An Econometric Model of a Rice Market

by

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The aim of this article is to set up a multi-regional econometric model in order to analyze the rice market structure of Japan, Korea and Formosa during 1914-37. This is a case study of a commodity market in which Japan, Korea and Formosa constituted one market yet retained their own regional characteristics. During this period about 15 per cent of Japan's annual rice consumption was imported from Korea and Formosa, and nearly one-third and one-half of the rice produced in Korea and Formosa, respectively, were exported to Japan each year. Obviously Korean and Formosan rice played an important role in affecting the Japanese rice price, and earnings from rice exports to Japan constituted a significant aspect of the economic development of Korea and Formosa. This model will estimate the Japanese rice price and Korean and Formosan rice exports, and investigate the properties of the rice market structure.

The conventional approach to empirical studies of international commodity flows focuses attention on the estimation of export and import elasticities, i.e., percentage change in export and import over percentage change in price.[1] Usually, exports and imports are treated as dependent variables, and those factors affecting exports and imports as independent variables, and single equation least-squares method is used for the estimation of parameters. This approach is inadequate because country A's export to country B is influenced not only by the import demand of B, but also by the effect of a change in price on domestic consumption in A. In other words, it fails to take domestic demand and interregional demand into account simultaneously. The conventional approach assumes implicitly that export or import is independently determined rather than interacting with domestic demand and supply. Moreover, a single equation approach makes it impossible to analyse a case with more than two rogions involved, because A's export to B depends not only on the relationship between A and B but also

1 T.C. Chang. *Cyclical Movements in the Balance of Payments* (Cambridge: University Pres, 1951). J. J. Polak, *An International Economic System* (Chicago: University of Chicago Press, 1953). H.P. Niesser and F. Modigliani, *National Incomes and International Trade; A Quantitative Analysis* (Urbana: University of Illinois Press, 1953).

on how much C exports to B.

In the present study, the simultaneous equation approach is taken and the instrumental variable method is used to estimate the parameters. A brief description of symbols used appears in Table 1.

Table 1

Glossary of Variables[2]

Symbol	*Brief Description*
A. Endogenous	
D_j, D_k, D_f	Amount of rice consumption in Japan, Korea and Formosa, in million koku[3]
P_j, P_k. P_f	Price of rice in Japan, Korea and Formosa in yen per koku
P'	Deflated Japanese rice price
S_j, S_k. S_f	Amount of rice stock in Japan, Korea and Formosa in million koku
E_{kj}	Amount of rice export from Korea to Japan, in million koku
E_{fj}	Amount of rice export from Formosa to Japan, in million koku
B. Exogenous	
Q_j, Q_k, Q_f	Amount of rice production in Japan, Koroe and Formosa in million koku
Q	Total rice production in Japan, Korea and Formosa
Y_j	Gross national product of Japan, in million yen
N_j, N_k, N_f	Population in Japan, Korea and Formosa, in million
I_j	Whole-sale price index of Japan, 1893-97=100
I_k	Whole-sale price index of Korea, 1910=100
I_f	Whole-sale price index of Formosa, 1914=100
T	Time trend of Japan, Korea and Formosa

1. Rice Demand and Stock Functions

Estimation of the rice demand function for each of the three regions is made by taking per capita disappearance of rice during the rice crop year (from November to October) as the dependent variable, and deflated rice price and time trend as the independent variables. An additional independent variable, per capita gross national product, is included for Japan only, as this data is not available for Korea and

2 Derivation and source of data are explained in Adpendix.

3 1 koku=4.96 bushels.

Formosa. The rice stock function is estimated for Japan only, as rice stock data is lacking for Korea and Formosa. Parameters of these rice demand and stock functions are estimated by taking per capita rice production as the instrumental variable and are fitted with first differences. Notation, derivation, and actual sample data of variables are explained in the Appendix. The results of our estimates are as follows:

Japanese rice demand function:

$$\frac{D_j}{N_j}=-0.057\frac{P_j}{I_j}+0.0014\frac{Y_j}{N_j I_j}-0.0016T+1.446$$

Korean rice demand function:

$$\frac{D_k}{N_k}=-0.027\frac{P_k}{I_k}-0.013T+0.899$$

Formosan rice demand function:

$$\frac{D_f}{N_f}=-0.013\frac{P_f}{I_f}-0.016T+1.113$$

Japanese rice stock function:

$$\frac{S_j}{N_j}=-0.0099\frac{P_j}{I_j}-0.00036T+0.208$$

Multiplying each parameter by its respective mean ratio gives price elasticities of −0.52, −0.6, and −0.15 for rice demand of Japan, Korea, and Formosa, respectively, and −1.01 for Japanese rice stock. Comparing our results with those obtained from previous studies, the price elasticity of Japan's rice demand by our estimate shows a slightly larger magnitude in absolute terms (e.g., Sugimote and Okawa obtained elasticities of −0.2 to −0.4, and 0 to −0.5 respectively for rice demand).[4]

Per capita rice consumption shows a negative trend for all three regions: the declining tendency being greater in Korea and Formosa than in Japan. The decline in Japan is probably the result of the greater availability of diversified foods and a long-run tendency to shift from cereal consumption to more expensive foods. Korea's and Formosa's decline is more likely to be the result of the shift from rice to cheaper foods such as millet in Korea and sweet potatoes in Formosa. The income elasticity of 0.21 for Japanese rice demand is an aggregate effect irrespective of possible differences of income elasticities for various occupational groups or for non-food uses of rice such as for ***sake***.[5]

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4 Eichi Sugimoto, ***Riron keizaigaku no kihon mondai*** (***Basic Problems of the Economic Theory***) (Tokyo: Nihon Hyoronsha, 1939). Kazushi Okawa, ***Shokuryo keizai no riron to keisoku*** (***Theory and Measurement of Food Economy***) (Tokyo: Nihon Hyoronsha, 1945).

5 Okawa found the income elasticity to be negative among industrial workers and salary earners but positive for farmers. Okawa, ***op. cit.***, pp. 9-34.

