_{RW} \\ \varepsilon_{BR} & \varepsilon_{BB} & \varepsilon_{BM} & \varepsilon_{BW} \\ \varepsilon_{WR} & \varepsilon_{WB} & \varepsilon_{WM} & \varepsilon_{WW} \end{bmatrix} \end{array} \tag{B.20}$$

where, the third column is a linear combination of columns (1) and (2). (See Equations B.2 through B.4.)

$$\begin{bmatrix} \varepsilon_{RM} \\ \varepsilon_{BM} \\ \varepsilon_{WM} \end{bmatrix} = R_T \begin{bmatrix} \varepsilon_{RR} \\ \varepsilon_{BR} \\ \varepsilon_{WR} \end{bmatrix} + (1 - R_T) \begin{bmatrix} \varepsilon_{RB} \\ \varepsilon_{BB} \\ \varepsilon_{WB} \end{bmatrix} \tag{B.21}$$

Finally, we generate the full 4 x 4 matrix of B.1, the third row being a linear combination of row (1) and row (2) of B.20. (See Equations B.15 through B.18.)

$$
\begin{array}{ll}
\underline{\text{(Row)}} & \underline{\text{R.O.}} \\
\text{(1)} & \text{X } R_T \\
\text{(2)} & \text{X } (1 - R_T) \\
\text{(3)} & \text{(1) + (2)} \\
\text{(4)} & \text{N.C.}
\end{array}
\begin{bmatrix}
\varepsilon_{RR} & \varepsilon_{RB} & \varepsilon_{RM} & \varepsilon_{RW} \\
\varepsilon_{BR} & \varepsilon_{BB} & \varepsilon_{BM} & \varepsilon_{BW} \\
\varepsilon_{RR} & \varepsilon_{RB} & \varepsilon_{RM} & \varepsilon_{RW} \\
\varepsilon_{WR} & \varepsilon_{WB} & \varepsilon_{WM} & \varepsilon_{WW}
\end{bmatrix}
\qquad \text{(B.22)}
$$

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