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A MATHEMATICAL FRAMEWORK FOR THE JAPANESE AGRICULTURAL MODEL

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October 1980
WP-80-156

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FOREWORD

Understanding the nature and dimension of the food problem and the policies available to alleviate it has been the focal point of the IIASA Food and Agriculture Program since it began in 1977.

National food systems are highly interdependent, and yet the major policy options exist at the national level. Therefore, to explore these options, it is necessary both to develop policy models for national economies and to link them together by trade and capital transfers. For greater realism, the models in this scheme of anlysis are being kept descriptive, rather than normative. In the end it is proposed to link models of twenty countries, which together account for nearly 80 per cent of important agricultural attributes such as area, production, population, exports, imports and so on.

In this paper Dr. Onishi describes a mathematical framework for an agricultural policy model for Japan.

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PREFACE

The Food and Agriculture Program of IIASA started in 1977. Since that time, methodology, simplified national models, and some detailed national models have progressed. In 1980, Japan joined the Program.

Japanese agriculture is protected by various kinds of policies such as producer price support policies, import tariff and quota policies and taxation policies. As a result, the production costs of many agricultural commodities in Japan are much higher than those of other countries. It is quite interesting to see what would happen to Japanese agriculture if the producer price of rice were set at the international rice price. If the import quota of beef and pork are entirely removed, could steer and hog production in Japan still continue? If Japan exports rice, would U.S. farmers' incomes be reduced? What kind of policies are effective for the alleviation of the world hunger problem? If we can experiment on even some of these problems through a world food model, Japan's participation in the Food and Agriculture Program could have some significance.

I would like to express my deep appreciation to Director R. Levien and Program Leader F. Rabar. Finally, I am grateful to Ms. Cynthia Enzlberger and Ms. Bonnie Riley for their patient typing and retyping of this paper.

Haruo ONISHI
July 1980

CONTENTS

1. THE PURPOSE OF THE FOOD AND AGRICULTURE PROGRAM

The oil crisis in 1973 and the food crisis in 1974 affected the world economy seriously. These crises have lead to many people paying more attention to global rather than national problems and to recognizing that economic growth is not unlimited. A few years later, the Food and Agriculture Program at IIASA was established to:

- evaluate the nature and dimensions of the world food situation,
- identify the factors affecting it, and
- find alternative policy action at the national, regional and global level.

Using the data and evaluations from this study it is hoped that solutions to alleviate existing and emerging food problems in the world can be found.*

*"Local Problems in a Global System (The Approach of IIASA's Food and Agriculture Program)", F. Rabar, FAP Newsletter No. 3, August 1979, p. 5.

2. LINKAGE REQUIREMENTS FOR A WORLD MODEL

A general equilibrium approach is taken to a world agricultural model. A variety of national agricultural models which reflect the characteristics of each country's agriculture are linked to a world agricultural model. To integrate many national models into a world agricultural model several conditions are imposed on each national agricultural model.

They are required (a) for a common goal of all countries and (b) for guaranteeing the existence of an equilibrium in a world agricultural model. They are the following:*

1) The IIASA commodity list should be accepted. It is possible to introduce more commodities than there are on the commodity list, but they must be only those products which participate in international exchange and which are defined by the list.
2) The time horizon will be 15 years and the time increment one year.
3) There is a one-year time lag after the production decisions are made. Production is given at the time point of exchange.
4) The models should be closed: The rest of the economy should be represented in one aggregated commodity.
5) Government policies should be explicitly formulated.
6) The models should behave as continuous, nonsmooth excess demand functions of international prices.
7) Excess demand functions are homogeneous of degree zero in international prices and incomes.†

3. THE OBJECTS OF MODELING JAPANESE AGRICULTURE

Japanese agriculture is closely related to agriculture and nonagriculture in the rest of the world. It is impossible to predict the effects of government policies on Japanese agriculture from an analysis of an agricultural sector model or even a Japanese economy model, because there are some reactions to government policies for Japanese agriculture from the rest of the world. Hence, it is of great importance to evaluate quantitatively the "net" effects of agricultural policies, trade policies, and taxation policies set by the Japanese government on Japanese agriculture in a global framework.

The purpose of this research is:

(1) to evaluate quantitatively the effects of agricultural policies, trade policies, and taxation policies regarding Japanese agriculture,
(2) to pursue appropriate labor allocation, land use, and capital formation, and
(3) to predict incomes and food consumption patterns in rural and urban areas between 1981 and 1995.

4. COMMODITY LIST

The commodities to be introduced into the production module differ from those listed in the Food and Agriculture Program at IIASA. In order to reflect the characteristics of Japanese agriculture in the model, 28 agricultural commodities are selected. All products and services in the rest of the national

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*FAP Newsletter No. 3, August, 1979, pp. 30-31.
†Keyzer, M.A., An Outline of IIASA's Food and Agriculture Model, January, 1980, p. 8.

production are treated as one aggregate nonagricultural commodity. However, it is possible to disaggregate the nonagricultural commodity into three commodities (a) capital goods, (b) consumption goods and services, and (c) minerals and energy, in a future version of the Japanese Agricultural Model, JAM. The commodity lists of IIASA and JAM are:

IIASA	JAM
1. Wheat	1. Wheat
2. Rice	2. Rice
3. Coarse grain	3. Barley
4. Oil and fats	4. Rye and oats
5. Protein feeds	5. Corn
6. Sugar	6. Oil and fats
7. Bovine meats	7. Protein feed
8. Pork	8. Sugar beets
9. Poultry and eggs	9. Sugar cane
10. Dairy products	10. Nonprotein feed
11. Vegatables	11. Bovine meat
12. Fruit and nuts	12. Pork
13. Fish	13. Poultry
14. Coffee	14. Eggs
15. Cocoa and tea	15. Dairy products
16. Alcoholic beverages	16. Starchy roots
17. Clothing fibers	17. Soybeans
18. Industrial crops	18. Vegetables
19. Nonagricultural commodities (the rest of the national production)	19. Grapes
	20. Other fruit
	21. Fish
	22. Tea
	23. Alcoholic beverages
	24. Tobacco
	25. Silk cocoons
	26. Ingusa plants
	27. Green feed
	28. Wood
	29. Nonagricultural commodities (the rest of the national production)

5. STRUCTURE OF THE MODEL

The model represents the Japanese economy and puts emphasis on the agricultural sector. The structure of the JAM consists of the following eight modules:

(1) Market clearance and social account,

(2) Population, labor availability, household and land availability,

(3) Consumption and intermediate demand,

(4) Agricultural production,

(5) Nonagricultural production and government employment,

(6) Investment and capital formation,

(7) International trade, price determination, net import quota, and buffer stock constraint, and

(8) Government policy.

The market clearance and social account module represents commodity balances, incomes, corporate profit, government revenues and expenditures, and gross national product.

The population, labor availability, household and land availability module is related to rural and urban population, rural and urban labor availabilities, numbers of rural and urban households, and acreages of paddy and upland fields.

The consumption and intermediate demand module deals with human, government, and animal consumption of agricultural and nonagricultural commodities, and intermediate demand for agricultural commodities which are used for the production of alcoholic beverages (sake, beer, whiskey, and wine), oil (vegetable oil and fish oil) and protein feed (soybean cake and fish cake).

The agricultural production module shows acreages of crops, labor allocation, capital allocation, nitrogen fertilizer application, production of crops, animals, fish and wood, expected producer price formation, and producer prices of disaggregated commodities.

The nonagricultural production and government employment module states working hours per worker during a year, capital use rate, wage rate of nonagricultural production, employment and production.

The investment and capital formation module deals with investments by government, farmers (including fishermen and forestry workers) and enterprises, savings, capital formation and depreciation of capital.

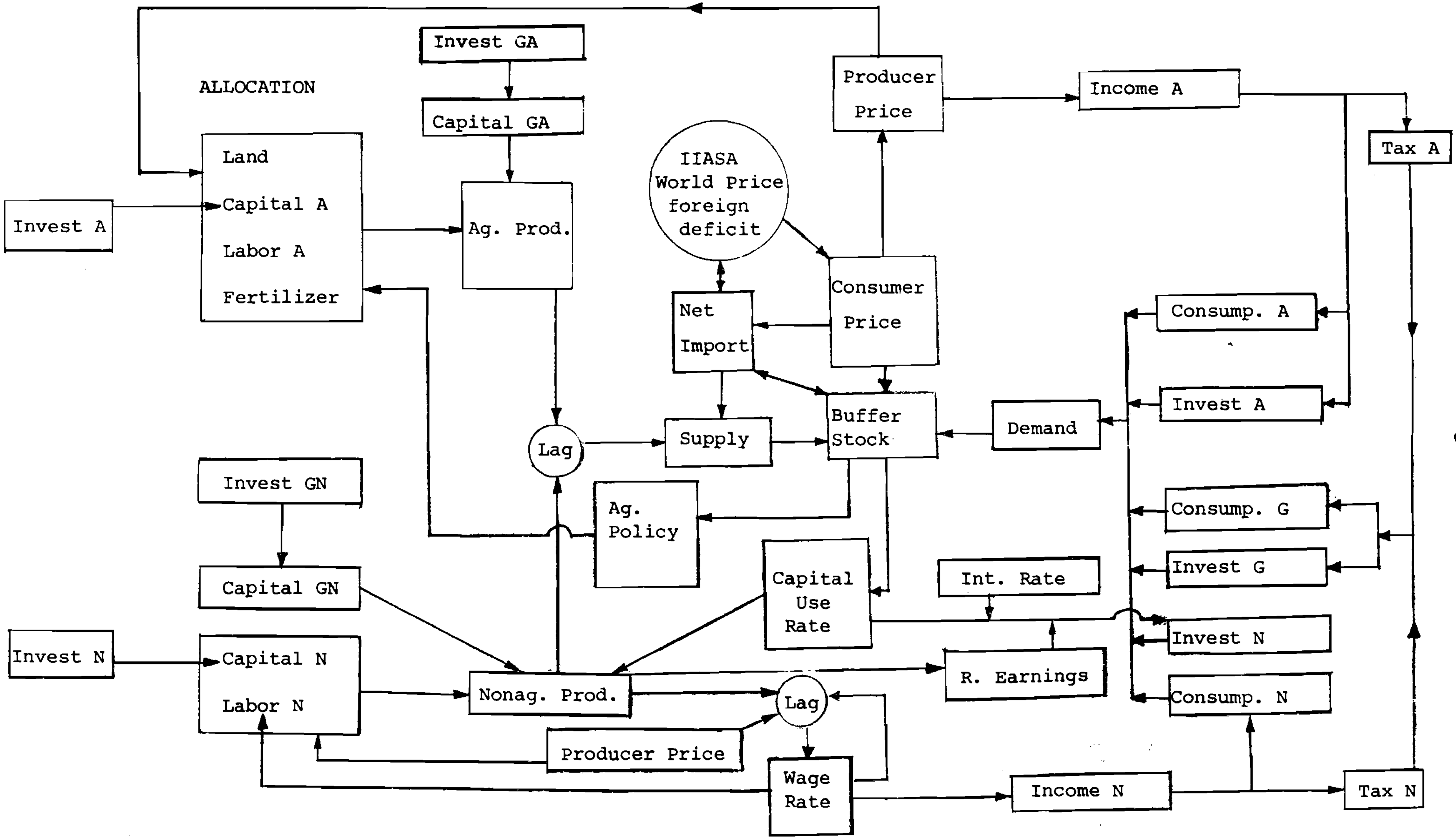
In the international trade, price determination, net import quota and buffer stock constraint module, net imports, upper and lower bounds of net imports quota, buffer stocks, upper and lower bounds of buffer stocks, relations between IIASA's world prices and world prices with which Japan is faced (in terms of 1970 base year), consumer prices, and producer prices are discussed.

Finally, tax rates, producer and consumer prices for wheat, rice and tobacco, tariff rates, subsidies, government wage rate, and imports of government-controlled commodities are determined in the government policy module.

6. EXPLANATIONS OF THE JAPANESE AGRICULTURAL MODEL (JAM)

Let us give brief explanations of most of the equations and identities in the model. The whole set of simultaneous equations model JAM and Variable Nota-

FLOW CHART OF JAM



A: Agricultural Sector
N: Nonagricultural Sector
G: Government

○ : given
□ : determined

tion is given in the Appendix.