6 Yoshinosuke Yagi, ***Beika oyobi beika tosei mondai*** (***The Price of Rice and Its Control***) (Tokyo: Yuhikaku, 1932,) pp. 416-25 and 447-52, Osatsugu Hishimoto, ***Chosen mai no kenkyu*** (***A Study of Korean Rice***) (Tokyo: Chigura Shobo, 1938), pp. 952-66, Shigetafu Kawano, ***Taiwan beikohu keizairon*** (***A Discussion on the Rice Economy of Formosa***) (Tokyo: Yuhikaku, 1940), pp. 303-20.

2. Interregional Price Relationships

Thorough empirical investigations of price differentials and price relationships between rices grown in Japan, Korea and Formosa have been made by Japanese economists.[6] They found that coefficients of correlation between prices in the three regions are exceedingly high, which proved that the different types of rice were highly substitutable and that the three regions formed, indeed, one rice market. For our purpose, however, it is not sufficient to know that these prices are correlated; we should know how they are related.

There are two methods of approach to this question. First, if sufficient data were available on transportation costs per unit of rice exported from Korea and Formosa to Japan, then the prices of rice in Korea and Formosa could be obtained by deducting the transportation costs and the average price differentials due to the differences in quality from the Japanese rice price. Second, least-squares regression can be fitted for the Korean-Japanese and Formosan-Japanese prices. The second method is taken and the results of our calculations are as follows:

Korea-Japan $$P_k = 0.85\ P_j + 2.03$$
$$(0.04)$$
$$R^2 = 0.95$$

Formosa-Japan $$P_f = 0.5\ P_j + 2.99$$
$$(0.04)$$
$$R^2 = 0.88$$

These two equations show high correlation coefficients, but also indicate that the price ratio between Korea-Japan is higher than that between Formosa-Japan. This is because the taste of Korean rice more nearly approaches the Japanese liking than Formosan rice does. Multiplying each parameter by the respective mean ratio, it is found that a 1 per cent increase in the Japanese rice price is associated with a rise in the Korean price of rice by 0.99 per cent and Formosan rice price 0.83 per cent, i.e., the Korean price was more directly influenced by the Japanese price of rice than the Formosan price. This is due to the fact that Korea is closer to Japan geographically and the quality similarity suggested above tended to encourage higher substitutability between Korea-Japan rices than between Formosa-Japan rices.

3. Overall Model of the Rice Market

The above results are combined and summarized in the overall rice market model below. The diagrammatical presentation of the structure of this interregional rice market is illustrated in Figure 1. In this figure, the central market price, P'_1, cxpresses the deflated price determined by the total demand and total supply curves of the three regions. P'_2 is the deflated price of the central market under the condition of Japan considered separate from Korea and Formosa.

(1) $\frac{D_j}{N_j}=-0.057\frac{P_j}{J_j}+0.0014\frac{Y_j}{N_j I_j}-0.0016T+1.446$

(2) $\frac{D_k}{N_k}=-0.027\frac{P_k}{I_k}-0.013T+0.899$

(3) $\frac{D_f}{N_f}=-0.013\frac{P_f}{I_f}-0.016T+1.113$

(4) $\frac{S_j}{N_j}=-0.0099\frac{P_j}{I_j}-0.00036T+0.208$

(5) $P_k=0.85P_j+2.03$

(6) $P_f=0.50P_j+2.99$

(7) $E_{kj}=Q_k-D_k$

(8) $E_{fj}=Q_f-D_f$

(9) $Q_j+Q_k+Q_f=D_j+D_k+D_f+\triangle S_j$

4. Estimation of Prices and Exports

Simultaneous solution of these nine linear equations determines the central market price of rice and the amounts of rice exports from Korea and Formosa to Japan. The expression of these variables is given as follows.[7]

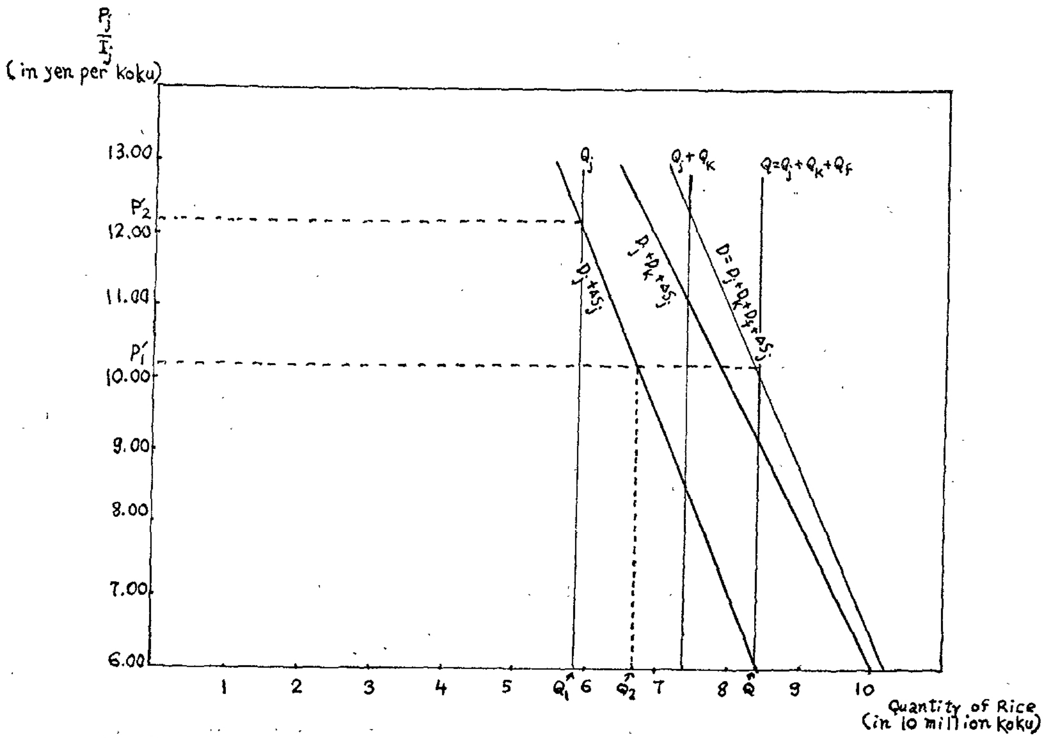

FIGURE 1 ILLUSTRATED STRUCTURE OF THE RICE MARKET

7 All variables are at time period t unless otherwise specified as (−1) for one-year time lag.

(10) $Q_j + Q_k + Q_f = D_j + D_k + D_f + \triangle S_j$

$$= \frac{P_j}{I_j}\left(-0.057\ N_j - \frac{0.023\ N_k}{I_k / I_j} - \frac{0.0065\ N_f}{I_f\ /\ I_f} - 0.0099 N_j\right)$$

$$+ \left(0.0014\frac{Y_j}{I_j} - 0.055\frac{N_k}{I_k} - 0.034\frac{N_f}{I_f}\right)$$

$$- (0.0016\ N_j + 0.0013\ N_k + 0.016\ N_f)\ T$$

$$+0.0099\left(\frac{P_j}{I_j}N_j\right)(-_1) + (1.446\ N_j + 0.899\ N_k + 1.113\ N_f)$$

