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THE ROLE AND SIGNIFICANCE OF MECHANIZATION IN THE AGRICULTURAL DEVELOPMENT OF JAPAN

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Since the Second World War, the investment in farm machines in Japanese agriculture has increased remarkably. This analysis centres on the role and significance of (a) small-scale mechanization dominated by power tillers, and (b) medium and large-scale mechanization dominated by tractors, combine auto-threshers and ordinary type combines in the agricultural development of Japan.

Small-scale farm mechanization was adopted in order to secure any given level of rice production at the lowest possible cost, rather than as a means of increasing the yield per hectare. In other words, mechanization was simply a substitute for labour. However, such small-scale farm mechanization has not brought about much increase in farm labour productivity. Large-scale farming and large-scale mechanization are prerequisites for increasing agricultural labour productivity. The extensive use of large-scale mechanization in Japan will depend upon finding solutions to several problems.

In 1985, the amount of fixed capital formation in agriculture in Japan was 3,672.3 billion yen, an increase of 15.3 times in nominal terms and 3.7 times in real terms over the 240.4 billion yen of 1960 (Table 1). The rate of increase in agricultural investment was 11.5% in nominal terms and 5.4% in real terms. This fixed capital formation can be roughly classified as land, buildings, farm machinery, plants and livestock. During 1960–85, the value of farm machinery increased remarkably. The rate of increase of investment was 11.0% (nominal) and 7.0% (real terms).

Since the Second World War, the most significant change in farm equipment has been the remarkable increase in the use of power tillers as shown in Table 2. In 1985, 59% of the farm households had power tillers. The demand for tractors on which the operator rides and power rice transplanters has also increased in recent years, as has the demand for small combine harvesters and combine auto-threshers.

In this paper, I would like to analyze the role and significance of farm mechanization in the agricultural development of Japan, with special reference to power tillers and medium to large-scale farm machines such as driving type tractors, combine auto-threshers and ordinary type combines (small and large combine harvesters).

Table 1
Capital Formation in Agriculture

Item		1960	1970	1980	1985
			(billion yen)		
Capital formation	A	240.4	1091.7	3630.1	3672.3
	B	942.7	2481.1	3630.1	3480.9
Land	A	99.6	406.8	1765.9	1763.3
	B	485.9	1053.9	1765.9	1666.6
Buildings	A	30.2	213.7	590.9	538.5
	B	103.4	492.4	590.9	520.3
Farm machinery	A	84.1	376.2	1045.3	1146.0
	B	196.5	658.8	1045.3	1062.1
Plants	A	12.3	44.2	76.9	88.2
	B	69.5	117.2	76.9	80.0
Livestock	A	14.2	50.8	151.1	136.3
	B	88.8	158.3	151.1	151.6

A = Nominal terms B = Real terms (1980 prices)

Source: Ministry of Agriculture, Forestry and Fishery. *Nogyo oyobi Noka no Shakai Kanjyo* (Social Accounting of Agriculture and Farm households) 1987.

Table 2
Changes in the Numbers of Major Machines on Farms

Year	Power tiller	Driving type tractor	Power rice trans-planter	Power duster	Reaper and binder	Combine auto-thresher
	('000)	('000)	('000)	('000)	('000)	('000)
1955	87	0.1		87		
1960	746	5		305		
1965	2,490	19		850	18	
1970	3,161	303	33	2,171	263	47
1975	3,375	339	470	2,607	1,218	217
1980	2,752	1,471	1,746	2,139	1,619	884
1985	2,579	1,853	1,993	2,151	1,518	1,109
Rate of diffusion[a] in 1985 (%)	59	43	46	49	35	25

Source: Ministry of Agriculture, Forestry and Fishery. *Norinsho Tokei Hyo*, (Statistical Yearbook of Ministry of Agriculture, Forestry and Fisheries), 1970 – 1980.

[a] Percentages are derived by dividing the number of machines by the total number of farm households.

ECONOMIC EXPLANATION OF SMALL-SCALE MECHANIZATION

Because of the small-scale of most Japanese farms, the process of mechanization, as in the case of the power tiller, is very different from that which takes place in Western, large-scale farms.

