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*Technological Stages in Agricultural Development, Their Determinants and Perspective**

S. Sawada
Fukuoka University, Japan

TECHNOLOGICAL stages in agricultural development are generally characterized by a series of leading technologies which mainly govern each stage. Because of differences of external and internal conditions and their development patterns, such a series of leading technologies is never the same in different agricultural regions of the world. In this paper, I would like to discuss the technological stages of Asian agriculture, particularly of rice culture in the monsoon area, mainly referring to experiences of Japanese agriculture.

I. FORMATION OF TECHNOLOGICAL STAGES IN AGRICULTURE

For transforming traditional agriculture, T. W. Schultz emphasized the significance of modern inputs which were quite 'distinct' in their nature from traditional ones. Further, he pointed out the importance of education of farm people to cultivate the ability to accept the new technology which was closely connected with modern inputs, and the importance of investment in research, development and extension in agriculture.[1] From the recent changes in Asian agriculture following the introduction of high yield varieties, the significant development of agriculture in Korea and Taiwan in recent decades, and also one hundred years' experiences of the development of Japanese agriculture, his key points can be accepted. This article is to consider technological stages where different modern inputs are introduced and work together with other imputs.

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1. My first point is concerned with how to make farmers get modern inputs, even if technological knowledge can be transfered.[2] In the early stages, farmers do not have the surplus to buy them. Manufacturing industries are still in a primitive stage and cannot supply agriculture with enough of their products at reasonable prices. Under such severe conditions, farmers have to make advanced facilities and materials by a 'self-round-about' method of production which means the accumulation of farmers' own labour, because only labour is a relatively abundant resource in the early stages. I am not talking about the stone age, in Japan and some neighbouring countries, river banks for flood control and many irrigation facilities requisite for rice culture, were created by mobilizing thousands of village people. As another example, in the early stages, soil fertility had to be maintained with manure. The farmers' routine was to procure grass or young leaves from distant areas, mostly common mountain areas, from early summer to fall, using hand-sickles and bamboo baskets. They even reared cows or horses from calves and colts, the main purpose of which was to get manure. Even the selection of high yield varieties was done by the laborious effort of veteran farmers. Such are the formation and introduction of modern inputs. In later stages, farmers have some surplus, and can afford to buy current inputs, such as new kinds of seed, organic or chemical fertilizer, insecticides and pesticides. These inputs can be paid for in a short period. Moreover, they are all neutral to the scale of farm. The scale of farms is closely connected with the social framework, the transformation of which is generally delayed. In further stages, farmers can afford to get even machinery. Manufacturing industries gradually grow up, and supply agriculture with fertilizer and other current inputs, and machinery. The introduction of machinery in agriculture closely relates to the transfer of labour force from agriculture to other industries which are maturing.

2. Modern inputs cannot work alone. They have to work with many kinds of traditional inputs which already exist. The earlier the stage, the greater the complementarity between modern and traditional inputs because in the early stages modernization of inputs is very limited. Thus, the role of modern inputs must largely take into consideration how to utilize traditional inputs better than before, or to realize the interaction effect between modern and traditional inputs. It should be noticed further that a specific kind of modern input in one stage gives rise to another kind of modern input in the next stage which interacts closely on the preceding modern input. Some traditional inputs are improved to have high interaction effects with modern inputs which are newly introduced. For instance, new varieties respond well to fertilizer, and generally need much insecticides and pesticides. Thus, the former will give incentives to the introduction of the latter. New varieties generally have a strong and widely spread root system. To develop such potentiality well, soil must be drained at specific seasons, and ploughed and harrowed thoroughly. Thus, denoting hydrological, biological, chemical and mechanical technologies as H, B, C and M respectively, the advancement in B technology will give

incentives to the advancement in H technology on the one hand, and to the advancement in C and M technologies on the other hand. The advancement in C technology will be an incentive to give rise again to the improvement of B technology such as newer varieties having a higher response to fertilizer, and so on. As such, modern inputs must be the ones which pursue a high interaction effect with other inputs. In a sense, the qualities of modern inputs include the modernization or innovation in the relationship between factors.

