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Long-run supply function of farm products in Japan[a]

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It has been considered that agricultural production is hardly responsive to price fluctuations of agricultural products. For example, Tatsuo Inoue, in his monograph, pointed out that the production of rice and barley, representative in agricultural products of Japan, had been hardly responsive to their price fluctuations.[5] It was, however, difficult for us to believe confidently that agricultural production in general is inelastic to price fluctuation, since methods used in earlier researches appeared not to be pertinent for that purpose.

For this reason, an effort was made to make clear this situation by analyzing the relationship of wheat, barley, and naked barley involved in the price production mechanism. The reason why we selected wheat, barley, and naked barley for our investigation, is quite clear considering how the supply side is affected by price fluctuations, particularly facing the serious situations due to 1) the over-production of barley and naked barley in Japan, 2) the liberarization of trade.

Historical background and method

Until recently it was next to impossible to establish formula for obtaining answers to the type of question posed here. However, research on models with distributed lags has been promoted by the efforts of I. Fisher, L. M. Koyck,[7] M. Nerlove,[9] and others making it possible to find a clue to the solution of the problem.

Some attempts were made to estimate long-run supply functions by applying the simple straight line method to time series data, but these attempts contain clear-cut contradictions from the methodological standpoint, and it can be said that the absolute values of the figures ob-

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tained under such a formula are all too low. This has already been pointed out by M. Nerlove[10] and we shall also study long-run supply functions, following Nerlove's model.[a]

At first, let us consider this problem by clarifying the historical background of fluctuations in the acreage of wheat and barley fields under cultivation, on the basis of the painstaking work of Messrs. Takeo Mizuno, Shigeo Hosono, and others. According to Hosono's research, wheat and barley are harvested in winter in districts others than Hokkaido.[4] If a paddy field is cropped with wheat or barley to allow a second harvest, this is because its topographical conditions are close to those of a dry field even through it is classified as a paddy field. Wheat and barley are the superior field crops for the winter season. Barley, wheat, and naked barley are crops which compete with one another in winter.

Table 1. Fluctuations in acreage of wheat, barley, naked barley, and rapessed fields under cultivations: 1880-1955 (unit: 2.450 acres).

Year	Wheat	Barley	Naked barley	Total	Rapeseed	Acreage under cultivation
1880	363.4	603.8	458.1	1,425.3	190	4,477.9
1890	440.9	644.8	606.7	1,692.8	170	4,913.2
1900	473.8	650.1	681.7	1,805,5	155.2	5,060.7
1910	475.4	614.6	677.8	1,769.6	139.0	5,655.7
1920	532.7	534.8	663.3	1,730.9	112.5	6,084.7
1930	495.9	385.1	486.4	1,367.3	73.6	5,922,5
1940	804.2	350.8	428.1	1,583.0	91.5	6,008.3
1950	759.4	433.5	576.4	1,769.4	104.5	5,096.6
1955	668.8	437.1	566.8	1,672.7	209.4	5,446.2
1880	100	100	100	100	100	100
1890	122	106	130	119	89	110
1900	130	108	146	127	82	113
1910	131	102	145	124	73	126
1920	147	89	142	122	59	136
1930	136	64	104	96	39	132
1940	222	58	91	111	48	134
1950	209	72	123	124	55	113
1955	184	72	122	117	110	122

Source: Shigeo Hosono, 1959. Komugi Keizai (Wheat Economy), pp. 156-179.

[a] It is not that there is no problem in the method of computing parameter based on the distributed lags model, but in this connection, see the following references 2), 3), and 6).

As can be seen in Table 1, the acreage under cultivation in Japan showed a decrease from around 1926 to the postwar days, but this decrease was not continuous not only because of changes in individual acreages but because of the difference in the methods of surveying acreage and because of the process of agricultural development from prewar days. The acreage of paddy fields has shown a levelling-off trend since the 1933–1934 period in which the all time peak was registered. An increase in the acreage of paddy fields has a tendency very analogous to that in the movement of the rice crop. In this respect, the acreage of fields has a wavelike trend; it registered its first high in 1920, its second high in 1937, and its third after the war's end with a clear through even during the war.