(11) $E_{kj} = Q_k - D_k$

$$= D_j + D_f + \triangle S_j - Q_j - Q_f$$

$$= \frac{P_j}{I_j} - \left(0.057\ N_j - \frac{0.0065\ N_f}{I_f / I_j} - 0.0099\ N_j\right)$$

$$+ \left(0.0014\frac{Y_j}{I_j} - 0.034\frac{N_f}{I_f}\right)$$

$$- (0.0016\ N_j + 0.016\ N_f)\ T + 0.0099\frac{P_j}{I_j}N_j\ (-1)$$

$$+ (1.446\ N_j + 1.113\ N_f) - Q_j - Q_f$$

(12) $E_{fj} = Q_f - D_f$

$$= D_j + D_k + \triangle S_j - Q_j - Q_k$$

$$= \frac{P_j}{I_j}\left(-0.057\ N_j - \frac{0.023\ N_k}{I_k / I_j} - 0.0099\ N_j\right)$$

$$+ \left(0.0014\frac{Y_j}{I_j} - 0.055\frac{N_k}{I_k}\right) - (0.0016\ N_j + 0.013\ N_k)\ T$$

$$+0.0099\left(\frac{P_j}{I_j}N_j\right)(-1) + (1.446\ N_j + 0.899\ N_k) - Q_j - Q_k$$

In the expression (10), P_j is the only endogenous variable, and the others are exogenous. Therefore, by representing all exogenous variables in (10) by actual time series sample data, yearly price can be estimated. In similar ways E_{kj} and E_{fj} are also estimated for each year. The estimated and actual values of P_j/I_j, E_{kj}, and E_{fj} are plotted in Figures 2, 3, and 4 respectively.[8]

It is readily observable that the estimated prices depict fairly well the annual oscillations of actual prices in terms of the general trend of price movement. As to year-to-year fluctuations, in sixteen out of twenty-four years the estimated prices indicate correctly the turning points of actual price movements, though in certain years there was definite deviation of estimated from actual prices. Figure 3 shows that the estimated and actual amounts of rice exports from Korea to Japan move in the same direction

8 P' or P_j/I_j is estimated instead of P_j becauae price index in Japan was influenced greatly by the price of rice, P_j. By taking I_j as a predetermined variable, the estimated and actual P_j would exaggerate the closeness of fit, due to the high correlation between I_j and P_j. P_j is endogenous, and P_j/I_j is estimated as an endogenous variable.

except in 1933, 1935, and 1937. Prior to 1919 the estimated exceeds the actual amount of rice exports considerably. This may have been the result of less reliability in data of the early years, or of the importance of rice exports to Japan other than from Korea and Formosa during these years. Estimated and actual rice exports from Formosa to Japan, as shown in Figure 4, indicate the closeness of our estimate, although there are such years as 1919, 1920, and 1921 when the deviations are relatively large.

5. Properties of the Model

Investigations of properties of the model will focus on five questions: (A) what would be the effect of change in rice production upon the interregional price level and export of rice? (B) what would be the effect of population growth, change in income, or rice consumption trend upon the price level and export of rice? (C) what would happen to the price of rice if Korea and Formosa suddenly diverted their entire exports of rice to another country instead of to Japan? (D) How much should Korea and Formosa produce in order to maximize their total export receipts? and (E) How much should Japan, Korea and Formosa produce in order to maximize their total revenues from rice production?