6.1. Market Clearance and Social Account Module

6.1.1. Demand for Commodities

As far as wheat and rice are concerned, the commodities supplied from farmers and traded in the international market are not the same as those consumed. Hulled wheat and rice are supplied and traded, while wheat flour and polished rice are consumed. It is assumed that the commodities wheat, rice, coarse grains, bovine meat, pork and nonagricultural commodities can be stored, while all other commodities are perishable. The commodities rice, coarse grains, vegetables, fruit and fish can be used for processed commodities. Nonagricultural commodities are used as consumption goods, investment goods and intermediate goods.

6.1.2. Domestic Supplies of Commodities

Commodities produced are consumed one year later in order to satisfy the common requirements of IIASA's general equilibrium system.

6.1.3. Excess Demands for Commodities

Excess demand is defined as total consumption minus total domestic supply. If excess demand is positive, it is regarded as import. On the other hand, if excess demand is negative, it is regarded as export. The reduced forms of excess demand function must be homogeneous of degree zero in IIASA's world prices.

6.1.4. Agricultural, Farm and Rural Incomes

Crop income of crop i, CIi, is defined as the gross sales of crop i minus the cost for intermediate goods used for production of crop i. Animal income of animal i, AIi, is accounted as the gross sales of animal i (including the joint products) minus the cost for intermediate goods and feeds. The allowances for capital depreciation are determined by a function of total capital in agriculture. Agricultural income AGIN is defined as the sum of farming income FARI, fishery income FISI, and forestry income FORI, where farming income implies the sum of all crop and animal incomes. Farm income FI consists of agricultural income AGIN, nonagricultural income NAFI, net income transfer from overseas ITOF, dividend DIVF, and subsidies from fallow paddy fields ARP2·AR2. Rural income RI includes the income transfer (subsidies) from the government. Per capita incomes and per household incomes are defined for convenience.

6.1.5. Urban Income

Urban income UI consists of wage incomes UWI from nonagricultural production and government work, dividend DIVU, and net income transfer from overseas ITOU. Disposable urban income DUI is obtained from the subtraction of nonagricultural personal tax NPTX·UI from urban income. Per capita urban income and per household urban income are introduced for convenience.

6.1.6. Nonagricultural revenue

The previous year's production brings the current gross revenue $NC19 \cdot NQ19_{-1}$ due to the common requirements for the IIASA linkage system. Gross profit is defined as the gross revenue plus net income transfer from overseas ITON minus indirect tax $ITXN \cdot NC19 \cdot NQ19_{-1}$ minus wage WRN·ENAL minus allowances for capital depreciation DAN. Capital depreciation allowances are considered to be a function of capital stock KN and capital use rate KURN. Dividend DIVI is determined by gross profit GP19. Then, retained earnings RE is defined as the gross profit plus capital depreciation allowances minus corporate tax CTX·GP19 and dividend DIVI. Dividend is divided into dividend to farmers (including fishermen and forest workers) and dividend to urban dwellers.

6.1.7. Government Revenue and Expenditure

The government including central and local collects personal taxes FI·APTX and UI·NPTX, indirect taxes CP6·D6·ITXS, CP16·D16·ITXB, and CP19·Q19·ITXN, corporate tax GP19·CTX, tariffs $\sum$TRi·Mi·WPi sales of wheat, rice and tobacco CP1·D1, CP2G·D2G, and C18T·Q18T, and net income transfer from overseas ITOG.

On the other hand, the government spends money on the consumption and investment of nonagricultural commodities CP19·(IG+CG), purchases of wheat, rice, and tobacco from farmers and overseas, PP1·Q1, WP1·M1, PP2G·Q2G, P18T·Q18T, and W18T·M18T, income transfer to agriculture SUBA, subsidies for fallow paddy fields ARP2·AR2, and wages for government employees WRG·LGOV.

6.1.8. Gross National Product, National Income, and General Price Level.

Gross national product GNP is defined as the sum of the gross incomes $\sum$PPi·Qi_{-1} of all commodities divided by general price level GPL. The general price level is obtained as the Laspires index. National income NAIN is the sum of agricultural income AGIN and nonagricultural income NP19·NQ19.

6.2. Population, Labor Availability, Household, and Land Availability Module.

6.2.1. Rural and Urban Population

Change in population is influenced by various factors such as demographic, economic, and social factors. It is quite difficult to explain the change in population only by economic factors. Hence, total population in Japan is treated as exogenous in the model. Given total population, rural and urban population are derived. Rural population is a function of total population TPOP, rural and urban standard of living represented by per capita disposable rural-urban income ratio $(PDRI/PDUI)_{-1}$, government investment IGA_{-1} in agriculture and rural activities to make rural life attractive, and pressure of urban overpopulation reflecting high living costs, high land price, high food price, lack of sewage system, etc. $(UPOP/TPOP)_{-1}$. Then, urban population is defined as the subtraction of rural population from total population.

6.2.2. Labor Availability

Total labor availability LAR in rural areas is determined by rural population RPOP, ratio of rural household expenditures on food, beverages and housing over rural disposable household income $(REFH/DRHI)_{-1}$ representing rural standard of living, and time trend variable indirectly representing the situation in which people in rural areas try to get higher education and as a result the age at which they start work is later.

Labor availability in rural areas is used up by labor for farming (crop and animal production), LFAR, labor for fishery LFIS, labor for forestry work LFOR and nonagricultural production LNAR (including part-time jobs). Labor availability in urban areas LAU is determined by urban population, ratio of urban household expenditures on food, beverages and housing over disposable urban household income, and time trend variable. The meanings of these explanatory variables are similar to those of labor availability in rural areas.

6.2.3. Household

The numbers of rural and urban households are determined in the model by the respective population and time trend variable.

6.2.4. Paddy and Upland Field Availability

Paddy field acreage availability is the previous year's paddy field acreage minus the sum of additional land acreage used for urbanization and further industrialization and the acreage of paddy field changed into upland field. The definition of upland field acreage can be easily understood through the definition of paddy field acreage. The acreage of additional land used for urbanization and further industrialization is affected by changes in GNP ΔGNP_{-1}, retained earnings RE_{-1}, change in urban population $\Delta UPOP$, and time trend variable t. The ratio of paddy and upland field deteriorated by urbanization and further industrialization is fixed in the model.

The change of paddy field into upland field depends on rice production reduction policy variable $ARP2_{-1}$ and ratio of land productivities of rice and dairy products in terms of incomes $(CI2/A2)_{-1}/(AI10/AGF)_{-1}$.

6.3. Consumption and Intermediate Demand Module

6.3.1. Human Consumption

Linear expenditure system is adopted for rural and urban human consumption. Total rural and urban household expenditure RHE and UHE are functions of respective disposable household incomes DRHI and DUHI and ratios of respective population over labor engaged in agricultural and nonagricultural production RPOP/LAR and UPOP/EUL. Rural and urban expenditure on the i-th consumer's commodity REi and UEi are determined by the respective linear expenditure systems, where rural and urban committed consumptions of the i-th consumer's commodity are expressed by RCi and UCi respectively.

6.3.2. Government Consumption

It is assumed that the government does not consume agricultural commodities but consumes nonagricultural commodities. The government consumption of nonagricultural commodities is determined by real government revenue GR/ CP19 and real national income $(NAIN/CP19)_{-1}$. The last explanatory variable represents a little Keynesian influence.

6.3.3. Intermediate Demand

Rice, coarse grains, starchy roots, soybeans, vegetables (sesame seeds, rape seeds, etc.), grape and fish are used for the production of processed commodities such as alcoholic beverages (sake or rice wine, beer, whiskey, wine), oil and cakes. Nonagricultural commodities used as intermediate goods are nitrogen fertilizer, vinyl sheet, net, chemicals, fuel oil, etc. Real national income, the previous year's intermediate demand quantity, consumer price ratio, and time trend variable are considered to determine intermediate demands.

6.3.4. Animal Consumption

Protein feed, non-protein feed, and green feed are consumed by steers, bulls, cows, pigs, broilers and hens. It is assumed that the consumption quantities of protein, non-protein, and green feed per head of animal are fixed and half of the animals slaughtered (or consumed) had consumed these feeds.

6.3.5. Nutrition

Per capita protein, carbohydrates, and fats are calculated for rural and urban dwellers.

6.4. Agricultural Production Module

Twenty-eight agricultural commodities are focussed on. Instead of mentioning all of the 28 submodules of agricultural production module, we would like to concentrate only on wheat production and bovine and milk production, because it is not difficult to understand other submodules.

First of all, it is assumed that the production decision time differs from the harvest and exchange time and the farmers would like to maximize the expected farming income subject to acreage, nitrogen fertilizer, capital and labor constraints.

We can set up a basic problem as follows:

$$\max_{Ai,Li,Ki,Ni,NFi} \sum (PPi^* - \alpha i) \cdot Qi$$

subject to

$$\sum_{i \neq 2} Ai \leq AUF$$

$$A2 \leq APF$$

$$\sum Li \leq LFAR \cdot WHR$$

$$\sum Ki \leq KFAR$$

$$\sum_{i=1}^{3} NFi \leq NFTL$$

where

$$Qi = f(Ai, NFi, Ki, KGA, Li, \overline{WIi}, \overline{t})$$

for wheat, rice, and coarse grains

$$Qi = f(Ai, Ki, KGA, Li, \overline{t})$$

for other crops,

$$Qi = f(Ni, Ki, KGA, Li, \overline{t})$$

for animals, and

$$PPi^* = \lambda PPi^*_{-1} + (1-\lambda) PPi_{-1}$$

with the Box–Jenkins approach

where

$\alpha i \cdot Qi$ denotes the cost of intermediate goods and/or feeds and all variable notations can be found in the appendix Variable Notations.

The average working days per farmer during a year WHR is determined by capital-labor ratio (KFAR + KFIS + KFOR)/ (LFAR + LFIS + LFOR) and the previous year's real per capita rural income $(PDRI/CP2)_{-1}$. The total quantity NFTL of nitrogen fertilizer is determined first and then it is used for various crops. It is a function of the previous year's quantity $NFTL_{-1}$, the previous year's real crop income, and the previous year's real nitrogen fertilizer price $(PNF/PP2)_{-1}$. The nitrogen fertilizer price PNF depends on the nitrogen fertilizer quantity NFTL, the previous year's nitrogen fertilizer price PNF_{-1}, and consumer price of nonagricultural commodities CP19.

6.4.1. Production of Wheat

In the production of wheat, it is assumed that farmers anticipate the expected wheat producer price $PP1^*$ through the Box-Jenkins formulation. The acreage of wheat A1 is determined by the previous year's acreage $A1_{-1}$ and the ratio of expected wheat income per farmer over wage rate of nonagricultural production $(PP1^* \cdot Q1_{-1})/(WRN_{-1} \cdot L1_{-1})$. The nitrogen fertilizer quantity applied per acre of wheat NF1/A1 is determined by the previous year's application quantity $(NF1/A1)_{-1}$ and the expected wheat producer price divided by nitrogen fertilizer price $PP1^*/PNF$. Since A1 is predetermined for this equation, the nitrogen fertilizer quantity used for wheat production can be derived as NF1. The capital used for wheat production K1 is a function of the previous year's capital use $K1_{-1}$ and capital labor ratio KFAR/LFAR. The amount of labor used for wheat production L1 in terms of man days is determined by the previous year's labor $L1_{-1}$ and the ratio of expected wheat income per farmer over wage rate of nonagricultural production $(PP1^* \cdot Q1_{-1})/ (WRN_{-1} \cdot L1_{-1})$. Accordingly, the production function of wheat is specified as a function of acreage, nitrogen fertilizer application quantity, private capital used, government capital, labor, weather index, and time trend variable. Instead of production function, a wheat yield function can be considered. The final decision whether the production function is more suitable for wheat production in Japan than the yield function depends on estimation.

Since the submodules of other crops are similar to the submodule of wheat production, we would like to skip them and refer to the production of bovine meat and milk.