Table 2 shows the changes in the acreage of wheat, barley, and naked barley fields under cultivation by paddy field and dry field. The acre-

Table 2. Fluctuations in acreage of wheat, barley, and naked barley under cultivation by paddy field & dry field (index & percentage).

Period (Average)	Wheat			Barley & naked barley			Total		
	Dry field	Paddy field	Total	Dry field	Paddy field	∫Total	Dry field	Paddy field	Total
1891-1900	100	100	100	100	100	100	100	100	100
1909-1913	96	136	107	95	104	99	95	111	101
1914-1919	102	163	119	87	105	94	91	117	101
1920-1924	96	152	112	78	95	85	83	107	92
1925-1929	86	161	107	65	86	73	71	101	82
1930-1934	91	209	123	54	76	63	65	103	78
1935-1939	114	277	158	49	74	59	68	114	84
1940-1944	135	322	186	52	85	65	76	132	96
1950-1954	128	249	161	64	91	75	83	121	96
1891-1900	73	27	100	62	38	100	64	36	100
1909-1913	65	35	100	59	41	100	61	39	100
1925-1929	59	41	100	55	45	100	56	44	100
1935-1939	52	48	100	51	49	100	52	48	100
1950-1954	58	42	100	53	47	100	55	45	100
1891-1900	29	19	25	71	81	75	100	100	100
1909-1913	29	24	27	71	76	73	100	100	100
1925-1929	35	31	33	65	69	67	100	100	100
1935-1939	48	48	48	52	52	52	100	100	100
1950-1954	45	40	42	55	60	58	100	100	100

Sources: Ministry ot Agriculture and Forestry, Annual Statistical Table and 32nd Statistical Table; Shigeo Hosono, op. cit., p. 165.

age of wheat fields rapidly increased after 1932 when the increased wheat production program was carried out, and the acreage of dry fields for wheat also increased after about the middle of the Meiji era. However, the acreage of paddy fields used for production of wheat, barley, and naked barley to reap a second crop registered a marked increase; for example, the acreage of paddy fields used for wheat increased to almost the same value as that of dry fields used for wheat at the time of its high before the war's end, although the former equaled only one-third of the latter during the 1891–1900 period. After the war's end, the acreage of wheat fields was brought a little closer to the normal level, but the ratio of acreage of paddy fields used for wheat to that of dry fields for wheat has not yet been restored to the level existing before the increased production program was enforced. As for barley and naked barley, the acreage of paddy and dry fields both decreased compared with that for wheat, but it has been on the increase since during the war.

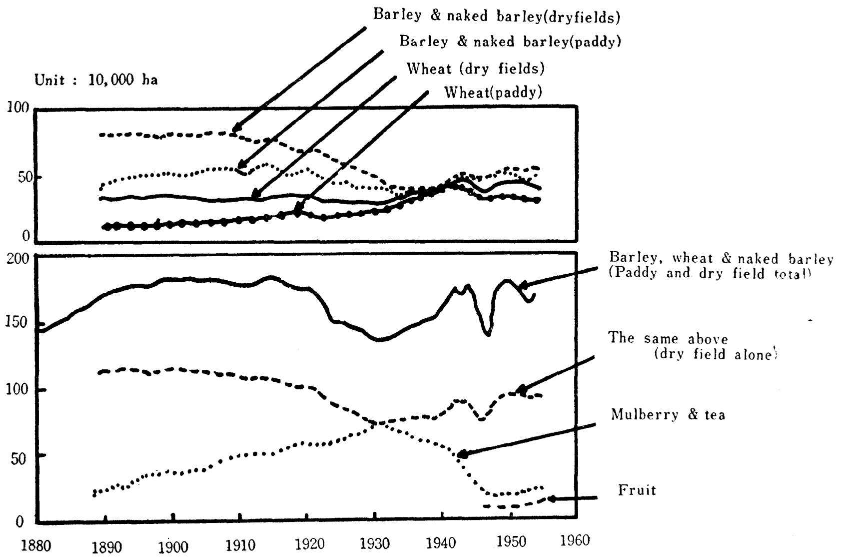

Fig. 1. Fluctuations in acreage of paddy and dry fields for cultivation of wheat, barley, and naked barley & in acreage of dry fields for wheat, barley, and naked barley, mulberry, tea, and fruit gardens.