3. Advancement in M technology means generally the introduction of larger machinery. How small-scale farms can use such large, efficient machinery, having new capabilities including scale economy, is a large problem. In many Western countries where large-scale farms were already formed in early years, the problem may not be acute. In many Asian countries there are still millions of small-scale farms. The procedures for solving the problem involves how to systematize working or social units in respect to farming, processing, marketing, and the distribution and utilization of information, all of which mostly depend on using large-scale machinery or apparatus. Such systematization of social units is also a technology in a broad sense which may be denoted as S. Such systematization is needed because the change of social frameworks are generally delayed in conformity with the development of technology. Accordingly, some kinds of institutional change are strongly needed. For the development of S technology, sociological studies of developing societies should be very helpful. In every stage, the capability of farmers to accept and command new technologies is required. Accordingly, education is a generative power for every technological development. In advanced stages such capability must be cultivated further to include social discipline such as is needed to form a community or loyalty to co-operatives.

4. Thus, we may arrange stages of technological development in course of time, according to the kind of technology which played a major role in each stage, such as H-B-C-M-S. As stated above, the new technology or modern input is not the sole element relevant to the development of the agricultural productivity of that stage. All technologies or inputs are correlated with each other to raise the productivity in each stage, centring on the effect of modern inputs. The introduction of modern inputs gives incentives to the advancement of other technologies. Such a dynamic formation of technological stages may be shown as in Figure 1.

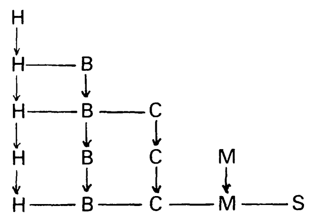

FIG. 1. Formation of technological stages.

Arrow signs show the shift of technologies or inputs from one stage to the next one. Bar signs show the close relationship between technologies or inputs, not only between adjacent ones, but also among every one in each stage. It should be noticed that elements shift from one stage to the next stage as shown by arrow signs, but have not necessarily the same quality as in the preceding stage. They are improved particularly to complement newly introduced modern inputs.

II. ON SOME ASPECTS OF THE JAPANESE CASE

1. In Japan, irrigated paddy accounted for 96 per cent of the whole area of paddy in 1965.[3] In 1955, irrigation was operated as follows: 18 per cent

TABLE 1. *Construction periods of ponds and river irrigation facilities*

	Unknown	Before 1868	Meiji era (1868–1911) Early half	Later half	Total	1912–War II	After War II	Grand Total
Ponds* (No.)	3286	9278	1247	450	1697	2547	910	17,718
(%)	18·5	52·4	7·0	2·6	9·5	14·4	5·1	100·0
River irrigation facilities (canals and head works)† (No.)	134	1177	249	55	304	133	31	1779
(%)	7·5	66·2	14·0	3·1	17·1	7·5	1·7	100·0

Source:

* Tameike–Daichō (Pond Ledger), Ministry of Agriculture and Forestry, 1955. All ponds irrigating over 20 hectares of paddy were enumerated.

† Kankōsuiriken–Chōsahōkokusho (Report on Traditional Water Rights), Ministry of Construction, 1969. All irrigation facilities relating to traditional water rights on first-class rivers administered by Ministry of Construction were enumerated.

from ponds, 73 per cent from rivers, and 9 per cent from wells or other sources.[4] The total number of ponds was 277,025. But most of them were small. The number of ponds irrigating over 20 hectares was 17,718, accounting for 70 per cent of all paddy irrigated by ponds. The construction periods of these large ponds were investigated in 1955. As for river irrigation, traditional water rights and related irrigation facilities (mainly canals and head works) were investigated in 1967–68 for all first-class rivers administered by the Ministry of Construction. The amount of water estimated as used for irrigation from rivers under traditional water rights was about 60 per cent of the total amount of water estimated as used for irrigation from rivers. The paddy irrigated under the traditional water rights investigated was about 23 per cent of the paddy irrigated under all traditional water rights. I classified all ponds and river irrigation facilities investigated as above according to their construction periods as shown in Table 1.

Ponds and river irrigation facilities of which construction periods were unknown may be presumed as constructed before 1868. If so, 70·9 per cent of the present ponds and 73·7 per cent of the present river irrigation facilities may be presumed to have been already constructed before 1868, when the feudal system was abolished, and the Meiji era began. The development of rice culture since the Meiji era owes much to the irrigation facilities already constructed before then, although they were improved or sometimes reconstructed later. Since about the beginning of this century, Shinriki, Kamenowo and other high yield varieties which brought about the, so-called, Green Revolution in Japan, were introduced. Accordingly, H technology seems to have played a great role as the prerequisite for the following technological advancements. River banks for flood control, ponds and irrigation facilities which now exist in countless number throughout the country, were the result of nothing but enormous accumulation of labour of village people in the feudal time and even under the modern government. That was the way to get 'modern inputs' in the early years.