6.4.2. Production of Bovine Meat and Milk

The number of steers N7 is determined by the net birth rate B7 and the number of steers surviving at the end of the previous year $NS7_{-1}$. The net birth rate is affected by the previous year's bovine meat price-pork price ratio $(PP7/PP8)_{-1}$, the previous year's bovine meat price-mixed feed price ratio $(PP7/PNF5)_{-1}$ and time trend variable $\bar{t}$. Expected producer price of bovine meat $PP7^*$ is of Box-Jenkins type. The number of slaughtered steers SL7 is a function of the number of steers N7 and the ratio of expected bovine meat price over pork price $PP7^*/PP8_{-1}$. Then, the number NS7 of steers which can survive at the end of a year is determined as the number of steers minus the number of slaughtered steers. The average weight of bovine meat per head of steer is a function of time trend variable. Government research into animal husbandry may have helped to increase the average weight.

The number of cows is determined by the net birth rate B10 and the number $NF10_{-1}$ of cows surviving at the end of the previous year. Half the calves are cows and the rest are raised as bulls for the production of bovine meat. The net birth rate is influenced by the milk price change $PP10_{-1}/PP10_{-2}$, average green feed intake $QQGF/NF10_{-1}$, and time trend variable $\bar{t}$. The number of cows slaughtered SF10 is determined by the number of cows N10, the previous year's ratio of bovine meat price over milk price $(PP7/PP10)_{-1}$, and the production quantity of green feed QQGF. The number of cows which can survive at the end of a year is obtained by subtracting the number of cows slaughtered from the number of cows raised. The number of bulls slaughtered SM10 is determined by the number of bulls raised $NM10_{-1} + 1/2 \cdot B10 \cdot NF10$ and the previous year's ratio of bovine meat price over pork price $(PP7/PP8)_{-1}$. The number NM10 of bulls which can survive at the end of a year is the number of raised bulls minus the number of slaughtered bulls. Therefore, the production quantity of bovine meat is the sum of the production quantities of bovine meat of steers, cows and bulls. On the other hand, the production quantity of milk is determined by the number of cows $N10 - 1/2 \cdot SF10$ and the average green feed intake $QQGF/NF10_{-1}$. The capital K7 and labor L7 used for the production of bovine meat are assumed to be proportional to the number of steers and bulls raised. Similarly, the capital K10 and labor L10 used for milk production are assumed to be proportional to the number of cows raised. The explanation of other submodules of animal, fish, and wood production is omitted, because it is easy to understand them.

6.5. Nonagricultural Production and Government Employment Module

6.5.1. Nonagricultural Labor Employment, Wage Rate, Capital Use Rate, and Production

The number of employees is determined not only by economic variables of real wage rate WRN/NP19 and capital-labor ratio KN/LNAP but also by the institutional variable meaning the Japanese permanent employment system and represented by the previous year's employment level $ENAL_{-1}$. Therefore, even if the real wage rate increases substantially, employment may not go down much due to the previous year's employment level. The time lag number 1 of $ENAL_{-1}$ implies that for at least one year a considerable number of employees do not lose jobs as a result of a traditional employment custom even if a recession hits the Japanese economy.

There is an assumption that the labor from the rural area is always hired, so that this labor does not include the labor in rural areas which wished to find jobs in the nonagricultural sector but did not find them. However, the labor in rural areas which tried and failed to find jobs in nonagricultural production is always absorbed by agriculture. As a result, the labor engaged in agricultural production may include disguised unemployment. Unemployment is always in urban areas if it occurs.

Average working days, in terms of 8 hours per day, of a worker during a year WHN is a function of capital-labor ratio (KN+KGN)/LNAP including government capital in the nonagricultural sector, the previous year's working days showing rigidity of working days WHN_{-1}, per capita urban expenditure on food, beverages and housing $(UEFH \cdot NUH)_{-1}/UPOP_{-1}$ which reflects the important aspects of the Japanese economy to be improved, and time trend variable t.

Capital use rate KURN is considered to be related to capital productivity change, inventory stock-production ratio, and government investment change which is considered to stimulate stagnant nonagricultural production.

Nonagricultural production is determined by a Cobb-Douglas production function of capital actually used KAUN, and total working days TWHN with constant returns to scale. Hicks neutral technical progress is assumed to prevail in nonagricultural production. So far, nonagricultural production quantity NQ19 has not included wood production quantity. IIASA's nonagricultural production quantity Q19 includes both non-IIASA nonagricultural production NQ19 quantity and wood production quantity QFOR.

6.5.2. Government Employment

Government employment is needed mainly for social services which are useful for daily life and private production. The national railroad, telephone and telegram, NHK (government broadcasting), etc. which are semi-government enterprises are treated as private enterprises in the model.

The number of government employees is determined by the total labor availability for nonagricultural production LNAP and ratio WRG/WRN of government wage rate and nonagricultural wage rate. The ratio of government employees hired in rural areas over government employees hired in urban areas is treated as constant over time.

6.6. Investment and Capital Formation Module

6.6.1. Investment

It is assumed that the government invests for an increase in social stability, national security, production efficiency, development and growth, whenever serious social instability, deterioration of national security, stagnant economic activities, etc. occur. As explained in the government policy module, social stability from an economic viewpoint is related to equity and opportunities for employment. National security is connected with national defense, protection of agricultural production, and storage of important commodities. Research and improvement of infrastructure make some contributions to efficiency, development, and growth. The main explanatory variables of government investment are the real national income $(NAIN/GPL)_{-1}$ and real government revenue $(GR/GPL)_{-1}$. However, since the government is bureaucratic, the previous year's real government investment IG_{-1} also influences the determination of current government investment IG. Government investment is divided into government investment in agriculture and rural activities denoted by IGA and government investment in the nonagricultural sector denoted by IGN. Government investment in agriculture depends on the previous year's level IGA_{-1}, food self-sufficiency rate $FSSR_{-1}$, and the per capita agricultural-urban income ratio $(PCAI/PCUI)_{-1}$. Then, government investment in the nonagricultural sector IGN is defined as the remaining.

It is assumed that if the long-run desirable capital KN* exceeds the previous year's capital KN_{-1}, there is an incentive to invest in the nonagricultural sector. Thus, the long-run desirable investment IN* is

$$IN^* = KN^* - KN_{-1}$$

Long-run desirable capital is considered to be a function of the long-run expected demand D*, the long-run expected domestic supply demand ratio DSDR*, the long-run expected capital use rate KURN*, and the long-run expected real profit rate PR19*. Thus, we have

$$KN^* = f(D^* \cdot DSDR^*, KURN^*, PR19^*)$$

The product the of long-run expected demand and expected domestic supply-demand ratio is regarded as the long-run expected effective demand for nonagricultural commodities which the Japanese industry could satisfy. In other words, it is the long-run expected sales. The long-run expected sales are assumed to be a function of arithmetically weighted average production quantity during the last three years, so that we have

$$D^* \cdot DSDR^* = f(\sum (4-i) \cdot Q19_{-i}/6)$$

The long-run expected capital use rate is assumed to be a function of arithmetically weighted average capital use rate during the last three years, so that we have

$$KURN^* = f(\sum_{i=1}^{3} (4-i) \cdot KURN_{-i}/6)$$

The long-run expected real profit rate is regarded as a function of arithmetically weighted average real profit rates during the last three years as shown by

$$PR19^* = f(\sum_{i=1}^{3}(4-i)\cdot GP19_i/6)$$

Real retained earnings and real interest rates affect investment in the nonagricultural sector. Accordingly, we have an investment function for the nonagricultural sector as follows:

$$IN = f(IN^*, RE/CP19, IR)$$
$$= f(KN_{-1}, \sum(4-i)\cdot Q19_{-i}/6, \sum(4-i)\cdot KURN_{-i}/6,$$
$$(4-i)\cdot GP19_{-i}/(6\cdot CP19_{-1}\cdot KN_{-i})$$

Japanese agriculture heavily relies on government agricultural policies. The improvement of the infrastructure in rural areas, biological, economic and technical research, and extension work by the government improve agriculture. Farmers (including fishermen and forest owners) invest in agriculture if the long-run expected capital KA* exceeds the previous year's total capital in agriculture $(KFAR + KFIS + KFOR)_{-1}$. Thus we can write

$$IA^* = KA^* - (KFAR+KFIS+KFOR)_{-1}$$

The long-run expected capital in agriculture depends on the long-run expected government capital in agriculture KGA* and the long-run expected real profit rate PRA*, which are expected not by the government but by farmers. However, since the long-run expected government capital KGA* is based on the long-run expected government investment in agriculture IGA*, we can write

$$KA^* = f(IGA^*, PPA^*)$$

The long-run expected government investment IGA* is considered to be a function of the arithmetically weighted average food self-sufficiency rate during the last three years and arithmetically weighted average government investment in agriculture during the last three years, so that we can write

$$IGA^* = f(\sum(4-i)\cdot FSSR_{-i}/6, \sum(4-i)\cdot IGA_{-i}/6)$$

On the other hand, the government tax policy for agriculture and government subsidies (or income transfer) to agriculture influence the expectation formation of the long-run profit real rate. Therefore, we consider that the long-run real expected profit rate is a function of arithmetically weighted average real rural income during the last three years.

We can write

$$PRA^* = f((1/6)\cdot \sum(4-i)\cdot RI_{-i}/CP19_{-i}\cdot(KFAR + KFIS + KFOK)_{-i})$$

Accordingly, we consider that the private investment in agriculture, after real interest rate is taken into consideration, takes the following form:

$$IA = f(\sum(4-i)\cdot FSSR_{-i}/6, \sum(4-i)\cdot IGA_{-i}/6,$$
$$\sum(4-i)\cdot RI_{-i}/CP19_{-i}\cdot(KFAR + KFIS + KFOR)_{-i}\cdot 6),$$
$$IR, (KFAR + KFIS + KFOR)_{-1})$$

The investment in fishery IFIS out of total investment in agriculture IA is determined by arithmetically weighted average production quantity of fishery during the last three years, the previous year's investment in fishery, the ratio of fishery income over farming income per worker, and the previous year's capital in fishery. In a similar way, the investment in forestry IFOR is considered to be a function of arithmetically weighted average wood production quantity during the last three years, the previous year's investment in forestry, the ratio of forestry income over farming income per worker, and the previous year's capital in forestry. Then, the remaining investment defined as IA−IFIS−IFOR goes to the farming subsector.

Savings RS, US, GS are defined as disposable incomes minus expenditures or government revenue minus government expenditure. Retained earnings RE are also taken into consideration. The investment in housing IH (rural and urban) is equal to total savings (RS + US + GS + RE)/CP19 minus subtotal investments (IG + IA + IN).

6.6.2. Capital Formation

In general, the current capital stock is defined as the previous year's capital stock plus net investment. Net investment is equivalent to gross investment minus capital depreciation.

6.6.3. Depreciation of Capital

Depreciation of capital is mainly determined by the previous year's capital stock. However, if we think of rapid technical progress in Japan, capital may be replaced earlier than scheduled because firms, farms, fishermen and forest owners do not want to lose their competitive power. On the assumption that high economic growth is based on high technical progress, we introduce economic growth rate GNP_{-1} in addition to capital stock. The depreciation of housing is just a function of the previous year's housing capital.

6.7. International Trade, Price Determination, Net Import Quota, and Buffer Stock Constraint Module

6.7.1. International Trade and Price Determination

The foreign exchange rate is used here as an ex post converter of one US dollar into Japanese yen, and its change does not affect international trade because foreign reserves or foreign deficits and IIASA world prices in terms of 1970 US dollars are predetermined from the Japanese economy's point of view. Predetermined foreign reserves, after being converted from U.S. dollars into Japanese yen, are transferred to farmers, urban dwellers, enterprises, and government as income transfers from overseas ITOF, ITOU, ITON and ITOG.

World prices WPi with which Japan is actually faced are a linear form of IIASA world prices converted from US dollars into Japanese yen $FXR \cdot \overline{IP}i$. World price WP19 of nonagricultural commodities observed in Japan includes international transportation unit cost, international trade margin, etc., so that world price WP19 is adjusted by $a^I_{19} \cdot FXR \cdot \overline{IP}19$. World prices of agricultural commodities with which Japan is confronted are a linear homogeneous function of IIASA world prices of agricultural commodities and nonagricultural commodities, i.e., $a^I_i \cdot FXR \cdot \overline{IP}i + b^I_{19i} \cdot FXR \cdot \overline{IP}19$.