Source: Shigeo Hosono; op. cit., p. 167.
Note: For 1947, statistics on cultivation by paddy and dry field are unavailable; so 1946 is linked directly with 1948, skipping 1947.

The empirical values given in Table 2 can be graphed as shown in Fig. 1. Wheat, barley, and naked barley registered almost the same area cultivation on paddy fields up to the end of the Meiji era, but from the beginning of the Taisho era the area of dry fields cropped with barley and naked barley was lowered but that of paddy fields cropped with wheat was raised. Falling between the two levels, the curves for paddy-field barley and naked barley and dry-field wheat pursued a stable development until about 1932, compared with the former two curves. From about 1933, however, these four curves began to converge toward one point, and this convergence changed again to dispersion after 1940.

There were also vicissitudes in paddy-field wheat, barley, and naked barly as a second crop. The total acreage of paddy field used for production of wheat, barley, and naked barley recorded it's first high during World War I, a second high after the enforcement of the increased wheat production program in 1932, and a third high in 1950 after the end of World War II.

Fluctuations in the acreage of dry fields used for wheat, barley, and naked barley are far greater than those in paddy fields as is shown in the lower part of the chart. The increased wheat production program brought about an increase in the acreage of dry fields for wheat, barley, and naked barley in inverse proportion to changes in the acreage of mulberry and tea gardens. The decrease in the acreage of mulberry and tea garden and the increase in the acreage of wheat and barley fields, seen during the war, were the result of a coercive policy and not due only to the economic effects of the increased wheat production program. The acreage of fruits gardens also showed a sudden increase, but the tendency to divert arable land from such traditional crops for the purpose of producing wheat and barley presumably will not become marked as in the case of mulberry garden after the end of World War I.[a]

Under such circumstances, it can be said that the use of paddy fields increased while that of dry fields decreased as far as wheat, barley, and naked barley were concerned. This means that the use of paddy fields for reaping second crops increased and that in the winter season, dry fields were used mainly for production of crops other than wheat, barley or naked barley or were out of use. The reason behind the increased use of paddy field for harvesting after-crops lies in the necessity of eliminating the shortage in labor force caused by the drying of rice-fields as two-crop farming, the strengthening of the rice-producing farm households' demand for adoption of an intensive farming formula, and the Government's encouragement. However, we must not

[a] In Fig. 1, the mulberry, tea, wheat, barley, and naked barley fields under cultivation have clear-cut substitute relations with one another, but we were unable to consider this problem because of lack of data.

overlook the fact that paddy fields yield smaller winter crops than pure dry fields. Moreover, power threshers and tillers are used mainly by rice-producing farm house holds, and in the case of farm house holds engaging in the production of dryfield crops, such machines are not used except by farm households in specific areas or those producing special cash crops. There are many cases where farm households using paddy fields for the purpose of reaping second crops affords an opportunity to eliminate a seasonal shortage in the labor force. However, this explanation is insufficient to explain why the production of wheat, barley, and naked barley as second crops has been rather decreasing since the war's end, which brought farming machines into agricultural districts. In short, the harvest of wheat and barley increased until 1950 and decreased year by year after 1951 chiefly because of the farmers' reaction to changes in their prices.

It was the increased wheat production program which reflected strongly the supply response to prices by farmers engaged in the production of wheat, barley, and naked barley. According to Takeo Mizuno's research, the Government in 1932 adopted two policies for increased production of wheat; one was to raise the import tariff on wheat and wheat flour and the other was to raise the producer prices of wheat through control over sales by producers.[8]

In June 1932, the Government raised the import tariff on wheat and wheat flour to a considerable extent. At that time, there was a world-wide panic, and the prices of imported wheat continued to decline year after year and those of domestic produced wheat also decreased from

Table 3. Rate of wheat prices to prices of rice, barley, & naked barley.