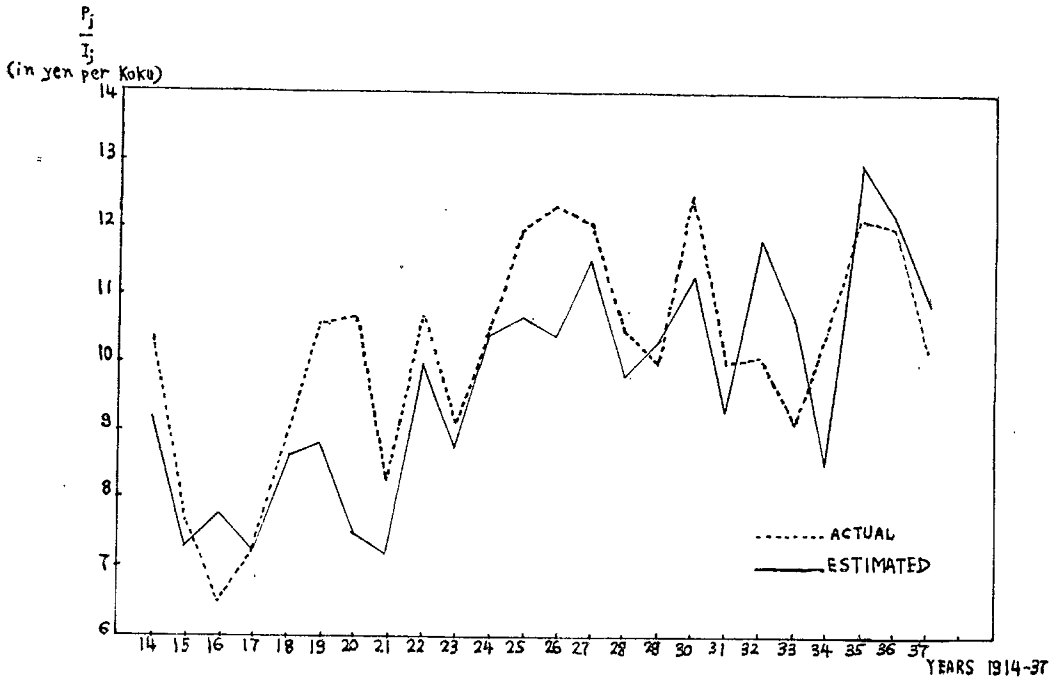

FIGURE 2 ESTIMATED AND ACTUAL PRICES

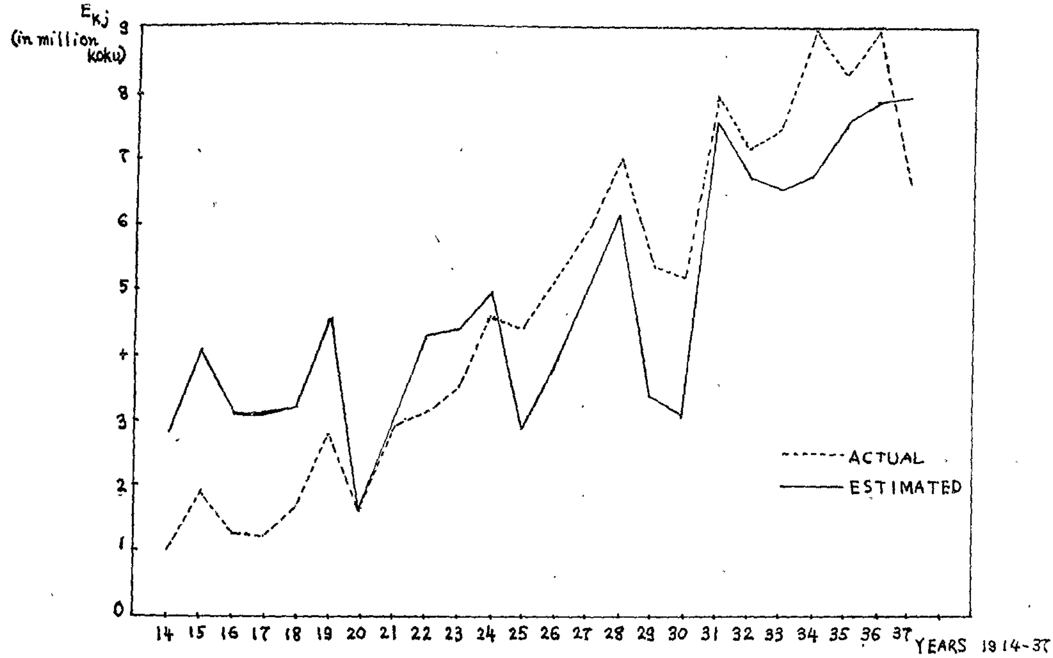

FIGURE 3 ESTIMATED AND ACTUAL RICE EXPORTS FROM KOREA TO JAPAN

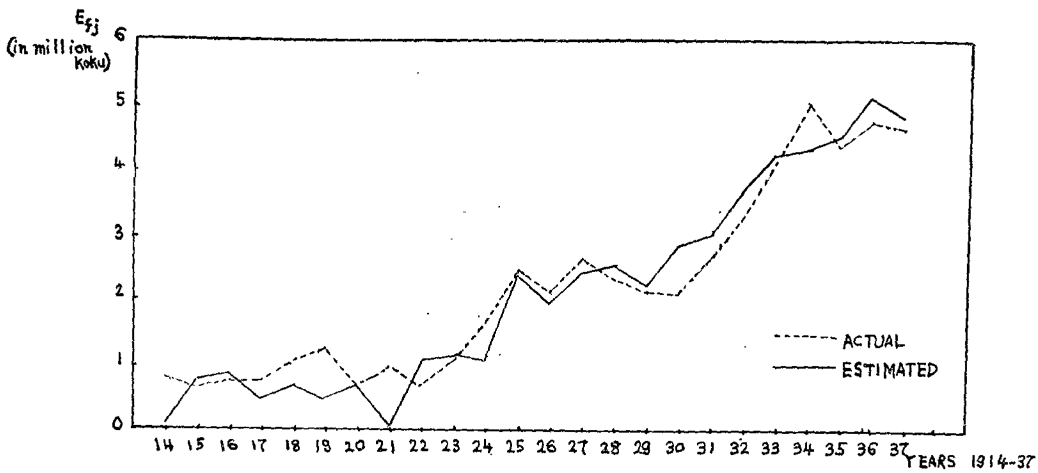

FIGURE 4 ESTIMATED AND ACTUAL RICE EXPORTS FROM FORMOSA TO JAPAN

(A) and (B). Shift of Supply and Demand functions

Answers to the first two questions constitute comparative static properties of the model, i.e., the impact of once-and-for-all change in exogenous variables in the system upon the equilibrium price and export. Numerical effects or the slope of a change in an exogenous variable on price and exports can be obtained by taking the first derivative of price or exports with respect to the respective exogenous variable from formulas (10), (11), and (12). The expression of elasticity is then obtained by multiplying the slope by the respective mean ratio. The results of these calculations are summarized in Table 2 and 3. Each entry in these tables records the effect of a change in Q_j, Q_k, Q_f, Q, N_j, N_k, N_f N, $\frac{Y_j}{N_j I_j}$, T, upon P' (deflated Japanese rice price$=\frac{P_j}{I_j}$), E_{kj}, E_{fj}. It reads, for example, that an increase of Q_j by 1 million koku would result in a fall in P' by 0.21 yen, or a 1 percent increase in Q_j would cause 1.26 per cent reduction in P'. In all cases, when the effect of change in one upon the other variable is considered, all other variables are assumed to remain constant.