Target prices of consumer prices are functions of actual world prices WPi and tariff rate TRi, if imposed. The coefficient a^W_{ci} is considered to represent processing unit costs (for example, wheat is traded, while wheat flour is consumed), domestic transportation unit cost, margins, and so on. If there is no effective import and export quota and there are enough storage capacities for buffer stock, then the target prices turn out to be consumer prices. However, if import or export quotas are effective and/or if buffer stock hits the upper bound of storage facilities or lower bound of buffer stock, then consumer price diverts by the value of Lagrangean multiplier from the target price.

Producer price PP19 of nonagricultural commodities is determined by a Cobb-Douglas function of world prices WP19 and consumer price CP19 of nonagricultural commodities. Producer prices PPi of free-market agricultural commodities are determined by Cobb-Douglas functions of respective consumer price CPi and consumer price CP19 of nonagricultural commodities. These functions are homogeneous of degree one.

6.7.2. Net Import Quota

The upper bounds of net import quotas of all commodities except for bovine meat and pork are set with the maximum purchases by accumulated foreign reserves $\overline{AFR}/IPi$. The lower bounds of net import quotas of all commodities except for coarse grains and nonagricultural commodities are zero. The upper bound of bovine meat import is set by a function of national income divided by consumer price of bovine meat, ratio of bovine meat production income per farmer over nonagricultural wage rate, and change in ratio of bovine meat producer price over rice producer price. The upper bound of pork import quota is affected by the upper bound of bovine meat import quota, real national income, ratio of pork-production income per farmer over nonagricultural wage, and change in real pork price.

The lower bound of import quota of coarse grains which are used for non-protein feeds is needed for short-run stability of animal production. It is considered to be proportional to the total animal demand for non-protein feed. Since the Japanese economy and daily life heavily depends on imports of petroleum and minerals, the lower bound of export exists and is considered to be a function of GNP.

6.7.3. Buffer Stock Constraint

The upper bounds of buffer stocks of storable commodities i = 1, 2, 3, 7, 8 and 19 in the IIASA commodity list are given as exogenous. However, the lower bounds of buffer stocks of the storable commodities are explicitly expressed as functions of economic variables. Whenever positive excess supply of wheat M1+DS1−D1 results, it is stored as buffer stock. From the viewpoint of national security, we believe that there is a minimum buffer stock of wheat $\overline{N}SB1$ which, for instance, can cover two months' consumption of wheat. Therefore, if the minimum buffer stock of wheat $\overline{N}SB1$ is not satisfied, the government decides to import more wheat and/or to change the wheat production policy.

We also believe that the minimum buffer stock of rice $\overline{N}SB2$, for instance, two or three months' consumption of rice, is needed from the viewpoint of national security. Although rice is overproduced in Japan, the government has been taking measures to ban exporting rice except for sporadic cases. The lower bound of rice stock is defined as the maximum among the amount of excess supply and the minimum buffer stock.

The lower bound of coarse grains for buffer stock is needed for short-run protection of animal production from the fluctuation of the world coarse grain price. Since animal production in Japan heavily depends on imported coarse grains, the lower bound depends on the total demand for non-protein feed DFC_{-1}, difference of real coarse grain producer price $\Delta(PP3/WP3)_{-1}$, and real accumulated foreign reserves $(AFR/WP3)_{-1}$. The lower bounds of buffer stocks of bovine meat and pork are equal to positive excess supplies of them, whenever the positive excess supplies occur. The lower bound of nonagricultural commodities in inventory depends on GNP_{-1}, real producer price change $\Delta(P19/WP19)_{-1}$ and real accumulated foreign reserves $(AFR/IP19)_{-1}$.

6.8. Government Policy Module

Government has various economic goals. These are (1) social stability, (2) national security, (3) efficiency, (4) development and growth, and (5) cooperation with the rest of the world. Social stability may be regarded as a short-run goal and related to equity and opportunity for employment. The rural-urban income gap, overpopulation in urban areas and high unemployment rate may belong to the problems of social stability. National security is related to national defense and uncertainty of domestic agricultural production and the international market. Energy and food storage and protection of domestic agricultural production are considered to be measures for national security in the model.

Government investment is here considered to make contributions mainly to efficiency, development, and growth. Construction of infrastructure, various kinds of research, and fostering key industries are some measures for efficiency improvement, development, and growth. Economic aid, forced purchase of overproduced wheat from certain countries, and income transfer to international organizations belong to the category of cooperation with the world. Income transfers from urban to rural areas SUBA, and rice producer prices PP2G and government investment in rural areas IGA can be considered to be very effective for social stability. Government control of wheat and rice, PP1, CP1, PP2G, CP2G, M1, BS1 and BS2, import quota and tariff rates UI7, UI8, TR7 and TR8, can be considered to be very effective for national security. Government investment in the agricultural as well as the nonagricultural sector IGA and IGN, and government capital stock KGA and KGN are treated as measures for the improvement of production efficiency and as incentives to economic activities. Tax policies affect the economic goals (1) to (4) to various degrees. Economic aid is not treated in the model.

6.8.1. Price Support Policies

The rice producer price plays a key role in the determination of the rice consumer price, and producer as well as consumer prices of wheat and tobacco. The wheat producer price PP1 is a function of the wheat world price WP1, the previous year's wheat producter price $PP1_{-1}$, the food self-sufficiency rate $FSSR_{-1}$, the ratio of rice storage over rice consumption $(BS2/D2)_{-1}$, the rice producer price PP2G, and the ratio of wheat storage over wheat consumption BS1/D1. The wheat flour consumer price CP1 is determined by wheat producer price PP1, polished rice consumer price CP2G, previous year's wheat flour consumer p rice $CP1_{-1}$, ratio of rice stock over rice consumption $(BS2/D2)_{-1}$, consumer price of nonagricultural commodities CP19 representing polishing and milling wheat, and ratio of wheat stock over wheat consumption BS1/D1. The determination of rice producer price PP2G depends on the previous year's rice producer price $PP2G_{-1}$, election dummy ELED, food self-sufficiency rate $FSSR_{-1}$, government deficits GS, ratio of rice stock over rice consumption $(BS2/D2)_{-1}$, and ratio of per capita rural income over per capita urban income $(PCRI/PCUI)_{-1}$. Consumer price CP2G of polished rice is a function of rice producer price PP2G, government deficits GS_{-1}, ratio of rice stock over rice consumption $(BS2/D2)_{-1}$ and consumer price CP19 of nonagricultural commodities which represents polishing cost. Producer price P18T of tobacco is affected by the previous year's tobacco producer price $P18T_{-1}$ and rice producer price PP2G. Tobacco consumer price C18T is determined by tobacco producer price P18T, the previous year's tobacco consumer price $C18T_{-1}$, ratio of government expenditures over government revenues GE/GR, and time trend variable which reflects the lung cancer problem.

The wage rate WRG for government employees is determined by the previous year's wage rate for government employees WRG_{-1} and the previous year's wage rate for nonagricultural production WRN_{-1}. The time lag of these explanatory variables implies wage rigidity.

6.8.2. Agricultural Production Policies

Income transfer to agriculture SUBA which is here called subsidies to agriculture is determined by food self-sufficiency rate $FSSR_{-1}$, ratio of per capita rural income over per capita urban income $(PCRI/PCUI)_{-1}$, and ratio of urban population over total population $(UPOP/TPOP)_{-1}$. Fallow payment per acre of paddy field is determined by ratio of rice stock over rice consumption $(BS2/D2)_{-1}$, land rice-income productivity $(PP2G \cdot Q2/A2)_{-1}$, and the previous year's rice acreage $A2_{-1}$.

6.8.3. International Trade Policies

Tariff rate TRi depends on the previous year's import-production ratio $(Mi/Qi)_{-1}$, government expenditures-revenues ratio GE/GR, real accumulated foreign reserves AFR/IP19, and previous year's tariff rate TRi_{-1}. Import of wheat M1 is determined by real accumulated foreign reserves AFR/IP19, the previous year's wheat production $Q1_{-1}$, the previous year's ratio of rice stock over rice consumption, and the previous year's ratio of wheat stock over wheat consumption. Import of tobacco M18T is a function of real accumulated foreign reserves AFR/IP19, GNP change ΔGNP, and the previous year's ratio of tobacco production over tobacco import $(Q18T/M18T)_{-1}$.

6.8.4. Taxation Policies

Nonagricultural personal tax rate NPTX is determined by GNP growth rate, real average government deficits during the last two years $(GS_{-1} + GS_{-2})/(2 \cdot GPL)$, and election dummy ELED. Agricultural personal tax rate APTX depends on GNP growth rate, real average government deficits during the last two years $(GS_{-1} + GS_{-2})/(2 \cdot GPL)$, previous year's food self-sufficiency rate $FSSR_{-1}$, and nonagricultural personal tax rate NPTX. The indirect tax rate imposed on consumption of sugar and sugar products denoted by ITXS is changed by the previous year's sugar indirect tax rate $ITXS_{-1}$ time trend variable t, and real average government deficits during the last two years $(GS_{-1} + GS_{-2})/(2 \cdot GPL)$. The indirect tax rate imposed on alcoholic beverages denoted by ITXB is a function of ratio of government expenditures over government revenues GE/GR, the previous year's alcoholic beverage indirect tax rate $ITXB_{-1}$, and time trend variable t. The indirect tax rate imposed on nonagricultural commodities denoted by ITXN is determined by GNP growth rate, ratio of inventory over production of nonagricultural commodities BS19/Q19, and real average government deficits during the last two years $(GS_{-1} + GS_{-2})/(2 \cdot GPL)$. Finally, corporate tax rate CTX is determined by GNP growth rate, ratio of inventory over production of nonagricultural commodities BS19/Q19, the previous year's retained earnings-gross profit ratio $(RE/GP19)_{-1}$, and real average government deficits during the last two years $(GS_{-1} + GS_{-2})/(2 \cdot GPL)$.

7. CONCLUDING REMARKS

Japan joined IIASA's Food and Agriculture Program in January of 1980. The purpose of this article is to show a mathematical framework for the Japanese agricultural model , JAM, which is suitable for IIASA's World Model Linkage. The model is designed to represent the Japanese economy with the emphasis on the agricultural sector. So far, the data bank necessary for the estimation of the model JAM has been made neither in IIASA nor in the University of Tsukuba. It is planned that we start making the data bank in the University of Tsukuba this September. Then, the estimation and economic simulation will be made. Finally, I would like to mention that JAM may be modified later when we start estimating JAM.