First, mechanization in Western countries has been applied to upland farming, whereas in Japan it has taken place primarily in irrigated paddy fields. A survey in 1967 showed that the mechanization ratio in Japan was 85.5% in paddy fields and 39.6% in upland fields. Secondly, although mechanization was adopted evenly in all processes of cultivation in Western countries, such a balanced advancement did not take place in Japan. In Japan, at first, machines were not introduced into all the processes of paddy farming, but were used primarily for ploughing, harrowing and puddling operations, in place of labour. However, since 1967, mechanization has been increasingly utilized in transplanting, reaping and so on. Thirdly, in Western countries, yield per hectare was clearly increased through mechanized deep-tilling, whereas in Japan the effect of power tillers on the yield of rice per hectare was slight. The results obtained by the agricultural experiment stations in various prefectures were confusing, some showing an increase in yields while others recorded a decrease. Ito pointed out that the deep-tilling capacity of the power tiller was no greater than that of the animal driven plough.

In the 1960s, power tillers dominated farm mechanization in Japan. This was different from the situation in Western countries, and various pieces of research have been done on this subject. Kayo classified explanations for the adoption of power tillers into five catagories, and added his own opinion. The five catagories are as follows.

1. Income Effect Theory: Returns on the use of power tillers fall short of the cost of such tillers and, in fact, such investment becomes over investment. Power tillers are actually adopted, simply because the farmer's income has increased by side jobs. This theory regards the motive for purchasing power tillers as something similar to the desire for durable consumer goods, such as washing machines, rather than that for pure producer goods.

2. Demonstration Effect Theory: This theory holds that farmers buy power tillers in order to compete with the next-door farmers who are already using them. This could be called 'Keeping up with the Jones'. Such a phenomenon is widely known as the demonstration effect, and was used by Duesenberry to explain the main motives behind the purchase of consumer goods. The application of such a theory to the introduction of power tillers is based on the assumption that they are not producer goods but consumer goods.

3. Disintegration of the Patriarchal Family Theory: As sons and daughters of farmers have shown a strong tendency to abandon farms in recent years, the heads of farm families buy tillers to encourage their children to remain in the traditional profession of agriculture. According to this theory, this situation has arisen from the weakening of the patriarchal family system.

4. Increased Leisure Valuation Theory: Mechanization is not used in order to provide additional time for more intensive farm management or for a side business that would increase earnings, but to increase leisure time.

5. Farmers' Physical Mutation Theory: In the days before the Second World War farm training started at the age of about twelve, when a young boy finished his primary school. After the war, this type of hard traditional training was no longer enforced because of the collapse of patriarchal family system: also, the period of compulsory education was extended to the age of fifteen. Thus, more and more farm children began to go to high school. As a result, young farmers failed to develop the physical strength necessary for heavy farm work. For these reasons, this theory holds that tiller had to be used on the farm.

All the abovementioned theories try to explain the mechanization of small-scale farms from viewpoints other than that of economic rationality. However, in 1964, the average purchasing price of a tiller was 190,000 yen without attachments. If attachments were included, the price could go up to around 300,000 yen. For most farmers this was extremely expensive, since the annual average net farm household income was only 670,000 yen in 1964. Thus, before a farmer decided to buy a power tiller, he was naturally obliged to bear in mind the future payments. The results of a survey of 2,061 farms, in 1964 carried out by Kikaika Shinko Kyokai (Association for the Promotion of Mechanization), showed that 84% of all farms surveyed adopted power tillers as a substitute for labour and that very few did so from demonstration effect motives or for other non-economic reasons. It seems necessary, therefore, to review the motives for the use of power tillers by Japanese farmers from the standpoint of economics (Kudo).

REASONS FOR THE PROMOTION OF SMALL-SCALE FARM MECHANIZATION

There are various dominant factors that have contributed to the wide-spread use of power tillers in Japan. First, after the Second World War land improvement projects were carried out in the main rice production areas. Once a land improvement project was carried out, drainage became better, rearrangement of paddy fields made each plot larger, and the introduction of machinery became easier.