Table 2

Effect of Unit Changes in Supply on Price and Exports

Unit changes in Supply of:	Effect on: Price (P') Slope	Elasticity	Korean Exports (E_{kj}) Slope	Elasticity	Formosan Exports (E_{fj}) Slope	Elasticity
Japan (Q_j)	−0.21	−1.26	−0.15	−1.85	−0.02	−0.52
Korea (Q_k)	−0.21	−0.39	0.85	2.71	−0.02	−0.09
Formosa (Q_f)	−0.21	−0.05	−0.15	−0.12	0.98	2.76
Total (Q)	−0.21	−1.66	0.07	1.12	0.07	1.82

As shown in Table 2, production increase in any region would cause a fall in P', thus, was advantageous to consumers but unfavorable to producers in the regions. As to the effect on E_{fj} and E_{fj}, an increas of production in any region other than Korea or Formosa herself, would be disadvantageous to Korean and Formosan because of a fall in E_{kj} and E_{fj} as well as in P'. For example, an increase in Q_j and Q_f would reduce both E_{kj} and P'.

In regard to total supply of rice, a 1 per cent increase in Q would cause a 1.66 per cent drop in P', i.e., the coefficient of flexibility of rice price was−1.66. Thus, the price elasticity of the total demand curve D in Figure 1, was−0.6, or the inverse of the coefficient of flexibility of rice price. Since a 1 per cent increase in production would result in 1.66 per cent decline in the rice price, farmers in the regions as a whole would have increased their earnings by producing less rice, thus raising the rice price. This macro- economic truth, however, does not hold for an individual farmer because rice production in Asia is cultivated by many small-scale farmers and an individual farmer's output is too small to affect price. Consequently, less production would mean smaller revenue for the individual farmer.

Table 3

Effect of Unit Changes in Demand on Price and Exports

Unit changes in:	Effect on: Price (P')		Korean Exports (E_{kj})		Formosan Exports (E_{fj})	
	Slope	Elasticity	Slope	Elasticity	Slope	Elasticity
Population in Japan (N_j)	0.23	1.50	0.31	3.42	0.18	4.12
Population in Korea (N_k)	0.13	0.23	−1.06	−4.52	0.09	0.83
Population in Formosa (N_f)	0.21	0.09	0.27	0.22	−1.94	−3.61
Total Population (N)	0.21	1.72	0.23	3.68	0.23	8.05
Per capita Japanese income ($\frac{Y_j}{N_j I_j}$)	0.018	0.028	0.012	0.41	0.001	0.08
Time trend (T)	−0.11	−0.01	0.36	0.07	0.11	0.04

The increase in population will shift the demand curve to the right and raise the rice price. Table 3 shows that a 1 per cent increase in population of Japan, Korea, and Formosa would raise the price of rice by 1.5, 0.23, and 0.09 per cent. Apparently these results were determined by relative level of per capita consmption in the three regions as well as the size of population in each region. Japan's effect is the greatest because her per capita consumption of rice and population are the greatest of the three. However, Korea's population was over four times that of Formosa's, but the effect of population on price was only 2.5 times as great because of lower per capita consumption in Korea relative to Formosa.

The demand curve would shift upward in response to a rise in per capita income in Japan, which would in turn cause an increase in E_{kj} and E_{fj}. A 1 per cent increase in per capita income in Japan would cause 0.41 and 0.08 per cent increase in E_{kj} and E_{fj}. These income elasticities of rice exports from Korea and Formosa are conceptually similar but different in method of derivation from conventional method of calculating income elasticities of the export. The former took account of all regional demand behaviors and price relationships while the latter consider only the international trade aspect of the impact without taking the domestic impact of the change in pruduction into account. The superiority of our model is clearer if more than two regions are involved in interregional transaction.

Negative time trends of rice consumption in the three regions would shift the total demand curve downward and induce the fall in price. The average yearly decline in price was 0.11 yen, or 0.01 per cent. However. the time trend of rice consumption would increase E_{kj} and E_{fj} as long as the yearly reduction of rice consumption in Korea and Formosa was greater than that of Japan.Table 3 shows that on the average E_{kj} increased 0.36 million koku, or 0.07 per cent annually, whereas E_{fj} increased 0.11 million koku, or 0.04 per cent annually.

(C) Rice price with separation of Korea and Formosa from the Japanese market

One important aspect of the price instability of rice in Japan was the behavior of the Korean and Formosan rice exports. With a complete absence of rice imports from these two regions, the rice price in Japan would have been obviously at a higher level, e.g., at P'_2 in Figure 1. Moreover, any increase in the amount of rice imports would result in the lower price in Japan. The increase in Korean and Formosan exports after 1928 created a serious problem of rice price depression because of the further reduction of price brought about by these imports on the already high level of Japanese production. In this section, two questions will be investigated: (1) to what extent was the Japanese price depressed by the colonial rices? and (2) what was the impact of the increase in colonial rice exports of 1 million koku on the Japanese price?

The Japanese price, without any rice flows from Korea and Fromosa, would depend on her demand and supply alone. The expression of the market equilibrium can be derived readily from our integrated model by isolating those equations in relation to the Japanese demand and supply.

$$(13)\qquad Q_j = Q_j + \triangle S_j$$
$$= \left(-0.057P' + 0.0014\frac{N_j}{N_j I_j} - 0.0016\,T + 1.446 - 0.0099P' + 0.0099P'(-1)\right) N_j$$

Under the mean equilibrium setting in which all variables have mean values, the above formula (13) can be used to solve for P'. The result obtained is P' = 12.4, i. e., the Japanese mean rice price would have been 12.4 yen if no rice was imported from Korea and Formosa. In contrast to the actual mean rice price of the Japan during the period under consideration, 10.2 yen, it shows about 12 per cent higher. Or, the inclusion of Korea and Formosa in the Japanese rice market resulted in the suppression of rice price in Japan by 18 per cent. It is no wonder that the reaction of the Japanese farmers to the downward trend of rice was centered on the issue of imported rices, especially after 1928.

In addition to the long-run trend in the growth of Korean and Formosan rices, the cyclical fluctuation of rice imports affected the Japanese rice price. The effect of an increase in rice imports by 1 million koku on the price of rice cannot be investigated directly from our integrated model because these imports are endogenous variables which are supposed to be determined by the system. However, the effect of these imports on the Japanese price can be approximated by considering the impact of the given change in these imports upon the isolated Japanese rice market. The calculation shows a 1 million koku increase in the rice imports would reduce the price of rice by 0.25 yen, or a 1 per cent increase in the total rice imports would result in a 1.75 per cent reduction in the price of rice. Such a year as 1934, when the exports to Japan increased by 2.4 million koku or 20 por cent relative to 1933, would have resulted in a drop in the Japanese rice price by 0.58 yen or a 37 per cent decrease in the price of rice. These results indicate that rice imports from Korea and Formosa rendered substatantial influence on the Japancse rice price and its stability.