2. The introduction of high yield varieties (B technologies) was supported by the earlier development of H technology. The new varietal improvement in turn supported, on the one hand, further development of existing irrigation systems (principally through improved drainage facilities) and, on the other hand, new C and M technologies in the form of fertilizer and improved short-soled ploughs. Organic fertilizers were used in increasing amounts. They were fish cakes, dried fish, rape seed cakes and soybean cakes. The last one began to be imported from Manchuria from around 1907, and the import increased to an enormous amount, forming the Age of Soybean Cake. However, it should be noticed that fish cakes and dried fish had been used already from feudal times in some districts where rice culture developed. High yield varieties began to diffuse in those districts first, because fertilizer was already used to some extent. Thus, the schema of Figure 1 may be modified slightly as C coming earlier than B. But, huge consumption of fertilizer began after the introduction of high yield varieties. As for short-soled ploughs, they were made in many places, particularly in western Japan, around the beginning of this century and diffused rapidly throughout the country. They could reach a depth of three or four inches easily, compared with the two inches of the long-soled ploughs, which were used in a few limited areas at that time. Such short-soled ploughs were really a modern input at that time. However, they needed draft animals. How could farmers get them? They already had them. There were already 2·7 million work stock in 1900 comprising horses in northern districts and draft cows in western districts. They slightly increased later to 3 million just before World War II. These stock were used for transporting crops, fodder and miscellaneous goods, and for stamping manure and grass into paddy fields, and also for raking the fields just before transplanting. Such 'traditional inputs' were well utilized by short-soled ploughs, the then 'modern input'. As Schultz pointed out,

modern inputs which are quite different in their qualities from traditional ones, are absolutely necessary for transforming traditional agriculture. But Japanese experiences teach us that modern inputs must have some qualities to make good use of traditional inputs or to foster interaction between modern and traditional ones.

3. Concerning education, only education at primary schools is taken up here. The national average primary-school attendance rate was 46·3 per cent in 1886, when a four-year system of compulsory education began. This rate was improved to 97·4 per cent in 1907, when the term was changed to six years. Wastage was rather great in early years. But it decreased considerably in later years. The attendance rate after allowing for wastage was 30·2 per cent in 1886, and 89·9 per cent in 1907. To see the effect of such general education on agricultural development, a cross-prefecture analysis in early years will be helpful, as there were considerable differences in attendance rates among the 47 prefectures. I checked the relation between prefectural averages of rice yield in 1887–93 and prefectural averages of attendance rates adjusted in respect of wastage for every year near that period. The simple correlation coefficient between rice yields of that period and attendance rates of 1879 was highest. Such a time lag of ten years indicates the effect of primary-school education on the development of agriculture. I undertook a cross-prefecture analysis of the relation between rice yields and several factors, including time-lag attendance rates for that period, by a multiple regression method. The effect of attendance rate was very significant and its contribution ratio was as high as 30·1 per cent.[5]

4. Industrialization in Japan absorbed much labour from the rural area. The extent of absorption was quite different among prefectures particularly in early years. Thus, to check the effect of industrialization, in terms of the decreasing ratio of rural people, on the development of agriculture in the early years, I also used a cross-prefecture analysis. The number of people occupied in agriculture is given only as estimates. Statistically, the number of farm households is given for every prefecture. So, I undertook a cross-prefecture analysis of the relation between prefectural averages of rice yield and A.D. year numbers of the years when the number of households was at a maximum because the absolute number of households was ambiguous for some prefectures. The analysis was done for the period, 1903–07. The result shown in Table 2.