APPENDIX 1

1. MATHEMATICAL FRAMEWORK FOR THE JAPANESE AGRICULTURAL MODEL

1.1. Market Clearance and Social Account Module

1.1.1. Demand for Commodities

D1	$= (RT1 + UT1)/a_1^1 + \overline{F}1 + BS1$
D2	$= (RT2 + UT2 + ID2)/a_2^2 + \overline{F}2 + BS2$
D3	$= RT3 + UT3 + F3 + ID3 + BS3$
Di	$= RTi + UTi$ for $i = 4,6,9,10,14,15,16,17,18$
Di	$= RTi + UTi + BSi$ for $i = 7,8$
D5:	Refers to (3·4) Animal Consumption
D11	$= RT11 + UT11 + w_r^{11} \cdot F11R + ID11$
D12	$= RT12 + UT12 + w_g^{12} \cdot I12G$
D13	$= RT13 + UT13 + ID13$
D19	$= RT19 + UT19 + GC + IG + IA + IN + IH + ID19 + BS19$

1.1.2. Domestic Supplies of Commodities

DSi $= Qi_{-1} + BSi_{-1}$ for i = 1,2

DSi $= Qi_{-1} + BSi_{-1}$ for i = 3,7,8,19

DSi $= Qi_{-1}$ for i = 4,5,6,9,10,11,12,13,15,16,17,18

DS14 $= 0$

1.1.3. Excess Demands for Commodities

Mi $= Di - DSi$

1.1.4. Agricultural, Farm and Rural Incomes

CIi $= PPi \cdot Qi_{-1} - CP19 \cdot a_i^{19} \cdot Qi_{-1}$ for i = 6,11,12,15,16,17,18

CIi $= PPi \cdot Qi_{-1} - CP19 \cdot (a_a^{19} \cdot Qi_{-1} + a_{ft}^{19} \cdot NFi_{-1})$ for i = 1,2,3

CI $= \sum CIi$ for i = 1,2,3,6,11,12,15,16,17,18

AIi $= PPi \cdot Qi_{-1} - CP19 \cdot a_i^{19} \cdot Qi_{-1} - CP5 \cdot FDi_{-1} \cdot Qi_{-1}$ for i = 7,8,9,10

AI $= \sum AIi$ for i = 7,8,9,10

FARI $= CI + AI$

FISI $= PP13 \cdot Q13_{-1} - CP19 \cdot a_{13}^{19} \cdot Q13_{-1}$

FORI $= PFOR \cdot QFOR_{-1} - CP19 \cdot a_{fo}^{19} \cdot QFOR_{-1}$

DAA $= f(KFAR + KFIS + KFOR)$

AGIN $= FARI + FISI + FORI$

FI $= AGIN + NAFI + ITOF + DIVF + ARP2 \cdot AR2$

NAFI $= WRN \cdot (LNAR - LGR) + WRG \cdot LGR$

DFI $= (FI - DAA) \cdot (1-APTX) + DAA$

RI $= FI + SUBA$

DRI $= DFI + SUBA$

DRHI	$= DRI/NRH$
PDRI	$= DRI/RPOP$
FAIF	$= FARI/LFAR$
FIIF	$= FISI/LFIS$
FOIF	$= FORI/LFOR$
PCAI	$= AGIN/(LAR - LNAR)$
PCFI	$= FI/RPOP$

1.1.5. Urban Income

UWI	$= WRN \cdot (ENAL - (LNAR - LGR)) + WRG \cdot LGU$
UI	$= UWI + DIVU + ITOU$
DUI	$= UI \cdot (1 - NPTX)$
DUHI	$= DUI/NUH$
PDUI	$= DUI/UPOP$

1.1.6. Nonagricultural Revenue

GP19	$= NC19 \cdot NQ19_{-1} \cdot (1 - ITXN) + ITON - WRN \cdot ENAL - DAN$
DAN	$= f(KN, KURN)$
DIVI	$= f(GP19)$
RE	$= GP19 \cdot (1 - CTX) - DIVI + DAN$
DIVF	$= a_f^d \cdot DIVI$
DIVU	$= DIVI - DIVF$

1.1.7. Government Revenue and Expenditure

GR	$= FI \cdot APTX + UI \cdot NPTX$
	$+ CP1 \cdot D1 + CP2G \cdot D2G + C18T \cdot Q18T$

$+ CP6 \cdot D6 \cdot ITXS + CP16 \cdot D16 \cdot ITXB$

$+ CP19 \cdot Q19 \cdot ITXN + \sum TRi \cdot Mi \cdot WPi + GP19 \cdot CTX + ITOG$

GE $= CP19 \cdot (IG + CG) + PP1 \cdot Q1 + WP1 \cdot M1$

$+ PP2G \cdot Q2G + P18T \cdot Q18T + W18T \cdot M18T$

$+ SUBA + ARP2 \cdot AR2 + WRG \cdot LGOV$

1.1.8. Gross National Product, National Income and General Price Level

GNP $= \sum PPi \cdot Qi_{-1}/GPL$

GPL $= \sum (Qi_{-1}/\sum Qj_{-1}) \cdot PPi$

NAIN $= AGIN + NP19 \cdot NQ19$

1.2. Population, Labor Availability, Household, and Land Availability Module

1.2.1. Rural and Urban Population

RPOP $= f(\overline{T}POP_{-1}, (PDRI/PDUI)_{-1}, IGA_{-1}, (UPOP/\overline{T}POP)_{-1})$

UPOP $= \overline{T}POP - RPOP$

1.2.2. Labor Availability

LAR $= f(RPOP, (REFH/DRHI)_{-1}, \overline{t})$

LFAR $= f(LAR, KFAR/LAND, (FAIF/WRN)_{-1})$

LFIS $= f(LFIS_{-1}, KFIS, (FIIF/WRN)_{-1}, THMD)$

LFOR $= f(LFOR_{-1}, KFOR, (FOIF/WRN)_{-1})$

LNAR $= LAR - LFAR - LFIS - LFOR$

LAU $= f(UPOP, (DEFH/DUHI)_{-1}, \overline{t})$

LNAP $= LAU + LNAR$

1.2.3. Household

NRH $= f(RPOP, 1/\overline{t})$

NUH $= f(UPOP, 1/\overline{t})$

1.2.4. Paddy and Upland Field Availability

APF $= APF_{-1} - \alpha \cdot \Delta UILU - NPUI$

AUF $= AUF_{-1} - (1-\alpha) \cdot \Delta UILU + NPUI$

ΔUILU $= f(\Delta GNP_{-1}, RE_{-1}, \Delta UPOP, \overline{t})$

NPUI $= f(ARP2_{-1}, (CI2/A2)_{-1}/ (AI10/AGF)_{-1})$

LAND $= APF + AUF$

1.3. Consumption and Intermediate Demand Module

1.3.1. Human Consumption

RHE $= f(DRHI, RPOP/LAR)$

UHE $= f(DUHI, UPOP/EUL)$

REi $= RCi \cdot CPi + b_i^R \cdot (RHE - \sum RCi \cdot CPi)$

UEi $= UCi \cdot CPi + b_i^U (UHE - \sum UCi \cdot CPi)$

RTi $= NRH \cdot (REi/CPi + RCi)$

UTi $= NUH \cdot (UEi/CPi + UCi)$

1.3.2. Government Consumption

GC19 $= f(GR/CP19, (NAIN/CP19)_{-1})$

1.3.3. Intermediate Demand

ID2 $= f(ID2_{-1}, (NAIN/CP16)_{-1}, ID3)$

I2F $= f(Q2F)$

I2G $= ID2 - I2F$

ID3 $= f(ID3_{-1}, (NAIN/CP16)_{-1})$

I11R $= f(I11R_{-1}, \overline{t})$

I11S $= f(I11S_{-1}, \overline{t}, (NAIN/CP4)_{-1})$

I11V $= f(I11V_{-1}, I11S)$

ID11 $= w_r^{11} \cdot I11R + w_s^{11} \cdot I11S + w_v^{11} \cdot I11V$

I12G $= f(I12G_{-1}, (NAIN/CP16)_{-1}, \overline{t})$

ID13 $= f(ID13_{-1}, (CP4/CP13)_{-1})$

ID19 $= \sum_{i=1}^{18} a_i^{19} \cdot Qi + a_{ft}^{19} \cdot NFTL + a_{fo}^{19} \cdot QFOR$

1.3.4. Animal Consumption

D5 $= c_5^7 \cdot (NS7 + 1/2 \cdot SL7 + NM10 + 1/2 \cdot SL10) + c_5^8 \cdot (NS8 + 1/2 \cdot SL8)$
$+ c_5^{9b} \cdot (NS9B + 1/2 \cdot SL9B) + c_5^{9h} \cdot (NS9H + 1/2 \cdot SL9H)$
$+ c_5^{10} \cdot (NF10 + 1/2 \cdot SL10)$

DFC $= c_{fc}^7 \cdot (NS7 + 1/2 \cdot SL7 + NM10 + 1/2 \cdot SM10) + c_{fc}^8 \cdot (NS8 + 1/2 \cdot SL8)$
$+ c_{fc}^{9b} \cdot (NS9B + 1/2 \cdot SL9B) + c_{fc}^{9h} \cdot (NS9H + 1/2 \cdot SL9H)$
$+ c_{fc}^{10} \cdot (NF10 + 1/2 \cdot SF10)$

DGF $= c_{gf}^{10} \cdot (NF10 + 1/2 \cdot SF10)$

1.3.5. Nutrition

PCRA $= \sum a_i^{ap} \cdot RTi/RPOP$ for $i = 7, 8, 9, 10, 13$

PCRV $= a_{11}^{vp} \cdot RT11/RPOP$

PCRT $= RA + PCRV$

PCRC $= \sum a_i^c \cdot RTi/RPOP$ for $i = 1,2,3,6$

PCRF $= \sum a_i^f \cdot RTi/RPOP$ for $i = 4,7,8,9,13$

PCRK $= \sum a_i^{cal} \cdot RTI/RPOP$

PCUA $= \sum a_i^{ap} \cdot UTi/UPOP$ for $i = 7,8,9,10,13)$

PCUV $= a_{11}^{vp} \cdot UT11/UPOP$

PCUT $= PCUA + PCUV$

PCUC $= \sum a_i^c \cdot UTi/UPOP$ for $i = 1,2,3,6$

PCUF $= \sum a_i^f \cdot UTi/UPOP$ for $i = 4,7,8,9,13$

PCUK $= \sum a_i^{cal} \cdot UTi/UPOP$

PCAP $= \sum a_i^{ap} \cdot (RTi + UTi)/\overline{T}POP$ for $i = 7,8,9,10,13$

PCVP $= a_{11}^{vp} \cdot (RT11 + UT11)/\overline{T}POP$

PCTP $= PCAP + PCVP$

PCC $= \sum a_i^c \cdot (RTi + UTi)\overline{T}POP$ for $i = 4,7,8,9,13$

1.4. Agricultural Production Module

WHR $= f((KFAR + KFIS + KFOR)/(LFAR + LFIS + LFOR),(PDRI/CP2)_{-1})$

NFTL $= f(NFTL_{-1}, (CI/PP2)_{-1}),(PNF/PP2)_{-1})$

PNF $= f(NFTL, PNF_{-1}, CP19)$

1.4.1. Wheat Production

PP1* $= \lambda_i PPi^*_{-1} + (1 - \lambda_1) \cdot PP1_{-1}$

A1 $= f(A1_{-1},(PP1^* \cdot Q1_{-1})/(WRN_{-1} \cdot L1_{-1}))$

NF1/A1 $= f((NF1/A1)_{-1}, PP1^*/PNF_{-1})$

K1 $= f(K1_{-1}, KFAR/LFAR)$

L1 $= f(L1_{-1}, (PP1^* \cdot Q1_{-1})/(WRN_{-1} \cdot L1_{-1}))$

$Q1 = f(A1, NF1, K1, KGA, L1, \overline{WI1}, \overline{t})$

1.4.2. Hulled Rice Production

$AR2 = f(ARP2_{-1}, (BS2/Q2)_{-1})$

$A2 = APF - AR2$

$NF2 = NFTL - NF1 - NF3B - NF3R - NF3C$

$K2 = KFAR - K1 - K3B - K3R - K3C - K6B - K6C - K7$
$\quad - K8 - K9 - K10 - K11 - K12 - K15 - K17 - KGF$

$L2 = WHR \cdot LFAR - L1 - L3B - L3R - L3C - L6B - L6C - L7$
$\quad - L8 - L9 - L10 - L11 - L15 - L17 - LGF$