Year	Rate to rice	Rate to barley	Rate to naked barley
1928	65.7 %	143.6%	104.6%
1929	64.3	162.3	123.3
1930	58.6	144.9	97.0
1931	55.5	159.6	94.4
1932	75.3	221.0	126.9
1933	70.9	161.8	93.9
1934	54.3	141.8	87.7
1935	65.0	180.0	110.7
1936	76.1	187.8	109.8
1937	72.7	151.8	102.7

Source: Takeo Mizuno, 1944. Nihon Komugi no Keizaiteki Kenkyu, (Economic Research on Japanese Wheat), pp. 116-117.

Note: Each year refers to the wheat, barley, and naked barley year (July to June of the following year).

year to year after 1928. It is obvious that the tariff increase under such conditions rather brought about a boost in wheat prices, giving a serious impetus to increased production. On the other hand, the sales control movement led by agricultural cooperative associations was gradually stopped up, and it is true that aside from its direct effect, it helped psychologically to attract the consumers' attention to a considerable extent.

The enforcement of two such price policies resulted in a comparatively big increase in wheat prices. The ratio of wheat prices to the prices of rice, barley, and naked barley is given in Table 3. In other words, it is obvious that the rise in the relative prices of wheat to barley and naked barley brought about an increase in the acreage of wheat fields under cultivation and a decrease in that of barley and naked barley fields through the introduction of new wheat cultivation techniques such as sowing seeds widely and thickly, and disinfecting seeds through the breeding of high quality seeds by agricultural experiment stations in various districts.

Thus, according to the research of the two, the variation in the acreage of wheat, barley, and naked barley fields under cultivation depends on the price fluctuation of them, largely. Next let us consider econometric models concerning the acreage of barley fields under cultivation as one typical example. The data necessary are wheat and barley prices and the acreage of their fields under cultivation, but the former have already been calculated by the Food Agency and are shown in the form of the price rate of barley, wheat, and naked barley. Such prices refer to the prices of barley, naked barley, and wheat deflated by the wholesale price index. However, the wholesale price index is not very suitable as a deflater to define the supply activity of farmers who are engaged in producing wheat, barley, and naked barley; so the price index of agricultural products should be used. Taking the latter as typical of the prices of agricultural products, let us consider the price of rice and use the ratios of wheat, barley, and naked barley prices to rice price. As for the acreage of wheat, barley, and naked barley fields under cultivation, attention must be paid to the fact that there is some difference between figures for the acreage under cultivation, which exclude those of Okinawa, and figures in Shigeo Hosono's estimate, which have already been given in Table 1.

Taking the acreage under cultivation, which is regarded as converging to zero over a long period of time, as X_t^* with t as a period and regarding the ratio of the barley price to the rice price for the period $(t-1)$ as $P_{a\cdot(t-1)}$, we get the following long-run supply function of barley:

$$X_t^* = K + \alpha P_{a\cdot(t-1)} + U_t \qquad (2\text{-}1)$$

Here, K is a parameter to be estimated; U_t an error term; and α is the value of long-run elasticity (or a numerical value denoting a long-run reaction coefficient). As shown already, barley and wheat fields have a substitution relation to each other. Therefore, if the price of wheat is high compared with that of barley, the acreage of barley field under cultivation will decrease, and in the reverse case the acreage of barley fields under cultivation will increase. When the ratio of wheat price to rice price is regarded as conforming to $P_{b\cdot(t-1)}$, $(2-1)$ becomes

$$X_t^* = K + \alpha P_{a\cdot(t-1)} + \beta P_{b\cdot(t-1)} + U_t \qquad (2\text{-}2)$$

Here β is the elasticity of substitution, which shows the movement of the acreage of barley fields under cultivation resulting from fluctuations in the price of wheat.[a] Moreover, a clear-cut trend can be seen in the acreage of barley fields under cultivation. Now assume if time is denoted by T, then (2-2) becomes

$$X_t^* = K + \alpha P_{a\cdot(t-1)} + \beta P_{b\cdot(t-1)} + \gamma T + U_t \qquad (2\text{-}3)$$

Here γ is the trend coefficient.