According to this table, the earlier the year when the number of farm households was maximum, i.e. the number of farm households began to decrease, the larger the rice yield. I also undertook a cross-prefecture analysis of the relation between prefectural averages of rice yield and several other factors including the year number as above for that period by a multiple regression method, where the effect of the year number was very significant, and its contribution to explaining yield variance was as high as 45·2 per cent.[5]

In early years, Japanese agriculture suffered much from population surplus just like the present situation in many other Asian countries. Japanese experience shows that the decrease of population by industrialization is very necessary for the development of agriculture. Of course, as Schultz pointed out, mere decrease of labour force would have entailed the decrease of agricultural production. In the Japanese case, modern inputs such as chemicals with new varieties in early years and various machines later, were largely introduced along with the decrease of labour force. The decrease of labour force seems to have greatly stimulated the introduction of modern inputs.

We will discuss the present situation of Japanese agriculture, in the following section in relation to its prospects.

TABLE 2. *Rice yield and decrease of farm households, 1903–07*

Rice yield per tan*	Number of prefectures where number of farm households was maximum in:			Total	Average year‡
	–1900	1901–20	1920–		
I. below 1·3 koku†	0 (0)†	1 (20)	4 (80)	5 (100)	1935
II. 1·3–1·5 koku	0 (0)	4 (44)	5 (56)	9 (100)	1923
III. 1·5–1·8 koku	4 (24)	10 (59)	3 (17)	17 (100)	1912
IV. 1·8 koku and over	7 (64)	4 (36)	0 (0)	11 (100)	1894
Total	11	19	12	42§	

Source: Kayo, N. (ed.), op. cit. (4).

* 1 tan = 0·1 hectares. 1 koku = 150 kg in brown rice. Prefectures are classified according to prefectural average of 3-year moving averages of rice yields of that period, excluding the largest and the smallest year yields from the 5 consecutive year yields.

† Number in parentheses is the percentage.

‡ Average year means: year number/number of relevant prefectures. If the number of farm households showed an increasing tendency still in 1940, the number 1940 was given to each such prefecture.

§ Five prefectures were excluded because the enumeration of the number of farm households seems to have had some mistakes.

III. PERSPECTIVE OF THE FUTURE OF TECHNOLOGICAL DEVELOPMENT

The pattern of technological development as described above will give a perspective of the future of technological development in each stage. As stated above, it will be very difficult to skip over some stages without solving the problems peculiar to those stages, mainly for the following two reasons: (1) some technological progress is often the prerequisite to further progress, and (2) the realization of technological progress in a certain stage depends upon the resources available to farmers in that stage to realize the progress. Thus, without flood control, new varieties of rice can hardly be introduced. Chemicals can be used even in a stage where farmers are still very restricted in finance, and so on. The package programme has often been discussed for realizing efficient technological progress in many developing countries. This programme attempts to set up an advanced stage by introducing a set of several kinds of technologies which are more or less beyond the reach of farmers in the present stage. It may solve problem (1), but can hardly solve problem (2) without providing farmers not only plans, but also abundant resources to realize the advanced technologies. Such resources will be needed in a huge amount, if the progress relates closely to the improvement of the infrastructure. Thus, only moderate programmes paying attention to the situation of the current stage will be feasible. In other words, the package cannot 'pack' too many new items.

As for the advanced stages, the following points should be noticed for the perspective of the future of technological development. My view also covers mainly Asian agriculture, paying attention to the present situation of Japanese agriculture.

1. The amount of labour in the agricultural sector is decreasing year by year, much of it leaving for other sectors. However, small-scale farming may continue for a fairly long time. The increase of agricultural production under limited area of land is still strongly indicated. Thus, labour-saving and yield-increasing technologies will both be urgently required. Heedless mechanization often entails the decrease of yield for some years. The advancement of biological and chemical technologies, and water control will be required along with mechanization. Mechanization itself may be contrived to promote biological and other technologies. For instance, transplanting machines are rapidly spreading for rice culture in western Japan for both labour-saving and yield-increasing reasons. Transplanting small seedlings grown in boxes, early in spring, make it possible for the flowering season to pass before the typhoon season comes. Direct sowing by machinery could hardly be adopted because the decrease in yield would more than offset the savings in labour.