Second, the number of people engaged in self-employed farming began to show a marked decrease after 1954, reflecting the fast growth of the Japanese economy (Table 3). At the same time, some members of each farm family began to work outside the farm and the number of so called part-time farm households began to increase (Table 4). The ratio of these part-time category I farm households (part-time farm households earning their main income from farming) and part-time category II farm households (part-time farm households earning their main income from other jobs) to total farm households has been calculated, and is shown in Table 4. If these estimates are accurate, part-time farm households remained close to 50% of the total before 1960, but have increased dramatically since about 1960, finally reaching 86% in 1985. A detailed study of the income structure of these farmers reveals that income from side jobs surpasses regular income from agriculture, resulting in the marked increase in category II part-time

farm households. This decrease of the population engaged in farming has also brought about a sharp rise in agricultural labour costs.

Table 3
Number of Farm Households, Population engaged in Own Farming and Cultivated Acreage

Year	Number of farm households	Population engaged in own farming	Cultivated acreage	Average farm size	Per capita cultivated acreage
	('000)	(10^4 persons)	('000 ha)	(ha)	(ares)[a]
1880	5,500	1,466	4,777	0.87	3.26
1900	5,502	1,419	5,228	0.95	3.68
1920	5,564	1,394	6,016	1.08	4.32
1940	5,484	1,350	6,155	1.12	4.34
1950	6,176	1,570	5,902	0.96	3.76
1960	6,057	1,337	6,119	1.01	4.58
1965	5,665	990	6,004	1.06	6.08
1970	5,402	811	5,530	1.02	6.81
1975	4,953	588	5,572	1.13	9.48
1980	4,661	506	5,461	1.17	10.79
1985	4,376	444	5,379	1.23	12.11

[a] 10 ares = 0.1 hectare

Source: *Nihon Nogyo Kiso Tokei* (Fundamental Statistics in Japanese Agriculture), ed. N. Kayo, 1977 and Ministry of Agriculture, Forestry and Fisheries *Norinsho Tokei Hyo* (Statistical Yearbook of Ministry of Agriculture, Forestry and Fisheries), 1987.

Third, improvements in the quality and efficiency of agricultural machines and implements have been significant. Before the Second World War, agricultural machines were manufactured mostly in small or medium sized factory enterprises and the business 'know how' was provided by the producers' experience. After the war, however, production techniques improved greatly, as a result of the switchover from small-scale plants to factories for the production of agricultural machines and implements. At present, modern engineering techniques are used for production and planning. Thus, improvements in quality as well as lower relative prices for machinery have been attained.

Fourth, the farmer's income level has risen, due to the spread of side jobs among farmers and the inflated price of rice. The results of the 1964 survey conducted by Kikai Shinko Kyokai of 2,061 farm households show that 77% of the funds used for purchasing power tillers came from individual sources, and very little capital was secured from the 'Farm Modernization Fund' (government subsidised low-interest loans) or other sources. Such a high ratio of personal financing indicates the burden of purchasing farm machines on the farmer's income and also reflects the limitations of financial support from financial institutions for agricultural mechanization. When farmers choose to borrow from financial institutions, they must think thoroughly and rationally; the marginal return obtained from employing these farm machines must cover the cost of repaying the loan.

The fifth and most important factor has been the increase in farmers' entrepreneurial ability. Prior to the Second World War, Japanese farmers possessed very little initiative. In Japanese agriculture, the role of entrepreneur had traditionally been played by such bodies as central and local governments, and agricultural cooperative institutions, so that the farmers themselves did not play a very active role. Tobata, writing in 1936, regarded them as 'mere managers', adopting Schumpeter's definition of entrepreneurs as those who further the economy. The promotion of agricultural mechanization centering around the use of power tillers has made Japanese farmers familiar with economic dealings, and has forced them out of the role of 'mere managers'.