K, α, β and γ in (2-3) are the parameters to be estimated, but adjustment coefficients must be considered because X_t^* is a quantity which cannot actually be observed. Taking the real acreage of cultivated barley fields in the period t as X_t and in the period $(t-1)$ as $X_{(t-1)}$, we obtain the following function as the simplest adjustment function:

$$X_t - X_{(t-1)} = \delta(X_t^* - X_{(t-1)}) \qquad (2\text{-}4)$$

If X_t, $X_{(t-1)}$, and X_t^* are represented by logarithmic values, δ is the coefficient of adjustment elasticity.

Next let us consider a statistical inference method on the basis of (2-3) and (2-4), transforming (2-4), we have

$$\delta X_t^* = X_t - (1-\delta) X_{(t-1)} \qquad (2\text{-}5)$$

Multiplying (2-3) by δ, we get

$$\delta X_t^* = \delta K + \delta\alpha P_{a\cdot(t-1)} + \delta\beta P_{b\cdot(t-1)} + \delta\gamma T + \delta U_t \qquad (2\text{-}6)$$

Substituting (2-5) in (2-6), the result is

$$X_t - (1-\delta) X_{(t-1)} = \delta K + \delta P_{a\cdot(t-1)} + \delta\beta P_{b\cdot(t-1)} + \delta\gamma T + \delta U_t \qquad (2\text{-}7)$$

Hence

$$X_t = \delta K + \delta\alpha P_{a\cdot(t-1)} + \delta\beta P_{a\cdot(t-1)} + (1-\delta) X_{(t-1)} + \delta\gamma T + \delta U_t \qquad (2\text{-}8)$$

[a] This definition of elasticity of substitution differs from the ordinary definition in that elasticity of substitution is the rate of fluctuations in relative quantity to those in relative prices.

If the values of δK, $\delta\alpha$, $\delta\beta$, $1-\delta$ and $\delta\gamma$ are estimated by applying the method of least squares to (2–8), it is possible to determine the value of δ from $1-\delta$ and to estimate the long-run supply functions of K, α, β, and γ. Moreover, let us here study the problem of identification concerning the estimation of parameters. Under formula (2–8), the independent variables $P_{a\cdot(t-1)}$, $P_{b\cdot(t-1)}$, and $X_{(t-1)}$ are all variables which are determined already in the preceding term, and the trend T can also be considered to be an already-determined variable. In this case, therefore, the problem of identification has no important meaning.

Econometric analysis

a) Determination of the ratio of wheat, barley and naked barley prices to rice prices: In the foregoing section, we explained the necessity of determining the ratio of wheat and barley and naked barley prices to rice price; our calculation made under the equation··· ratio of wheat, barley, and naked barley prices to rice = wheat, barley or naked barley price index ÷ rice price index···established by use of the rice, wheat, and barley price indices after 1900, which were computed