(D) Earnings from rice exports

Rice exports constituted about 40 per cont and 30 per cent of the earnings on current account of the balance of payments for Korea and Formosa during the period under consideration. Total earnings from rice exports with their multiplier effects influenced the national incomes of Korea and Formosa to a great extent. Moreover, the greater earnings from rice exports meant a larger quantity of industrial good could be obtained from Japan, provided that the terms of trade between rice and industrial goods were constant.

Total receipts from rice exports depended upon the price of rice and the amount of rice exported. The complete analysis of the strategy of maximizing total receipts from exports would require a full examination of regional interactions affecting the price of rice and the amounts of exports. However, for simplicity of analysis, production in only one region will be varied. while production of the other two regions are assumed to be at their mean values. Besides, all exogenous variables other than production are taken at their mean values. The optimum levels of production in regard to export earnings will then be derived. The question is how much rice Korea and Formosa should produce in order to maximize their total receipts from rice exports.

The answer to this question, derived from formulas (10), (11), and (12), indicates that 34.6 and 25.5 million koku are the levels of production under which Korea and Formosa could have attained their maximum receipts from rice exports. These levels are higher than their actual mean levels of production (15.2 and 6.2 million koku) were during 1914-37. A comparison of the optimum with the peak levels of production reveals that the former was twice as great in Korea and 2.5 times as great in Formosa as the latter. In other words, these two regions could have increased their export revenues by producing more rice. This would depend, of course, upon the various alternative uses of resources other than for rice which are not taken into accout in the present analysis.

Why did Korea and Formosa produce less than the amount at which they would gain most? This might be due in part to the difficulty of acreage expansion in Korea, and to competition with sugar-cane production in Formosa. In addition, the income of the Japanese farmer was suppressed by the low price by the expansion of production in Korea and Formosa. As a consequence, the Japanese government put a brake on the rice expansion program in Korea and Formosa before desired levels of production were reached.

On the other hand, our results may be due to the unrealistic assumption of linearity of the demand curve which implies that the level of Japanese rice consumption would increase proportionally to the fall in price. In reality the demand for rice would increase less in proportion to the fall in the price or rice if Japanese have reached a very high level of rice consumption. In this sense the demand curve is concave, expressing the diminishing rate of rice consumption as price falls. Thus, any additional exports from Korea and Formosa would merely force the price of rice down without proportional increase in the level of rice consumption in Japan as assumed in our model. If the level of cosumption in Japan was already at a high level, the increase of production in Korea and Formosa in the attempt to increase their total export receipts could not materialize.

(F) *Total revenues from rice production*

As indicated previously, the reduction of production in the three regions as a whole would increase the price of rice more than proportionally and would thus increase total revenue. However, for each region the reduction of production may accompany the increase of production in other regions. Total revenue for an individual region was, therefore, related not only to its own domestic production but also to the amount produced in other regions. The smaller the sum of production in two regions, the easier it would be for the remaining region to increase total revenue by adjusting the amount of its own rice production.

The complete analysis of the strategy of maximizing total revenue out of rice production requires, as in game theory, the matrix in which mutual interactions between the three regions are taken into account. For simplicity of analysis, however, this section will deal with the problem partially by taking production of a single region as variable and assuming production of the other two regions as fixed at their typical values.

Our results show that the maximum revenue levels of production are 51.4, 30.5, and 23.3 million koku for Japan, Korea, and Formosa respectively. The maximum revenue levels of production differ from actual levels of production for each region. In Japan, the mean level of production was 58.8 million koku, whereas the maximum revenue level is smaller, 51.4 million koku. In Korea, the maximum revenue level is 30.5 million koku, which is larger than either the mean level of production, 15.2 million koku, or the peak level of production reached in 1937, which was 19.4 million koku. This maximum revenue level of production is twice larger than the mean level of production and 1.6 times greater than that of the peak year. Likewise, for Formesa, the maximum revenue level of production, 23.3 million koku, exceeds the actual mean of production, 6.4 million koku, by 3.6 times and the peak level of production, 7.5 million koku, by 3.1 times.

It seems clear from these results that in general Japanese farmers would gain more by producing less rice and thus raising the price of rice. On the other hand, Korea and Formosa would gain by producing more rice because this would not reduce the price of rice proportionately. The small regions of Korea and Formosa could gain by producing more rice as the effect of production increase would not affect the price of rice as significantly as in a large region. This was particularly true for Formosa, the smallest region among the three. Production in Formosa would affect the price of rice but little, so that the expansion of rice production would be beneficial to her. In other words, the smaller region had the advantage in the large market.

In addition to consideration of the total revenue as affected by the different demand functions, it is also true that Korea and Formosa could gain by producing more because of lower average cost than in Japan. Apparently, the decline in the price of rice as a result of the increase in production would cause the marginal farm in Japan to be unprofitable. If price was below the average fixed cost, production would be at a loss. In Korea and Formosa, production would continue at a lower price than the minimum price level for Japan.

An inquiry is made as to the price of rice when either Japan, Korea, or Formosa would be producing at its own maximum revenue level. Considering the three regions, Japan, Korea, and Formosa in sequence, if amounts of production were at the maximum revenue levels of 51.4, 30.5, and 23.3 million koku, then the prices of rice weuld be 10.9, 6.1, and 5.8 yen. Since the mean price level of the whole regions was 10.2 yen, our results indicate that the 'price of rice would be higher if Japanese farmers tried to maximize their total revenue, whereas the price of rice would be lower if Korean and Formosan farmers were to maximize total revenues from rice production.

The policy implications of the properties of the model discussed from parts (A) to (E) can now be summarized. For the regions as a whole. any policy encouraging additional rice production in any one of the three regions would have had unfavorable effects on farmers' income, while the same policy would be wolcomd by consumers because of its resulting rise in purchasing power with respect to rice. For the separate region, the rice production expansion in Japan would hurt all farmers, including the Japanese, whereas the same policy in Korea or Formosa would hurt all farmers but the Korean or Formosan. In deciding the regions in which rice production should be encouraged to keep pace with the rapid population growth in these regions, the Japanese government was wise to select Korea and Formosa for this task because the rice production expansion policy in Japan would face resistance from all farmers, while the same policy in Korea and Formose would meet with the cooperation of the farmers in those areas.