$Q2 = f(A2, NF2, K2, KGA, L2, \overline{WI2}, \overline{t})$

$Q2F/Q2 = f((PP2F/PP2G)_{-1}, (BS2/Q2)_{-1})$

$Q2G = Q2 - Q2F$

$PP2 = (Q2G \cdot PP2G + Q2F \cdot PP2F)/Q2$

1.4.3. Production of Coarse Grains (Barley, Rye and Oats, and Corn)

$P3B = f(PP3, P3B_{-1}, w_b^3 \cdot Q3B/Q3)$

$P3R = f(PP3, P3R_{-1}, w_r^3 \cdot Q3R/Q3)$

$P3C = (PP3 \cdot Q3 - P3B \cdot Q3B - P3R \cdot Q3R)/Q3C$

$P3B^* = \lambda_3^b P3B^*_{-1} + (1 - \lambda_3^b) P3B_{-1}$

$P3R^* = \lambda_3^r P3R^*_{-1} + (1 - \lambda_3^r) P3R_{-1}$

$P3C^* = \lambda_3^c P3C^*_{-1} + (1 - \lambda_3^c) P3C_{-1}$

$A3B = f(A3B_{-1}, P3B^*/PP1_{-1})$

$A3R = f(A3R_{-1}, P3R^*/PP1_{-1})$

$A3C = f(A3C_{-1}, P3C^*/PP_{-1})$

$NF3B/A3B = f((NF3B/A3B)_{-1}, P3B^*/PNF)$

$NF3R/A3R = f((NF3R/A3R)_{-1}, P3R^*/PNF)$

$NF3C/A3C = f((NF3C/A3C)_{-1}, P3C^*/PNF)$

$K3B = f(K3B_{-1}, KFAR)$

$K3R = f(K3R_{-1}, KFAR)$

$K3C = f(K3C_{-1}, KFAR)$

$L3B = f(L3B_{-1}, P3B^*/PP1_{-1})$

$L3R = f(L3R_{-1}, P3R^*/PP1_{-1})$

$L3C = f(L3C_{-1}, P3C^*/PP1_{-1})$

$Q3B = f(A3B, NF3B, K3B, KGA, L3B, \overline{W}I1)$

$Q3R = f(A3R, NF3R, K3R, KGA, L3R, \overline{W}I1)$

$Q3C = f(A3C, NF3C, K3C, KGA, L3C, \overline{W}I1)$

$Q3 = w_b^3 \cdot Q3B + w_r^3 \cdot Q3R + w_c^3 \cdot Q3C$

1.4.4. Production of Sugar Beets and Sugar Cane

$P6B = f(CP6, P6B_{-1}, w_b^6 \cdot Q6B/Q6, CP19)$

$P6C = f(CP6, P6C_{-1}, w_c^6 \cdot Q6C/Q6, CP19)$

$P6B^* = \lambda_6^b \cdot P6B^*_{-1} + (1 - \lambda_6^b)P6B_{-1}$

$P6C^* = \lambda_6^c \cdot P6C^*_{-1} + (1 - \lambda_6^c)P6C_{-1}$

$A6B = f(A6B_{-1}, P6B^*/WP6_{-1})$

$A6C = f(A6C_{-1}, P6C^*/WP6_{-1})$

$K6B = f(K6B_{-1}, KFAR)$

$K6C = f(K6C_{-1}, KFAR)$

$L6B = f(L6B_{-1}, (P6B^* \cdot Q6B_{-1})/(WRN_{-1} \cdot L6B_{-1}))$

$L6C = f(L6C_{-1}, (P6C^* \cdot Q6C_{-1})/(WRN_{-1} \cdot L6C_{-1}))$

$Q6B = f(A6B, K6B, KGA, L6B, \overline{W}I2)$

$Q6C = f(A6C, K6C, KGA, L6C, \overline{W}I2)$

$Q6 = a_b^6 \cdot Q6B + a_c^6 \cdot Q6C$

1.4.5. Production of Bovine Meat and Milk

N7	$= (1 + B7)\cdot NS7_{-1}$
PNF5	$= \delta_1\cdot PNPF + \delta_2\cdot CP5$
B7	$= f(PP7_{-1}/PP8_{-1}, PP7_{-1}/PNF5_{-1}, \overline{t})$
PP7*	$= \lambda_7\cdot PP7^*_{-1} + (1 - \lambda_7)\cdot PP7_{-1}$
SL7	$= f(N7, PP7^*/PP8_{-1})$
NS7	$= N7 - SL7$
E7	$= f(\overline{t})$
N10	$= (1 + 1/2\cdot B10)\cdot NF10_{-1}$
B10	$= f(PP10_{-1}/PP10_{-2}, QQGF/NF10_{-1}, \overline{t})$
SF10	$= f(N10, PP7_{-1}/PP10_{-1}, QQGF)$
NF10	$= N10 - SF10$
SMI0	$= f(NM10_{-1} + 1/2\cdot B10\cdot NF10, PP7_{-1}/PP8_{-1})$
NM10	$= NM10_{-1} + 1/2\cdot B10\cdot NF10_{-1} - SM10$
Q7	$= E7\cdot(SL7 + a_{mc}\cdot SF10 + SM10)$
Q10	$= f(N10 - 1/2\cdot SF10, QQGF/NF10_{-1})$
K7	$= a_k^7\cdot(N7 + NM10)$
L7	$= a_l^7\cdot(N7 + NM10)$
K10	$= a_k^{10}\cdot NF10$
L10	$= a_l^{10}\cdot NF10$

1.4.6. Production of Pork

N8	$= (1 + B8)\cdot NS8_{-1}$
PP8*	$= \lambda_8\cdot PP8^*_{-1} + (1 - \lambda_8)\cdot PP8_{-1}$
B8	$= f(PP8^*/CP5_{-1}, \overline{t})$
SL8	$= f(N8, PP8^*/CP5_{-1})$
NS8	$= N8 - SL8$

E8	$= f(F)$
Q8	$= E8 \cdot SL8$
K8	$= a_k^8 \cdot N8$
L8	$= a_l^8 \cdot N8$

1.4.7. Production of Poultry and Eggs

P9B	$= f(PP9, P9B_{-1}, w_b^9 \cdot Q9B/Q9)$
P9E	$= (PP9 \cdot Q9 - P9B \cdot Q9B)/Q9E$
P9B*	$= \lambda_q^b \cdot P9B^*_{-1} + (1 - \lambda_q^b) \cdot P9B_{-1}$
P9E*	$= \lambda_q^e \cdot P9E^*_{-1} + (1 - \lambda_q^e) \cdot P9E_{-1}$
N9B	$= f(NS9B_{-1}, P9B^*/PP8_{-1})$
N9H	$= f(NS9H_{-1}, P9E^*/CP5_{-1})$
SL9B	$= f(N9B, N9H, P9B^*/CP5_{-1})$
SL9H	$= f(N9H, P9E^*/CP5_{-1})$
NS9B	$= N9B - SL9B$
NS9H	$= N9H - SL9H$
E9B	$= f(\overline{t})$
Q9B	$= E9B \cdot (SL9B + a_{HEN} \cdot SL9H)$
Q9H	$= f(N9H - 1/2 \cdot SL9H)$
Q9	$= w_b^9 \cdot Q9B + w_e^9 \cdot Q9E$
K9	$= a_k^9 \cdot (N9B + N9H)$
L9	$= a_l^4 \cdot (N9B + N9H)$

1.4.8. Production of Starchy Roots, Soybeans, and Vegetables

P11R	$= f(PP11, P11R_{-1}, w_r^{11} \cdot Q11R/Q11)$
P11S	$= f(PP11, P11S_{-1}, w_s^{11} \cdot Q11S/Q11)$
P11V	$= (PP11 \cdot Q11 - P11R \cdot Q11R - P11S \cdot Q11S)/Q11V$

P11R*	$= \lambda^{r}_{11} \cdot P11R^{*}_{-1} + (1 - \lambda^{r}_{11}) \cdot P11R_{-1}$
P11S*	$= \lambda^{s}_{11} \cdot P11S^{*}_{-1} + (1 - \lambda^{s}_{11}) \cdot P11S_{-1}$
P11V*	$= \lambda^{v}_{11} \cdot P11V^{*}_{-1} + (1 - \lambda^{v}_{11}) \cdot P11V_{-1}$
A11R	$= f(A11R_{-1}, P11R^{*}/P11V_{-1})$
A11S	$= f(A11S_{-1}, P11S^{*}/P11V_{-1})$
A11V	$= f(A11V_{-1}, P11V^{*}/P11R_{-1})$
Q11R	$= f(A11R, \overline{WI2})$
Q11S	$= f(A11S, \overline{WI2})$
Q11V	$= f(A11V, \overline{WI2})$
K11	$= a^{11}_{kr} \cdot Q11R + a^{11}_{ks} \cdot Q11S + a^{11}_{kv} \cdot Q11V$
L11	$= a^{11}_{ls} \cdot Q11R + a^{11}_{ls} \cdot Q11S + a^{11}_{lv} \cdot Q11V$
Q11	$= w^{11}_{r} \cdot Q11R + w^{11}_{s} \cdot Q11S + w^{11}_{v} \cdot Q11V$

1.4.9. Production of Grapes and Other Fruits

P12G	$= f(PP12, P12G_{-1}, w^{12}_{g} \cdot Q12G/Q12)$
P12F	$= (PP12 \cdot Q12 - P12G \cdot Q12G)/Q12F)$
P12G*	$= \lambda^{g}_{12} \cdot P12G^{*}_{-1} + (1 - \lambda^{g}_{12}) \cdot P12G_{-1}$
P12F*	$= \lambda^{f}_{12} \cdot P12F^{*}_{-1} + (1 - \lambda^{f}_{12}) \cdot P12F_{-1}$
A12G	$= f(A12G_{-1}, P12G^{*}/P12F_{-1})$
A12F	$= f(A12F_{-1}, P12F^{*}/P12G_{-1})$
Q12G	$= f(A12G, \Delta Q12G_{-1}, \overline{WI2})$
Q12F	$= f(A12F, \Delta Q12F_{-1}, \overline{WI2})$
K12	$= a^{12}_{kg} \cdot Q12G + a^{12}_{kf} \cdot Q12F$
L12	$= a^{12}_{lg} \cdot Q12G + a^{12}_{lf} \cdot Q12F$
Q12	$= w^{12}_{g} \cdot Q12G + w^{12}_{f} \cdot Q12F$

1.4.10. Production of Fish

Q13 $= f(WHR \cdot LFIS, KFIS, \overline{THMD})$

1.4.11. Production of Tea

P15T $= f(CP15, P15T_{-1}, w_t^{15} \cdot Q15T/D15)$

P15T* $= \lambda_{15}^t \cdot P15T^*_{-1} + (1 - \lambda_{15}^t) \cdot P15T_{-1}$

A15T $= f(A15T_{-1}, P15T^*/WP14_{-1})$

Q15T $= f(A15T, \overline{WI2})$

K15 $= s_{kt}^{15} \cdot Q15$

L15 $= s_{lt}^{15} \cdot Q15$

Q15 $= w_t^{15} \cdot Q15T$

1.4.12. Production of Silk Cocoons

P17C $= f(PP17, P17C_{-1}, w_c^{17} \cdot Q17C/Q17)$

P17C* $= \lambda_{17}^c \cdot P17C^*_{-1} + (1 - \lambda_{17}^c) \cdot P17C_{-1}$

A17M $= f(A17M_{-1}, (P17C^* \cdot Q17C_{-1})/WRN_{-1} \cdot L17_{-1}))$

Q17C $= f(A17M)$

K17 $= a_{kc}^{17} \cdot Q17C$

L17 $= a_{lc}^{17} \cdot Q17C$

1.4.13. Production of Tobacco and Igusa Plants

P18T* $= \lambda_{18}^t \cdot P18T^* sub-1 + (1 - \lambda_{18}^t) \cdot P18T_{-1}$

A18T $= f(A18T_{-1}, P18T^*/PP11_{-1})$

L18T $= f(L18T_{-1}, (P18T^* \cdot Q18T_{-1})/(WRN_{-1} \cdot L18T_{-1}))$

Q18T $= f(A18T, L18T, \overline{WI2})$

A18I $= f(\overline{t})$

Q18I $= f(A18I)$

Q18 $= w_t^{18} \cdot Q18T + w_i^{18} \cdot Q18I$

K18 $= a_{kt}^{18} \cdot Q18T + a_{ki}^{18} \cdot Q18I$

L18 $= L18T + a_{li}^{18} \cdot Q18I$

1.4.14. Production of Woods

PFOR $= f(PP19,\ w_{fo}^{19} \cdot QFOR/Q19)$

QFOR $= f(WHR \cdot LFOR,\ KFOR + KGA)$

1.4.15. Production of Green Feed

AGF $= F(AGF_{-1},\ (PP10/PP2)_{-1},\ ARP2)$

QGF $= F(AGF)$

KGF $= a_k^{gf} \cdot QGF$

LGF $= a_l^{gf} \cdot QGF$

1.4.16. Production of Joint Products and Processed Foods

Q4 $= w_7^4 \cdot b_4^7 \cdot Q7 + w_8^4 \cdot b_4^8 \cdot Q8 + w_2^4 \cdot a_4^{2b} \cdot (RT2+UT2+ID2) \cdot (1/a_2^2 - 1)$
$+ w_4^{11} \cdot (a_{4s}^{11} \cdot I11S + a_{4v}^{11} \cdot I11V) + w_4^{13} \cdot a_{13}^4 \cdot ID13$

Q5 $= w_7^5 \cdot b_5^7 \cdot Q7 + w_8^5 \cdot b_5^8 \cdot Q8 + w_{11}^5 \cdot (1 - a_{4s}^{11}) \cdot I11S$
$+ w_{13}^5 \cdot (1 - a_4^{13}) \cdot ID13$