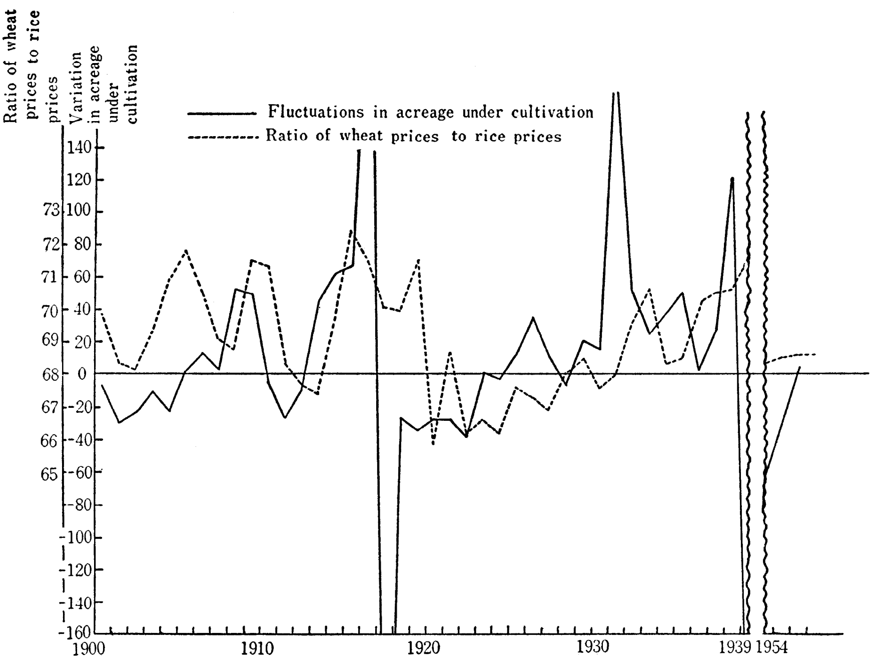

Fig. 2. Ratio of wheat prices to rice prices & fluctuations in acreage under cultivation.

by the Food Agency. Figures up to 1950 are computed on the basis of the Annual Report on Food Control Statistics for 1953 and those

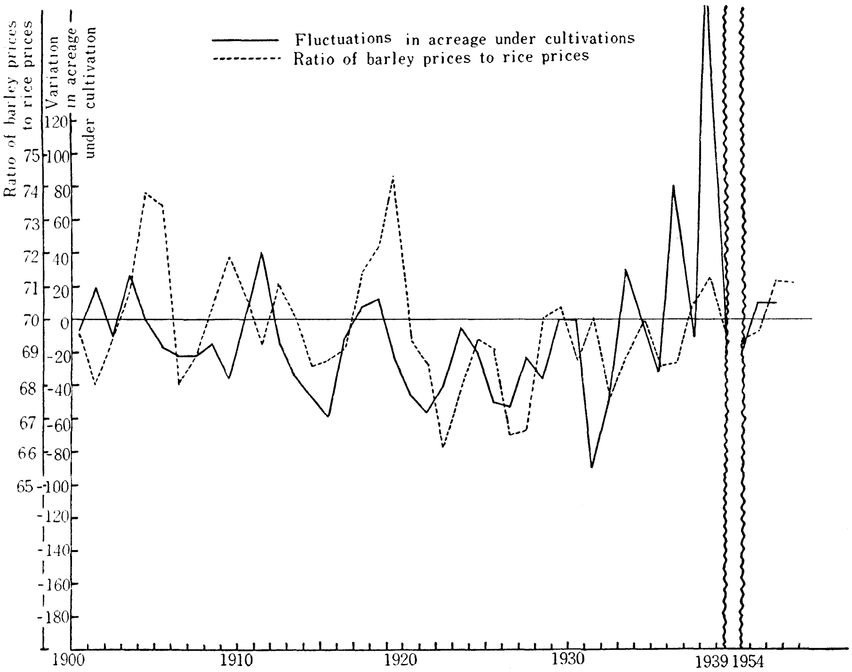

Fig. 3. Ratio of barley prices to rice prices & fluctuations in acreage under cultivation.

after 1951, on the basis of the fluctuations in the rate to rice price in the Shokuryo Kanri Tokei Nenpo (Annual Report on Food Control Statistics) for 1958. The two figures were then indicated in terms of 1934–1936 values.

b) Examination of measurement years: We have hitherto completed the integration of necessary data to obtain theoretical models and make measurements thereof; so let us next examine the measurement year by means of charts. When we take the left-hand member of formula (2–8) as denoting a variation in the acreage under cultivation in order to extract a trend, we get Fig. 2, 3, and 4. In other word, these figures show the rate of wheat, barley, and naked barley prices to rice price on the lateral axis and a variation in the acreage of wheat and barley fields under cultivation on the vertical axis. Concerning wheat, barley, and naked barley, there was fairly high correlation between the two factors from 1901 to 1939. After 1940, wheat and barley were placed under direct control with the establishment of the wartime structure, and this control continued until 1952.