Table 4

Number and Percentage of Farm Household Classified by Full-time and Part-time

Year	Total farm households	Full-time farm households	Part-time farm households	Part-time households Category I	Part-time households Category II
	('000)	('000)	('000)	('000)	('000)
1938	5,336	2,401	2,935	1,641	1,294
	(100)	(45)	(55)	(31)	(24)
1950	6,176	3,086	3,090	1,753	1,337
	(100)	(50)	(50)	(28)	(22)
1960	6,057	2,078	3,979	2,036	1,942
	(100)	(34)	(66)	(34)	(32)
1965	5,665	1,219	4,446	2,081	2,365
	(100)	(22)	(78)	(36)	(42)
1970	5,402	845	4,557	1,814	2,743
	(100)	(16)	(84)	(33)	(51)
1975	4,953	616	4,337	1,259	3,078
	(100)	(12)	(88)	(25)	(63)
1980	4,661	623	4,038	1,002	3,036
	(100)	(13)	(87)	(22)	(65)
1985	4,376	626	3,750	775	2,975
	(100)	(14)	(86)	(18)	(68)

Source: Keizo Tsuchiya. *Productivity and Technological Progress in Japanese Agriculture*, 1976 and Ministry of Agriculture, Forestry and Fisheries *Pocket Norin Suisan Tokei (Pocket Statistical Yearbook of Agriculture, Forestry and Fisheries)*, 1987.

Note: Part-time Category I farm households are farm households earning main income from farming, Part-time Category II farm households are farm households earning their main income from other jobs.

It may be concluded that the cause of the recent extensive implementation of power tillers can be traced to a desire to secure a certain amount of rice at the lowest possible cost, rather than a desire to increase yields, thus rationalizing the substitution of machinery for human labour (Tsuchiya, 1969). However, such small-scale mechanization has not contributed very much toward increasing agricultural production. In order to increase agricultural labour productivity,

medium and large-scale mechanization are required. In the following section, I will consider some problems concerning medium and large-scale mechanization.

DIFFUSION OF MEDIUM-SCALE FARM MECHANIZATION

As shown in Table 2, in 1985 the number of farm machines and the rate of diffusion (percentage of all farms) of reapers and binders, driving type tractors, power rice transplanters and combine auto-threshers were: 1,518,000 (or 35%); 1,853,000 (or 42%); 1,993,000 (or 46%); and 1,109,000 (or 25%), respectively. The process of farm mechanization in Japan can be divided into two phases. The first phase, from 1955 to 1966, was dominated by the use of power tillers. The second phase, from 1967 to the present, has been dominated by the use of reapers and binders, power rice transplanters, driving type tractors and combine auto-threshers.

The number of ordinary type combines began to increase after 1965, and reached 1559 in 1980. However, because of the high cost of these machines (about 15 million yen per machine in 1980), diffusion was difficult without government subsidies and efficient utilization.

Since the price of a combine auto-thresher was about 1.2 million yen in 1980, farmers could purchase this machine either alone or in groups. Diffusion was therefore very rapid and by 1985 the number had reached 1,109,000. Technically, the use of combine auto-threshers is actually more profitable in many cases: (1) the ordinary-type combine is heavy and cannot be used for work in paddy fields without complete drainage and hard ground, whereas the combine auto-thresher is light and can be used on partially drained paddy fields or immediately after rainfall during harvest time; (2) in the case of harvesting, the combine auto-thresher can harvest rice even in the early morning dew by biting off the head of the rice plant, thus making it possible to operate all day long; and (3) the use of large-scale machines requires special operators, where as medium-scale machines can be operated by the farmers with only brief instruction from the manufacturer. For these reasons, combine auto-threshers and medium-scale tractors have increased remarkably in numbers. In addition, in the second phase of mechanization, the power rice transplanter was introduced at the same time as the popularization of the combine auto-thresher, thus making mechanization available for all aspects of rice production.

It has become increasingly difficult for small-scale farmers to own combine auto-threshers, medium-scale tractors and other medium-scale agricultural implements, since these machines are very expensive. To cope with this problem, the cooperative use of agricultural machines and implements and contract farming have been introduced in rice cultivation. These systems are also employed for use of large-scale machines, such as large tractors, rice centres (communal large-scale grain drying houses), country elevators (communal unhulled rice drying and storage houses) and dry stores (drying and storage houses) within the agricultural cooperative associations.