6. Concluding Remarks

The multi-regional model of the rice market for Japan, Korea and Formosa prior to 1937 was demonstrated to be very useful in (1) estimating the rice price and amounts of rice exports from Korea or Formosa to Japan, and (2) analyzing the market structure of demand and supply. With this model, functional relationships between various variables affecting the demand and supply of rice were derived and their implications to the Japan's rice policy were determined. It is important, however, to review some limitations of the model here.

(1) No model can be completely accurate in estimating prices and exports, as it is a greatly simplified description of reality. Stock functions for Korea and Formosa are omitted from our model, and imports of rice from other countries than these two regions are excluded from the model because of significant differences in rice qualities. Besides, some variables are not taken into account, despite their possible importance in affecting the demand for rice, e.g., the competing and substitutable goods to rice.

(2) Our model is restricted by the assumption that these variables are linearly related. It is obvious that human behavior is too complex to be expressed by a linear relationship, although the linearity is a good first approximation and makes mathematical treatment possible.

(3) The function of the rice market is somewhat exaggerated because not all of the rice was traded in the market. Our treatment in aggregate terms obscures the fine distinction between the behavior of rice consumption at the farm and that traded in the market. In Japan, 45 per cent of her production of rice was estimated to be consumed at the farm without going through market transaction. In Korea and Formosa, the ratios were probably greater because a larger portion of the population was engaged directly with rice production.

(4) The model assumed that the qualities of rice produced in Japan, Korea and Formosa were exactly alike, but in spite of the general similarity they still retained certain minor differences. Generally speaking, Japan-grown rice brought a higher price than that grown in either Korea or Formosa. In a strict sense, unhomogenous commodities are nonadditive; therefore, the total supply of rice was not exactly the sum of rice produced in the three regions. By disregarding the quality differentials of rice in these three regions, the model overestimated amounts of rice produced in Korea and Formosa and underestimated that produced in Japan.

(5) The deviation of estimated from actual prices may be caused by government intervention in the rice market Our model assumed perfectly free competition internally as well as interregionally. The price stabilization policy taken by the Japanese Government after 1921, and particularly after 1931, means that the price of rice was not entirely determined by the free market forces of demand and supply.

Despite these limitations, the model demonstrated some definite merits. Because we constructed our model differently from conventional approach, we could consider the interaction of interregional and domestic demands for rice simultaneously; thus, the calculation of elasticities is more realistic. In addition, the model provides the explanation of the price fluctuation which can be used for the rice price stabilization policy.

APPENDIX

Data

Since most data used in this study are obtained from the same sources, they will be stated categorically below with the number identifying each of them.

(1) *Shokuryo kanri tokei nenpo(Statistical Yearbook of Food Control)*. Tokyo: Shokuryo Kanrikyoku, 1948.

(2) *Chosen beikoku yoran (Korean Rice Abstract)*. Keijo Norinkyoku, Chosensotokufu, 1934 and 1938.

(3) *Taiwan beikoku yoran (Formosan Rice Abstract)*. Taihoku: Beikokukyoku, Taiwansotokufu, 1939.

(4) *Chosensotokufu tokei nenpo (Statistical Yearbook of Korean Government)*. Keijo: Shokusanka, Chosensotokfu. Yearly publication.

(5) *Taiwansotokufu tokeisho (Statistical Yearbook of Formosan Government)*. Taihoku: Kanbochosaka, Taiwansotokufu. Yearly publication.

1. Q_j, Q_k, Q_f, and Q

Q_j and Q_k are from a single crop harvested in November of the previous year. Data are from (1). and (2). For Q_f, November crop of previous year and June crop of current year are added. Data for Q_f are from (3). Q is the sum of Q_j, Q_k, and Q_f.

2. S_j, S_k, and S_f

These are the amounts of rice stocks existing at the end of October. S_j, S_k, and S_f are obtained from (1), (2) and (3) respectively. Data for S_k and S_f are not available prior to 1931 and 1932.

3. D_j, D_k, and D_f

These consumption data are available in (1), (2) and (3) respectively. They are derived in the following manner: Regional consumption = regional production + (import - export) + net reduction in stock. All of them are based on the rice crop year from November to October. Net reduction in stock is assumed to be zero for Korea and Formosa prior to 1931 and 1932 because of unavailability of data.

4. E_{kj} and E_{fj}

Data are obtained from (2) and (3) based on the rice crop year.

5. N_j, N_k, N_f, and N

These population data are on May 1 of each year. N_j is from *Nihonteikoku tokei nenkan (Statistical Yearbook of the Japanese Empire)*. (Tokyo: Naikaku tokeikyoku, yearly publication). N_k and N_f are from (4) and (5). N is total population of three regions.

6. P_j, P_k, and P_f

These prices are obtained by taking monthly averages from November to October. P_j is the price of Japan-grown rice at Fukugawa market, Tokyo. P_k is the average price of Korea-grown rice in major cities in Korea. P_f is the price of Formosa-grown rice in Taipei. All are wholesale prices of brown rice of medium grade in yen per koku in each respective currency. P_j, P_k, and P_f are from (1), (2), and (3).

7. I_j, I_k, and I_f

I_j is general price index obtained from Seichi Tobata and Kazushi Okawa, ***Nihon no keizai to nogyo*** (***Japanese Economy and Agriculture***). Vol. 1 (Tokyo: Iwanami Shoten, 1956), pp. 190-91. I_k is wholesale price index from (4), and I_f is wholesale price index from (5).

8. Y_j

Data are from Seichi Tobata and Kazushi Okawa, ***Nihon no keizai to nogyo*** (***Japanese Economy and Agriculture***), Vol. 1 (Tokyo: Iwanami Shoten, 1956), pp. 190-91.

9. T

1926=O; 1 is added for each year after 1926, and 1 is subtracted for each year prior to 1926. For example, 1924=12 and 1937=11.