Of course, that period must not be taken into consideration because it did not witness any normal supply reaction to prices. The year 1954 was also an abnormal year which clearly saw different fluctuations. The year 1952 saw the adoption of the automatic approval system for the import of rapeseed oil, the resultant sudden decline in rapeseed oil prices, the sharp decrease in the acreage of rapeseed fields under cultivation, and the remarkable increase in the acreage of wheat and barley fields under cultivation.

However, the automatic approval system for rapeseed imports was abolished after one year's enforcement; so the years after 1955 must be regarded as normal years. As can be seen in Fig. 2, 3, and 4, there were considerably regular fluctuations between 1900 and 1939, with the exception of the period of confusion, and after 1955. Therefore, we shall regard the 1901–1939 period the object of study and apply the trend values thus obtained to the years after 1955.

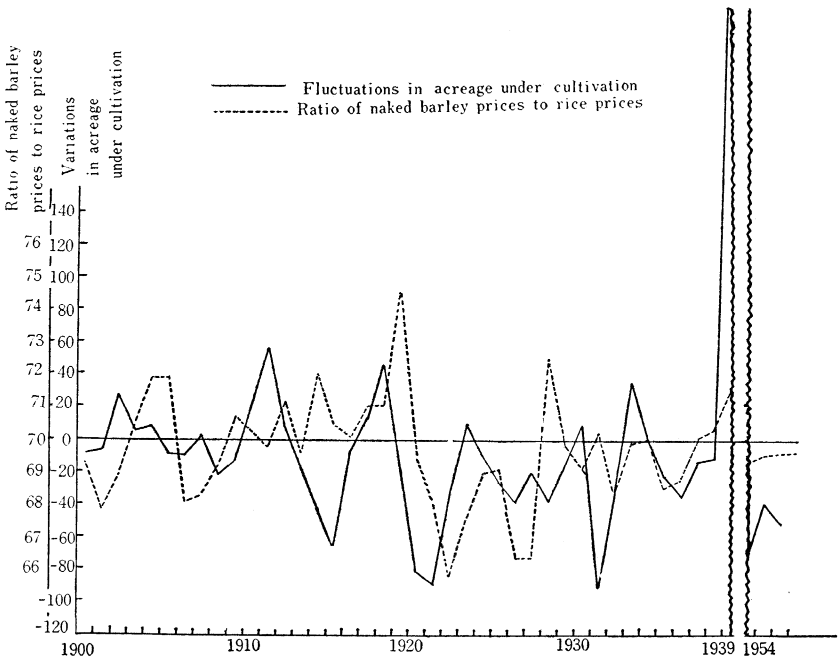

Fig. 4. Ratio of naked barley prices to rice price & fluctuations in acreage under cultivation.

c) Measurement: We have already assembled our study of all the necessary data and the measurement years; therefore, let us next make a econometric study of the problem. From formua (2–8), we can obtain the following detailed equation for barley:

$$X_t = 0.4643 + 0.8915\ X_{(t-1)} + 0.1359\ P_{a\cdot(t-1)} - 0.0631\ P_{b\cdot(t-1)}$$
$$\quad (0.5099)\ (0.0473) \qquad (0.0432) \qquad (0.0567)$$
$$-2.2607\ T + U_t \qquad (3\text{-}1)$$
$$(-1.2777)$$

$$R^2 = 0.9697 \qquad d = 2.0684$$

Figures in parentheses denote the standard error in the estimated values and show that these values are significance. R denotes the coefficient of multiple correlation and shows that these independent variables account for up to 97 per cent of the fluctuations in the acerage under cultivation. The term d is a statistical quantity which shows a verification using the Durbin and Watson serial correlation.[1] Corresponding to equation (2–8), we have