Q16 $= w_2^{16} \cdot a_{16}^2 \cdot ID2 + w_3^{16} \cdot a_{16}^3 \cdot ID3 + w_{11}^{16} \cdot a_{16}^{11} \cdot I11R$
$+ w_{12}^{16} \cdot a_{16}^{12} \cdot I12G$

Q17 $= w_7^{17} \cdot a_{17}^{12} \cdot Q7 + w_8^{17} \cdot b_{17}^8 \cdot Q8 + w_c^{17} \cdot Q17c$

1.4.17. Production of Non- protein and Green Feed

QFC $= w_c^{1b} \cdot (1 - a_4^1) \cdot (RT1 + UT1) + w_c^1 \cdot F\ bar\ 1$
$+ w_c^{2b} \cdot (1 - a_4^{2b}) \cdot (RT2 + UT2 + ID2)/(1/a_2^2 - 1)$
$+ w_c^2 \cdot F\ bar\ 2 + w_c^3 \cdot F3 + w_c^{6b} \cdot (1 - a_b^6) \cdot Q6B$

$+ w_c^{6c} \cdot (1 - a_c^6) \cdot Q6C + w_c^{11} \cdot a_f^{11} \cdot Q11R$

QQGF $= a_m \cdot MEAD + QGF$

1.4.18. Food Self- sufficiency Rate

FSSR $= \sum CPi \cdot Qi / \sum CPi \cdot Di$

1.5. Nonagricultural Production and Government Employment Module

1.5.1. Nonagricultural Labor, Employment, Wage Rate, Capital Use Rate, and Production

ENAL $= f(WRN/NP19, KN/LNAP, ENAL_{-1})$

EUL $= ENAL - (LNAR - LGR)$

WHN $= f((KN + KGN)/LNAP, WHN_{-1}, (UEFH! \cdot NUH)_{-1}/UPOP_{-1}, \overline{t})$

UE $= LNAP - ENAL - LGOV$

KURN $= f((NQ19/KN)_{-1}/(NQ19/KN)_{-2}, (BS19/Q19)_{-1}, IG/IG_{-1})$

KAUN $= KURN \cdot KN$

TWHN $= WHN \cdot ENAL$

WRN $= f((NP19 \cdot NQ19/ENAL)_{-1}, WRN_{-1})$

NQ19 $= a(t) \cdot KAUN^{b} \cdot TWHN^{1-b}$

Q19 $= w_{19}^{19} \cdot NQ19 + w_{fo}^{19} \cdot QFOR$

NP19 $= (PP19 \cdot Q19 - PFOR \cdot QFOR)/NQ19$

1.5.2. Government Employment

LGOV $= f(LNAP, WRG/WRN)$

LGR $= agr \cdot LGOV$

LGU $= (1 - agr) \cdot LGOV$

1.6. Investment and Capital Formation Module

1.6.1. Investment

$IG \quad = f((NAIN/GPL)_{-1}, IG_{-1}, (GR/GPL)_{-1})$

$IGA \quad = f(IGA_{-1}, FSSR_{-1}, (PCAI/PCUI)_{-1})$

$IGN \quad = IG - IGA$

$IN \quad = f(RE/CP19, \sum(4-i)\cdot Q19_{-i}/6, \sum(4-i)\cdot KURN_{-i}/6, IR, KN_{-1}, \sum(4-i)\cdot GP19_{-i}/(6\cdot CP19_{-i}\cdot KN_{-i}))$

$IA \quad != f(\sum (4-i)\cdot FSSR_{-i}/6, \sum(4-i)\cdot IGA_{-i}/6, \sum(4-i)\cdot RE_{-i}/(6\cdot CP19_{-i}\cdot(KFAR + KFIS + KFOR)_{-i}), IR, (KFAR + KFIS + KFOR)_{-1})$

$IFIS \quad = f(\sum(4-i)\cdot Q13_{-i}/6, IFIS_{-1}, (PFII/PFAI)_{-1}, KFIS_{-1})$

$IFOR \quad = f(\sum(4-i)\cdot QFOR_{-i}/6, IFOR_{-1}, (PFOI/PFAI)_{-1}, KFOR_{-1})$

$IFAR \quad = IA - IFIS - IFOR$

$RS \quad = DRI - RHI\cdot NRH$

$US \quad = DUI - UHE\cdot NUH$

$GS \quad = GR - GE$

$IR \quad = f(\dot{G}NP_{-1}, \dot{M}19_{-1})$

$IH \quad = (RS + US + GS + RE)/CP19 - (IG + IN + IA)$

1.6.2. Capital Formation

$KFAR \quad = KFAR_{-1} + IFAR_{-1} - DFAR$

$KFIS \quad = KFIS_{-1} + IFIS_{-1} - DFIS$

$KFOR \quad = KFOR_{-1} + IFOR_{-1} - DFOR$

$KN \quad = KN_{-1} + IN_{-1} - DN$

$KGA \quad = KGA_{-1} + IGA_{-1} - DGA$

$KGN \quad = KGN_{-1} + IGN_{-1} - DGN$

$KH \quad = KH_{-1} + IH_{-1} - DH$

1.6.3. Depreciation of Capital

$DFAR = f(KFAR_{-1}, \dot{GNP}_{-1})$

$DFIS = f(KFIS_{-1}, \dot{GNP}_{-1})$

$DFOR = f(KFOR_{-1}, \dot{GNP}_{-1})$

$DN = f(KN_{-1}, \dot{GNP}_{-1})$

$DGA = f(KGA_{-1}, \dot{GNP}_{-1})$

$DGN = f(KGN_{-1}, \dot{GNP}_{-1})$

$DH = f(KH_{-1})$

1.7. International Trade, Price Determination, Net Import Quota, and Buffer Stock Constraint Module

1.7.1. International Trade and Price Determination

$FXR = f((\dot{GNP}/\dot{\overline{U}}GNP)_{-1}, (AFR/WP19)_{-1}, FXR_{-1})$

$AFR = AFR_{-1} + \overline{F}R$

$\overline{F}R = - \sum \overline{I}Pi \cdot Mi$

$ITOG = a_g \cdot \overline{F}R \cdot FXR$

$ITOF = a_f \cdot \overline{F}R \cdot FXR$

$ITOU = a_u \cdot \overline{F}R \cdot FXR$

$ITON = (1 - a_g - a_f - a_u) \cdot \overline{F}R \cdot FXR$

$WPi = a_i^I \cdot FXR \cdot \overline{I}Pi + b_{19i}^I \cdot FXR \cdot \overline{I}P19$ for $i \neq 2$ and 19

$WP19 = a_{19}^I \cdot FXR \cdot \overline{I}P19$

$TPi = a_{ci}^{\overline{W}} \cdot (1 + TRi) \cdot WPi$ for $i \neq 1$ and 2

$CPi = TPi + LUi - LLi$ for $i \neq 1$ and 2

$LUi \cdot (UIi - Mi) = 0$

$LLi \cdot (Mi - LLi) = 0$

$LUi \cdot (BSi - LBi) = 0$

$LLi \cdot (UBi - BSi) = 0$

PPi $= a_i \cdot CPi^{b_i} \cdot CP19^{1-b_i}$ for i ¯ 19

PP19 $= a_{19} \cdot WP19^{b_{19}} \cdot CP19^{1-b_{19}}$

1.7.2. Net Import Quota

UIi $= AFR/\overline{I}Pi$ for $i \neq 7$ and 8

LIi $= 0$ for $i \neq 3$ and 19

LI3 $= a_{li}^{3} \cdot DFC$

UI7 $= f(AI7/L7 \cdot WRN,\ \Delta(PP7/PP2), NAIN/CP7)$

UI8 $= f(AI8/L8 \cdot WRN,\ \Delta(PP8/PP2), UI7,\ NAIN/CP8)$

LI19 $= -f(GNP_{-1})$

1.7.3. Buffer Stock Constraint

UBi = given for i = 1,2,3,7,8,19

LB1 $= \max(M1 + DS1 - D1,\ \overline{N}SB1)$

LB2 $= \max(DS2 - D2,\ \overline{N}SB2)$

LB3 $= f(DFC_{-1},\ \Delta(PP3/WP3)_{-1},\ (AFR/WP3)_{-1})$

LB7 $= \max(M7 + DS7 - D7,\ 0)$

LB8 $= \max(M8 + DS8 - D8,\ 0)$

LB19 $= f(GNP_{-1},\ \Delta(PP19/WP19)_{-1},\ (AFR/I\ bar\ P19)_{-1})$

1.8. Government Policy Module

1.8.1. Price Support Policies

PP1 $= f(WP1, PP1_{-1},\ FSSR_{-1},\ (BS2/D2)_{-1},\ PP2G,\ (Bs1/D1)_{-1})$

CP1 $= f(PP1,\ CP2G,\ CP1_{-1},\ (BS2/D2)_{-1},\ CP19,\ (BS1/D1)_{-1})$

PP2G $= f(PP2G_{-1},\ \overline{E}LED,\ FSSR_{-1},\ GS_{-1},\ (BS2/D2)_{-1},\ (PCRI/PCUI)_{-1})$

CP2G $= f(PP2G,\ GS_{-1},\ (BS2/D2)_{-1},\ CP19)$

P18T	$= f(P18T_{-1}, PP2G)$
C18T	$= f(P18T, C18T_{-1}, GE/GR, \overline{t})$
WRG	$= f(WRG_{-1}, WRN_{-1})$

1.8.2. Agricultural Production Policies

SUBA	$= f(FSSR_{-1}, (PCRI/PCUI)_{-1}, (UPOP/\overline{T}POP)_{-1})$
ARP2	$= f((BS2/D2)_{-1}, (PP2G \cdot Q2/A2)_{-1}, A2_{-1})$

1.8.3. International Trade Policies

TRi	$= f((Mi/Qi)_{-1}, GE/GR, AFR/\overline{I}P19, TRi_{-1})$ for $i = 6,7,8,10$
M1	$= f(AFR/\overline{I}P19, Q2_{-1}, (BS2/D2)_{-1}, (BS1/D1)_{-1})$
M18T	$= f(AFR/\overline{I}P19, \Delta GNP, (Q18T/M18T)_{-1})$

1.8.4. Taxation Policies

NPTX	$= f(\dot{G}NP, (GS_{-1} + GS_{-2})/2 \cdot GPL, \overline{E}LED)$
APTX	$= f(\dot{G}NP, (GS_{-1} + GS_{-2})/2 \cdot GPL, FSSR_{-1}, NPTX)$
ITXS	$= f(ITXS_{-1}, \overline{t}, (GS_{-1} + GS_{-2})/2 \cdot GPL)$
ITXB	$= f(GE/GR, ITXB_{-1}, \overline{t})$
ITXN	$= f(\dot{G}NP, BS19/Q19, (GS_{-1} + GS_{-2})/2 \cdot GPL)$
CTX	$= f(\dot{G}NP, BS19/Q19, (RE/GP19)_{-1}, (GS_{-1} + GS_{-2})/2 \cdot GPL)$

APPENDIX 2

VARIABLE NOTATIONS

A Note on Notations

1. An endogenous variable which is not a policy variable does not have any hat or bar over its notation, e.g., PP7, Q3, FI.
2. An endogenous variable which is a policy variable has a hat over its notation, e.g., PP2G, ITXS, TR7.
3. An exogenous variable has a bar over its notation, e.g., $\overline{\text{WI1}}$, $\overline{\text{ELED}}$, $\overline{\text{t}}$.
4. The time trend variable is expressed as $\overline{\text{t}}$.
5. A lagged variable has a subscript with a minus sign, e.g., GNP_{-2}, PP1_{-2}.
6. An expected price variable has an asterisk at the right-hand side of its notation, e.g., PP1*, PP8*.