TIME SERIES DATA, 1914-1937

Year	Q_j	Q_k	Q_f	Q	S_j	S_k	S_f	D_j
	(in million koku)							
1914	50.26	12.11	4.53	66.90	5.85	---	---	51.59
1915	57.01	14.13	4.89	76.03	6.24	---	---	59.54
1916	55.92	12.85	4.99	73.86	5.81	---	---	58.19
1917	58.45	13.93	4.63	77.01	4.47	---	---	61.22
1918	54.57	13.69	4.80	73.75	2.36	---	---	62.74
1919	54.70	15.29	4.63	74.62	4.16	---	---	62.08
1920	60.82	12.71	4.89	78.42	5.51	---	---	62.32
1921	63.21	14.88	4.98	83.07	8.16	---	---	65.03
1922	55.28	14.32	5.20	74.71	7.30	---	---	62.86
1923	60.89	15.01	5.31	81.02	6.79	---	---	66.71
1924	55.44	15.18	5.25	75.86	5.21	---	---	65.78
1925	57.17	13.22	6.27	76.66	5.50	---	---	67.05
1926	59.70	14.77	6.10	80.58	5.97	---	---	68.22
1927	55.59	15.30	6.64	77.53	5.77	---	---	67.16
1928	62.10	17.30	6.84	86.24	7.84	---	---	70.28
1929	60.30	13.51	6.45	80.27	7.03	---	---	69.47
1930	59.56	13.70	7.11	80.37	5.72	---	---	68.91

1931	66.88	19.18	7.52	93.57	9.14	.32	---	72.98
1932	55.22	15.87	8.07	79.16	8.91	.62	.68	68.34
1933	60.39	16.35	8.67	88.40	9.01	.62	.91	72.41
1934	70.83	18.19	8.93	97.96	16.43	.60	.35	76.82
1935	51.84	16.72	8.91	77.46	9.94	.48	.57	70.87
1936	57.46	17.88	9.53	84.87	8.01	.50	.69	73.32
1937	67.34	19.41	9.23	95.98	7.51	.32	.60	78.86

TIME SERIES DATA, 1914-1937
CONTINUED

Year	D_k	D_f	E_{kj}	E_{fj}	N_j	N_k	N_f
	(in million koku)				(in million persons)		
1914	11.12	3.89	1.02	0.81	52.31	15.62	3.53
1915	11.84	4.04	1.87	0.69	53.04	16.04	3.57
1916	11.04	4.26	1.33	0.80	53.75	16.40	3.59
1917	12.06	3.90	1.20	0.79	54.38	16.76	3.63
1918	11.56	3.99	1.73	1.14	54.89	17.00	3.66
1919	12.39	3.78	2.78	1.29	55.24	17.09	3.69
1920	10.91	4.32	1.64	0.66	55.74	12.20	3.74
1921	11.63	4.02	2.90	1.03	56.41	17.34	3.80
1922	11.10	4.72	3.14	0.74	57.13	17.51	3.87
1923	11.46	4.11	3.45	1.13	57.87	17.71	3.94
1924	10.82	3.68	4.55	1.66	58.62	17.95	4.01
1925	9.53	4.42	4.43	2.52	59.41	18.38	4.09
1926	10.14	4.37	5.21	2.19	60.35	19.05	4.20
1927	10.03	4.93	5.90	2.67	61.33	19.12	4.29
1928	10.35	4.79	7.07	2.43	62.24	19.15	4.39
1929	8.58	4.78	5.38	2.25	63.16	19.24	4.49
1930	8.85	4.99	5.17	2.18	64.05	19.64	4.61
1931	10.54	4.87	7.99	2.70	64.99	20.26	4.74
1932	8.39	4.68	7.20	3.42	65.90	20.37	4.87
1933	8.51	4.78	7.53	4.22	66.92	20.67	5.00
1934	8.71	4.27	8.95	5.12	67.80	20.90	5.13
1935	8.13	4.20	8.43	4.51	69.01	21.38	5.22
1936	8.51	4.63	8.97	4.82	70.02	21.94	5.38
1937	12.58	4.59	6.74	4.86	70.98	24.09	5.53

TIME SERIES DATA, 1914-1937
CONTINUED

Year	Y_j	P_j	P_k	P_f	I_j	I_k	I_f
	(in million yen	(in yen)			(1893−97 =100	(1910 =100)	(1914 =100)
1914	182	17.39	11.98	10.82	167	110	100
1915	176	13.02	9.09	8.29	169	109	106
1916	212	13.21	11.17	9.20	204	129	124
1917	295	18.57	16.12	13.51	257	173	152
1918	404	30.01	26.16	19.25	337	235	196
1919	590	43.89	38.36	26.90	413	298	223
1920	522	48.56	40.23	25.43	454	305	257
1921	473	29.20	22.42	15.96	351	230	200
1922	469	36.85	29.63	17.81	343	229	200
1923	493	31.57	25.00	16.44	347	228	193
1924	531	37.64	31.30	20.45	361	246	196
1925	540	41.95	36.62	24.73	353	259	195
1926	523	38.44	30.01	23.46	313	234	186
1927	511	35.93	30.71	19.22	297	219	181
1928	517	31.38	25.82	19.04	299	214	175
1929	511	29.19	25.98	19.43	291	207	170
1930	433	27.34	24.26	16.40	218	180	152
1931	392	18.46	15.25	10.54	185	145	136
1932	428	20.69	19.28	13.57	205	144	139
1933	481	21.42	20.00	14.29	235	160	149
1934	498	24.90	22.16	15.96	240	162	155
1935	542	29.86	28.11	21.03	246	180	158
1936	591	30.70	29.52	21.93	256	191	163
1937	681	31.76	31.38	20.80	311	206	189

米市場之計量經濟模型

劉 榮 超、數 子

本文之目的在試用計量經濟學之方法，把日本韓國與臺灣在 1914-1937 的期間所構成的米市場之經濟現象，由少數方程式表現出來，而且根據此一模型分析米市場的特性與需求彈性。利用這種模型可以估計米價之波動情況與其原因，從而能設立穩定米價之方策。同時，採用這種模型一方面可以把國際貿易與國內供需並顧，另一方面可以把三個區域間的連帶關係加以解釋。