The development of medium-scale mechanization in rice cultivation can easily save working labour (Shoji). In 1960, the working time in rice production per 10 ares (0.1 hectare) was 172.7 hours, whereas in 1985 it was only 55.1 hours (Table 5). The yield per 10 ares also increased from 448 kg in 1960 to 527 kg in 1985. The productivity of labour increased approximately 2.8 times over the whole

period. Because of the high price of machines, the instalment purchasing system was adopted, causing over investment especially on large-scale farms. Sometimes, farmers went out of business because of the large amount of overhead costs resulting from over investment in relation to farm size.

Table 5
Working Hours in Rice Production

Item	1960	1965	1970	1975	1980	1985
				(hours/10 ares)[a]		
Seed preparation	0.7	0.6	0.7	0.5	0.6	0.5
Seed bed preparation	9.1	7.8	7.4	6.6	6.7	6.1
Soil preparation	16.8	14.4	11.4	9.2	8.1	6.8
Basic fertilization	6.8	5.6	5.2	3.5	2.8	2.3
Direct sowing	0.1	0.2	0.2	0.3	0.1	0.1
Transplanting	26.3	24.4	23.2	12.2	8.6	7.3
Additional fertilization	1.8	1.1	1.4	1.3	1.3	1.5
Weeding	26.6	17.4	13.0	8.4	6.0	4.3
Water control	21.9	12.0	10.8	9.9	9.7	9.3
Prevention	0	3.4	3.0	2.7	2.3	2.2
Reaping and threshing	57.0	47.6	35.5	21.8	15.1	11.4
Drying and hulling	5.8	6.5	6.0	5.1	3.9	3.3
Total labour hours	172.7	141.2	117.8	81.5	65.2	55.1
Power implements operated hours	7.6	14.4	18.5	17.9	14.2	14.5
Yield (kg/10 ares)	448	445	487	525	489	527

[a] 10 ares = 0.1 hectare

Source: Ministry of Agriculture Forestry and Fisheries. *Kome oyobi Mugirui no Seisanhi* (Production Cost of Rice, Wheat and Barley), 1962 – 1987.

Moreover, the mechanization of cultivation was also adopted in order to raise productivity in wheat production. In 1960, labour time in wheat production per 10 ares (0.1 hectare) was 114 hours as compared with 23 hours in 1977. However, there was no substantial increase in wheat yields. In 1960, the yield was 252 kgs per 10 ares as compared with 275 kgs in 1977. The area of wheat cultivated decreased from 189,000 hectares in 1950 to 90,000 hectares in 1977. In 1969, the government provided a bonus for increasing wheat production. Also in 1978, a program for reassigning the utilization of paddy fields was put into practice in order to stimulate the production of wheat. As a result of these schemes together with the availability of higher yielding wheat varieties which raised the yield per 10 ares to 357 kg in 1986, the area used for wheat cultivation increased substantially to 245,500 hectares in that year.

PROBLEMS OF LARGE-SCALE MECHANIZATION

There are very few examples of complete large-scale mechanization, such as the use of large-scale tractors, ordinary type combines and direct sowing, because of the number of problems to solve regarding extensive deployment of large-scale mechanization. The following are some ideas as to how to introduce large-scale mechanization.

1. For large-scale mechanization, land improvement schemes are essential. For example, as improved drainage causes hardening of the earth, it helps to promote efficient utilization of large-scale mechanization. Also, improvements are needed to create large-scale plots and farm roads suitable for large-scale mechanization. Of the total paddy land in Japan, only 38.6% is suitable for mechanization, (i.e. has a slope of less than 1/100 over an area of more than 50 hectares). To promote large-scale mechanization, land improvement schemes are very important and a large amount of financing is needed as an initial investment by national or local governments.

2. The economic efficiency of large-scale mechanization seems to be in doubt, considering that the yield in areas of large-scale mechanization is less than that in areas of traditional technology and not as steady. Therefore, at present, well mechanized areas using large-scale machines are limited to areas of reclaimed land, such as Hachiro Gata, dairy farming and horticultural areas where rice is a minor crop, and major part time farming areas.

3. Employment of large-scale machines is normally concentrated in the planting and harvesting seasons. The use of these machines by their joint owners should be reorganized so that they are utilized as efficiently as possible. Also, these problems are related to the following discussion of cooperative groups in agricultural production.