2. The social framework is still very rigid and difficult to alter. The small-holding of land impedes the formation of large-scale farms. Farmers want to retain their small farms in every way. This is so, even with the large absorption of labour from agriculture to non-agricultural sectors. Thus, in Japan, the farm household population decreased by 24 per cent from 1960 to 1970, while the number of farm households decreased by 18 per cent. The ratio of part-time farm households to the total of farm households increased from 66 to 84 per cent for the same period. As large farms are quite few in this country, agriculture is now carried on to a great extent by part-time farm households! It may be said that Japanese agriculture stands at the crossroads.[6] Under such a situation, agriculture seems to be trending in this way: (*a*) keeping small farms with more use of small-scale machinery combined with more advanced technologies in the biological and other fields to get high yield, but (*b*) pursuing more use of large-scale machinery or equipment in some parts of the business including processing and marketing, by grouping in co-operatives, or as

integrated large companies. How to systematize all units concerned and regulate the relation between them becomes a large problem.

Here arises the systematization problem. In Japan, the number of power tillers was only 2819 in 1939, but increased up to 3,449,200 in 1970. The number of power threshers also increased to over 3 million in the same year. Power sprays or mists, harvesters and transplanting machines are rapidly increasing. Almost all of them are of small scale and used on farms as small as about 1·0 to 2·0 hectares. On the other hand, irrigation and water control, blight control, hulling or polishing of grains, sorting, storing (including chemical treatments and refrigeration), processing, packing, transportation and information service are efficiently done only when they are carried out on large scale. These activities are being done by co-operatives or large companies not by the individual farm. Now, Japanese agriculture faces many systemization problems as stated above.

3. Current inputs originated in chemical industries, such as chemical fertilizer, insecticide including bactericide, fungicide and herbicide. These are much used for three reasons: (1) their neutrality to the scale of the farm, (2) decrease in their prices with the development of chemical industries, and (3) eliminating labour which had been used for maintaining soil fertility, making much compost, keeping labour-intensive crop rotation, and weeding with traditional implements. Thus, comparing the rice culture in Japan with that in California, the amount of chemical fertilizer in terms of nitrogen used per hectare in Japan stands at almost ten times that in California. The rice-culture in Korea and Taiwan is also very fertilizer-intensive. In Japanese rice-culture, spraying is done often as many as 15 times. Such a situation is (1) urging further and comprehensive study of soil science, particularly the ecological study of soil fertility, (2) practically causing a problem, how to keep supplying organic matter to the soil, and (3) causing serious problems of pollution not only by being directly harmful to a great number of people but also breaking the chain of the ecological system of the natural world. The future of the development of agriculture in such an area greatly depends upon how these problems can be solved.

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SPECIAL GROUP A REPORT

The points and questions basically reflected two different ways of approaching the subject of forecasting technological developments. These two contrasting approaches were obviously present in the paper by Professor Sawada and in the opening comments that followed by Professor Sebestyen. Thus, one can say that to a large extent the questions raised were a way of taking position on the basic issue implicit in the presentations of the two main speakers in the session.

The big question emerged had to do with the means available to scientists and policy-makers in general, in order to deal relevantly with that subject. In particular, the problem emerged of what method one should use to forecast technological development. Some even questioned the appropriateness of any method at all, on the grounds that technological change is unpredictable and hence cannot be forecast. The hope then, for some at least, rested on farmers' ready ability to change their mentality and modernize their approach to life.

The consensus seemed, however, to be in the direction that technological change has to be planned and cannot be left to the normal course of events, if development is to be fostered. Once this is accepted and a mere historical approach is dismissed, the way is open to the development and selection of the relevant methodology. This seemed to be the concern of most of the participants. There was some discussion about the usefulness of the Markov chain methods presented in the commentary by Professor Sebestyen. However, a few other methods were mentioned as potentially useful, such as recursive programming, simulation and systems analysis. None of these emerged as fully appropriate for present needs.

Another point brought out in the discussion was that in the process of forecasting technological development, attention should be paid to the country's endowment in factors of production. This was recognized as an important point, since it is related to the transference of technology and calls for the development of technologies relevant to the conditions prevailing in the country in terms of factor endowments. It also calls for a certain degree of co-ordination between research at the micro and at the macro level.

Finally, it was recognized that the capacity to forecast technological development greatly depends on one's ability to take into account political considerations, since one of its main determinants is the process of political decision-making operating in the country.

Contributors to the discussion included: R. C. Agrawal, *West Germany*; J. Dillon, *Australia*; A. Egbert, *U.S.A.*; A. Giles, *Peru*; Ho Tak Kim, *Korea*; A. B. Lewis, *U.S.A.*; D. W. Ware, *Canada*; A. Weber, *West Germany*.