$$\delta K = 0.4643, \qquad (1)$$

$$\delta\, \alpha = 0.1359, \qquad (2)$$

$$\delta\, \beta = -0.0631, \qquad (3)$$

$$1 - \delta = 0.8915, \qquad (4)$$

$$\delta\, \gamma = -0.0226, \qquad (5)$$

From (4), we obtain

$$\delta = 0.1085.$$

Hence, by using (1), (2), (3), and (4), we shall find

$$K = 4.2799$$

$$\alpha = 1.2532$$

$$\beta = -0.5814$$

$$\gamma = -0.2084$$

Thus,

$$X_t = 4.2799 + 1.2532\ P_{a\cdot(t-1)} - 0.5814\ P_{b\cdot(t-1)} - 0.2084\ T \qquad (3\text{-}2)$$

Taking barley first, 1.2532 is calculated for the long-run elasticity, and −0.5814 for the substitution elasticity; namely these figures show that, if barley price[a] is reduced by 10 per cent, the acreage of barley fields under cultivation will decrease by 12.532 per cent, and that, if the price of wheat which is considered as an ordinary substitute crop for barley fall by 10 per cent, the acreage of barley fields under cultivation will increase by 5.814 per cent.

Second, analyzing the situation of wheat, 1.2407 is computed for the elasticity of long-run supply, and −0.5422 for the substitution elasticity;

[a] Prices for wheat, barley, and naked barley that are used mean ratios of their prices to price of rice.

this indicates that assuming the price of wheat fall by 10 per cent, the acreage of wheat fields under cultivation will decrease by 12.407 per cent and that the price of barley which is an alternative substitute crop for wheat fall by 10 per cent, the acreage of wheat fields under cultivation will increase by 5.422 per cent.

Third, for naked barley, the long-run supply elasticity is 3.0388 and the elasticity of substitution −1.8407, illustrating that the price of naked barley fall by 10 per cent, the acreage of naked barley fields will decrease by 30.388 per cent, and that, if the price of wheat which is a substitute crop for naked barley fall by 10 per cent, the acreage of naked barley fields will increase by 18.407 per cent.

From these analyses, it can be concluded that acreages of wheat barley and naked barley fields under cultivation can be highly responsive to fluctuations in their own prices or prices of substitute crops, and that the production of those three crops are highly elastic in response to price fluctuations.

d) Regional long-run supply function: In the previous sections, it has been demonstrated that the long-run supply functions for wheat, barley, and naked barley are of highly responsiveness. However, since those functions estimated were calculated from the total figures collected throughout Japan, it was necessary to know differences in the long-run supply functions in connection with regional difference. For convenience, several prefectures as unit district were selected in accordance with the order of acreages of the crops which were primarily concerned. The long-run supply functions were estimated for wheat in Gunma, Okayama, and Fukuoka, for barley in Ibaragi, and Gunma, and for naked barley in Okayama, Fukuoka, and Kagawa prefectures. For the analysis, the same method described previously was used.

For barley, the elasticities for long-run supply and for substitution were estimated to be 0.8255 and −0.5590 in Gunma and 0.5074 and −0.3267 in Ibaragi, respectively. In wheat, the corresponding estimates were 0.4250 and −0.1695 in Fukuoka, 0.4297 and 0 in Gunma, and 0.2212 and 0 in Okayama, respectively. These values for naked barley were found to be 0.8101 and −0.3647 in Fukuoka, 1.948 and −1.0677 in Kagawa, and 1.6233 and −1.0410 in Okayama, respectively.

These results have clearly demonstrated that regional long-run supply functions for wheat, barley, and naked barley are highly elastic as with the case of their national level supply functions.

Conclusion

The results obtained in this investigation have demonstrated that the long-run responses of acreage for wheat, barley, and naked barley under cultivation to their price fluctuations could not be inelastic but highly elastic with regard to both national and regional standpoints even in Japan. Therefore it should be emphasized that acreage of wheat, barley, and naked barley under cultivation will be affected extensively in such critical situations where variation in prices of them are forecasted, particularly facing to the over-production of barley and naked barley and many problems in connection with the liberalization of trade.

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