COOPERATIVE GROUPS IN AGRICULTURAL PRODUCTION

As previously mentioned, many problems concerning large-scale farm mechanization must be solved if it is to be successfully adopted. The number of groups cooperating in the use of agricultural machines, such as large-scale tractors, power dusters, power rice transplanters and combines increased from 20,148 in 1976 to 27,719 in 1985. The number of farm households included in these groups was 390,000 in 1985. In other words, about 9% of all farm households had joined these groups. The average number of farm households per group was 14.

Recently, the joint use of farm machines has increased in Japan. However, these farming groups have encountered a lot of problems. There is a tendency for these groups to dissolve. Between 1968 and 1985, 15,359 cooperative groups in agricultural production making up 62% of the total (24,890 in 1968) were dissolved. Also, in the case of rice production, the number of groups decreased from 6,363 in 1968 to 2,906 in 1985. Possible reasons for this rapid decrease in number include: (1) an increasing number of part-time farmers; (2) failure in management; (3) differences in labour quality; (4) restricting rice cultivation area by government; (5) decreasing enthusiasm; (6) an enlargement of the farm size of medium-scale farmers; and (7) insufficient financing. The increase in the number

of part-time farmers seems to be the main reason, causing an excessive burden of work on the full-time farmers. Profit is distributed according to the land area contributed to the cooperative farm, regardless of the fact that the full-time farmers contribute their own labour to cooperative work, whereas the part-time farmer households contribute only that of their women and old people. This tendency causes many complaints from full-time farmers and often leads to the dissolution of cooperative farming groups. Moreover, the availability of a machine operator, who is considered to be the most important person in the cooperative farming groups cannot be guaranteed because: (1) the division of work between cooperative work and work on private farms is difficult to arrange; (2) the machine operator cannot work for the cooperative farm permanently all year; and (3) he inevitably receives a lower payment for his cooperative work.

Among the cooperative groups in agricultural production, the number of groups cooperating in cultivation has declined, while the number of the joint-machine-use farming groups and contract farming groups are increasing relatively. The survey in 1985 indicated that 53% of the cooperative groups in agricultural production were based on the use of driving type tractors (of these, 60% had over 30 horse power) 22% on power dusters, 19% on the use of combines and 10% on power rice transplanters (Ohara). In this way, farming groups are able to extensively use these machines. The abovementioned survey also indicated that 40% of contract farming groups were agricultural cooperatives which had directly contracted with rice centres and country elevators owned by the cooperatives. Voluntary rice production groups accounted for 38% and other groups such as operator groups comprised 10%.

The proportion of rice farmers who consign farming to other persons increased from 31% in 1980 to 33% in 1985. This increase was only 2% for the whole period. There are many farmers who want the cooperative groups to carry out seeding, transplanting, harvest and threshing, while they continue or increase work such as land preparation and pest control themselves. Also, the number of rice farmers who consigned farming to other persons increased in small-scale farmers and decreased in large-scale farmers. In addition, there are other types of cooperative groups, contract consignment schemes for the management of agricultural cooperatives, and agricultural machine banks. Obviously, the contract farming groups are gradually moving toward small voluntary groups rather than large-scale farming groups (Ohara).

CONCLUSION

Since the Second World War, investment in farm machines in Japanese agriculture has increased remarkably, and this trend can be divided into two phases. In the first phase, from 1955 to 1966, the power tiller dominated farm mechanization. In the second phase, since 1967, the power rice transplanter and combine auto-thresher have dominated farm mechanization. In the first phase, small-scale farm mechanization was adopted in order to secure a certain level of rice production at the lowest possible cost, rather than increasing the yield per hectare. However, such small-scale farm mechanization has not brought about a great increase in farm labour productivity. The large-scale farm and large-scale mechanization are prerequisites for increasing labour productivity. For the extensive use of large-scale mechanization in Japan, there are some problems to overcome.

While the number of farmers leaving the land can be expected to increase, the proportion is still very small. Such being the case, it is very difficult to establish large-scale mechanization in Japanese agriculture. It will take many years to reach full mechanization in Japan and bring about large increases in farm labour productivity through the use of major farm equipment such as driving type tractors and ordinary type combines.

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