7. Small letters of the alphabet and Greek letters are coefficients to be estimated.

8. $\dot{GNP} = (GNP - GNP_{-1})/GNP_{-1}$

9. $\Delta GNP = GNP - GNP_{-1}$

10. $(BS19/Q19)_{-1} = BS19_{-1}/Q19_{-1}$

APTX	Agricultural personal tax rate
Ali	Animal (production) income of animal i
AGIN	Agricultural income
ARP2	Rice acreage reduction unit subsidy per acre
AR2	Acreage of paddy field reduced by rice acreage reduction policy
AFR	Accumulated foreign reserves in terms of 1970 US dollars.
Ai	Acreage of crop i
A3B	Acreage of barley
A3R	Acreage of rye and oats
A3C	Acreage of corn and other cereals
A6B	Acreage of sugar beets
A6C	Acreage of sugar cane
A11R	Acreage of starchy roots
A11S	Acreage of soybeans
A11V	Acreage of vegetables
A12G	Acreage of grape
A12F	Acreage of other fruits
A15T	Acreage of tea
A17M	Acreage of mulberry
A18T	Acreage of tobacco
A18I	Acreage of igusa
AGF	Acreage of green feed
APF	Acreage of total paddy fields
AGS	Accumulated government savings
ARS	Accumulated rural savings
AUS	Accumulated urban savings

AUF	Acreage of total upland fields
BSi	Buffer stock of commodity i
Bi	Net birth rate of animal i
CTX	Corporate income tax rate
CPi	Consumer price of commodity i
CIi	Crop income of crop i
C18T	Consumer price of tobacco
CP2G	Consumer price of polished rice sold by the government
CI	$= \sum CIi$
DAA	Depreciation allowances for agricultural capital
DAN	Depreciation allowances for nonagricultural capital
DFI	Disposable farm income
DRI	Disposable rural income
DRHI	Disposable rural household income
DUHI	Disposable urban household income
DUI	Disposable urban income
DIVI	Dividend
Di	Total demand quantity of commodity i
DFAR	Depreciation of farming capital
DFIS	Depreciation of fishery capital
DFOR	Depreciation of forestry capital
DN	Depreciation of capital in nonagriculture
DGA	Depreciation of government capital in agriculture
DGN	Depreciation of government capital in nonagriculture
DH	Depreciation of housing
DSi	Domestic supply quantity of commodity i
$\overline{E}$LED	Election dummy

ENAL	Employed nonagricultural labor (persons)
Ei	Production quantity of commodity i from animal i e.g., hogs→pork
EUL	Employed urban labor (persons)
E9B	Production quantity of poultry from broilers
FI	Farm income
FISI	Fishery income
FORI	Forestry income
FDi	Feed intake per head of animal i
FARI	Farming income
FSSR	Food self-sufficiency rate
FAIF	Farming income per farmer
FIIF	Fishery income per fisherman
FOIF	Forestry income per forestry worker
FXR	Foreign exchange rate
Fi	Quantity of commodity i consumed as feed
$\overline{FR}$	Foreign reserves (or foreign deficits) in terms of 1970 US$
GR	Government revenue
GE	Government expenditures
GS	Government savings (on balance)
$\overline{GROR}$	Government ruling and opposition party member ratio
GNP	Gross national product
GC	Government consumption quantity of commodity 19, i.e., nonagricultural commodity.
GP19	Gross profit of nonagricultural production
ITXS	Indirect tax rate imposed on sugar
ITXN	Indirect tax rate imposed on nonagricultural commodity
ITXB	Indirect tax rate imposed on alcoholic beverages

ITOG	Net income transfer from overseas to government
IGA	Government investment in agriculture
IG	Total government investment
IA	Investment in agriculture (private)
IGN	Government investment in nonagriculture
IN	Investment in nonagriculture (private)
IH	Investment in housing
IDi	Intermediate demand quantity of commodity i
ITOF	Net income transfer from overseas to farmers, fishermen, and forestry workers
ITOU	Net income transfer from overseas to urban dwellers
ITON	Net income transfer from overseas to nonagricultural corporations
$\overline{\text{I}}$Pi	IIASA world price of commodity i (prices in terms of 1970 US$)
I2F	Intermediate demand quantity of free-market rice used for production of sake liquor
I2G	Intermediate demand quantity of government-controlled rice used for production of sake liquor
I11R	Intermediate demand quantity of starchy roots used for production of alcohol
I11S	Intermediate demand quantity of soybeans used for production of vegetable oil (and protein-feed cake)
I11V	Intermediate demand quantity of vegetables (rape seeds, sunflower seeds, sesame seeds, etc.) used for production of vegetable oil.
I12G	Intermediate demand quantity of grape used for production

	of wine
ID13	Intermediate demand quantity of fish used for production of fish oil (and fish meal)
ID19	Intermediate demand quantity of nonagricultural commodities used for agricultural production
IR	Real interest rate
KN	Capital in nonagricultural sector
KFAR	Capital for farming
KFIS	Capital for fishery
KFOR	Capital for forestry
KURN	Capital use rate of capital in nonagricultural sector
Ki	Capital used for production of commodity i
K3B	Capital used for production of barley
K3R	Capital used for production of rye and oats
K3C	Capital used for production of corn and other cereals
K6B	Capital used for production of sugar beets
K6C	Capital used for production of sugar cane
KGF	Capital used for production of green feed
KAUN	Capital actually used for nonagricultural production
KGA	Government capital in agriculture
KGN	Government capital in nonagriculture
KH	Housing capital
LNAF	Labor for nonagricultural production from rural areas (persons)
LFAR	Labor for farming, i.e., cropping and animal production (persons)
LFIS	Labor for fishery (persons)
LFOR	Labor for forestry (persons)
Li	Labor used for the production of commodity i (man-days)

L3B	Labor for barley (man-days)
L3R	Labor for rye and oats (man-days)
L3C	Labor for corn and other cereals (man-days)
L6b	Labor for sugar beets (man-days)
L6C	Labor for sugar cane (man-days)
LGF	Labor for green feed (man-days)
LAR	Labor availability in rural area (persons)
LAND	Sum of acreage of paddy and upland fields
LAU	Labor availability in urban areas (persons)
LNAP	Labor availability for nonagricultural production
LLi	Lagrangean multiplier of constraint imposed on the lower bound of import of commodity i and/or constraint imposed on the lower bound of buffer stock of commodity i
LUi	Lagrangean multiplier of constraint imposed on the upper bound of import of commodity i and/or constraint imposed on the upper bound of buffer stock of commodity i
LIi	Lower bound of net import quota imposed on commodity i
LBi	Lower bound of buffer stock of commodity i
LGOV	Labor employed by the government
LGR	Labor employed from rural areas by the government
LGU	Labor employed from urban areas by the government
Mi	Net import of commodity i
M18T	Net import of tobacco
M1	Net import of wheat
MEAD	Acreage of meadow and pasture
NAFI	Nonagricultural income
NRH	Number of rural households

NUH	Number of urban households
NPTX	Nonagricultural personal tax rate
Ni	Number of animal i
NSi	Number of animal i surviving at the end of a year
NF10	Number of cows surviving at the end of a year
NM10	Number of bulls surviving at the end of a year
N9B	Number of broilers raised during a year
N9H	Number of hens raised during a year
NS9B	Number of broilers surviving at the end of a year
NS9H	Number of hens surviving at the end of a year
NFTL	Total quantity of nitrogen fertilizer
NFi	Nitrogen fertilizer quantity applied to crop i
NPUI	Net incremental acreage from paddy to upland field
NAIN	National income
PPi	Producer price of commodity i
PDRI	Per capita disposable rural income
PDUI	Per capita disposable urban income
PP2G	Producer price of (hulled) rice bought by the government
PFOR	Producer price of wood
PNF	Price of nitrogen fertilizer
PPi*	Expected producer price of commodity i
PP2F	Producer price of free-market (hulled) rice
P3B	Producer price of barley
P3R	Producer price of rye and oats
P3C	Producer price of corn and other cerea s
P3B*	Expected producer price of barley
P3R*	Expected producer price of rye and oats

P3C*	Expected producer price of corn and other cereals
P6B	Producer price of sugar beets
P6C	Producer price of sugar cane
P6B*	Expected producer price of sugar beets
P6C*	Expected producer price of sugar cane
P9B	Producer price of broilers (and hen poultry meats)
P9E*	Producer price of eggs
P9B*	Expected producer price of broilers (and hen poultry meats)
P9E	Expected producer price of eggs
P11R	Producer price of starchy roots
P11S	Producer price of soybeans
P11V	Producer price of vegetables
P11R*	Expected producer price of starchy roots
P11S*	Expected producer price of soybeans
P11V*	Expected producer price of vegetables
P12G	Producer price of grape
P12F	Producer price of other fruits
P12G*	Expected producer price of grape
P12F*	Expected producer price of other fruits
P15T	Producer price of tea
P15T*	Expected producer price of tea
P17C	Producer price of silk cocoons
P17C*	Expected producer price of silk cocoons
PCRA	Per capita animal protein intake in rural areas
PCRV	Per capita vegetable protein intake in rural areas
PCRT	Per capita protein intake in rural areas
PCRC	Per capita carbohydrates intake in rural areas

PCRF	Per capita fat intake in rural areas
PCRK	Per capita calories in rural areas
PCUA	Per capita animal protein intake in urban areas
PCUV	Per capita vegetable protein intake in urban areas
PCUC	Per capita carbohydrates intake in urban areas
PCUF	Per capita fat intake in urban areas
PCUK	Per capita calories in urban areas
PCAP	Per capita animal protein intake
PCVP	Per capita vegetable protein intake
PCTP	Per capita protein intake
PCC	Per capita carbohydrates intake
PCF	Per capita fat intake
PCK	Per capita calories
P18T	Producer price of tobacco
P18T*	Expected producer price of tobacco
PNF5	Price of non-protein and protein feed mix
PCFI	Per capita farm income
PCUI	Per capita urban income
PCAI	Per capita agricultural income
PNPF	Consumer price of nonprotein feed
QFOR	Production quantity of wood
Qi	Production quantity of commodity i (from which the quantity of commodity i used as an intermediate good, e.g., seeds are subtracted)
QGF	Production quantity of green feed
Q2G	Quantity of rice bought by the government
Q2F	Quantity of rice bought on a free market

Q3B	Production quantity of barley
Q3R	Production quantity of rye and oats
Q3C	Production quantity of corn and other cereals
Q6B	Production quantity of sugar beet
Q6C	Production quantity of sugar cane
Q9B	Production quantity of poultry
Q9E	Production quantity of eggs
Q11R	Production quantity of starchy roots
Q11S	Production quantity of soybeans
Q11V	Production quantity of vegetables
Q12G	Production quantity of grape
Q12F	Production quantity of other fruits
Q15T	Production quantity of tea
Q17C	Production quantity of silk cocoons
Q18T	Production quantity of tobacco
Q18I	Production quantity of igusa
QQGF	Total production quantity of grass and green feed
RI	Rural income
RPOP	Rural population
RE	Retained earnings
REFH	Rural household expenditure on foods, beverages and housing
RHE	Total rural household expenditure
REi	Rural household expenditure on commodity i
RTi	Total rural consumption quantity of commodity i
RCi	Rural household committed consumption quantity of commodity i
SUBA	Subsidy or income transfer to agriculture

SLi	Number of animal i slaughtered or consumed
SF10	Number of cows slaughtered
SM10	Number of bulls slaughtered
SL9B	Number of broilers consumed
SL9H	Number of hens consumed
$\overline{t}$	Time trend
TRi	Tariff rate of commodity i
$\overline{\text{THMD}}$	200-mile-regulation dummy
$\overline{\text{TPOP}}$	Total population
TPi	Targeted consumer price of commodity i
UI	Urban income
UWI	Urban wage income
UPOP	Urban population
UE	Unemployment
UEFH	Urban household expenditure on foods, beverages and housing
UHE	Total urban household expenditure
UEi	Urban household expenditure on commodity i
UTi	Total urban consumption quantity of commodity i
UCi	Urban household committed consumption quantity of commodity i
UIi	Upper bound of net import quota imposed on commodity i
UILU	Additional acreage of urban and industrial land
$\overline{\text{UGNP}}$	US GNP
UBi	Upper bound of buffer stock of commodity i
WRN	Wage rate of nonagricultural production
WPi	World price of commodity i with which Japan is faced
WHR	Working hours of a farmer during a year (Unit: days)
$\overline{\text{WI1}}$	Weather index for fall and winter

$\overline{WI2}$	Weather index for spring and summer
WHN	Working hours of a worker in nonagricultural production
WRG	Wage rate of government employee