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9. ABSTRACT

Both research in agricultural technology and construction of land infrastructure are characterized by indivisibility, externality, and jointness in supply and utilization. The theory of public good economics of the Samuelson-Musgrave tradition tells us that the goods and services with such attributes cannot be supplied at socially optimum levels if the supply is left to private firms within a competitive market mechanism. Public investments are required to correct for such market failure. The need for public institutions to conduct adaptive research and to build and coordinate the use of irrigation systems is especially critical in Asian agriculture, where the possibility for farm producers to conduct such activities by themselves is limited.

In this article the author attempts to demonstrate the critical importance of adaptive research and land infrastructure investment in the process of diffusion of agricultural technology, drawing on the history of rice technology development in Japan, Taiwan, and Korea, in contrast to the more recent development of rice technology in South and Southeast Asia, which has been heralded as the "green revolution". He attempts to identify what institutions have to be evolved for satisfying the basic requirements for technology diffusion in agriculture, and to infer what forces were responsible for inducing such institutional evolution.

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Conditions for the Diffusion of Agricultural Technology: An Asian Perspective

Yujiro Hayami

ECONOMIC DEVELOPMENT CENTER
Department of Economics, Minneapolis
Department of Agricultural and Applied Economics, St. Paul
UNIVERSITY OF MINNESOTA

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Conditions for the Diffusion of Agricultural Technology: An Asian Perspective

Yujiro Hayami

A unique aspect of agricultural production as a biological process is that it is basically conditioned by natural environments. Agricultural technology is so developed as to be efficient in the given environmental conditions in addition to being consistent with relative factor and product prices. In consequence, there is a tendency for agricultural technology to become location-specific, and its direct transfer is limited within a small area of similar environmental conditions.

The interregional transfer of agricultural technology on a scale of any national or international significance should involve the efforts of adaptation of location-specific technology to different environmental conditions. Alternatively (or simultaneously) the efforts should be made to modify the environments. The "natural environments" for agricultural production are not entirely natural but can be modified by investment in land infrastructure, such as irrigation and drainage. It is well known by economic historians that a condition for the spread of "high farming" in England in the mid-nineteenth century was land improvement by means of clay-pipe drainage.[1]

Basic conditions for the diffusion of agricultural technology are, thus, identified as (a) adaptation of a technology to different local environments, and (b) assimilation of environmental conditions to the environments where the technology was originated. Who are the agents of preparing such requisites for the diffusion of location-specific agricultural technology?

The role of innovative British landlords in the development and propagation of scientific crop rotation is a well-known story.[2] Also, both landlords and tenant farmers in England were active agents in land improvement. But, when we come to Asia, peasants earning

The study on which this paper is based was, in part, supported by a grant of the Rockefeller Foundation to the University of Minnesota Economic Development Center.

[1] J. C. Chambers and G. E. Mingay, *The Agricultural Revolution, 1750-1880* (London: Batsford, 1966), pp. 174-76.

[2] Lord Ernle, *English Farming, Past and Present* (6th ed; London: Heinemann, 1961).

a bare subsistence on a few acres of paddy fields are too small a unit to conduct adaptive research and to capture sufficient gains to pay for the research cost. The possibility for a peasant to improve the water supply to his field by himself is equally limited.

Both research in agricultural technology and construction of land infrastructure are characterized by indivisibility, externality, and jointness in supply and utilization. The theory of public good economics of the Samuelson-Musgrave tradition tells us that the goods and services with such attributes cannot be supplied at socially optimum levels if the supply is left to private firms within a competitive market mechanism.[3] Public investments are required to correct for such market failure. The need for public institutions to conduct adaptive research and to build and coordinate the use of irrigation systems is especially critical in Asian agriculture, where the possibility for farm producers to conduct such activities by themselves is limited.

In this article I attempt to demonstrate the critical importance of adaptive research and land infrastructure investment in the process of diffusion of agricultural technology, drawing on the history of rice technology development in Japan, Taiwan, and Korea, in contrast to the more recent development of rice technology in South and Southeast Asia, which has been heralded as the "green revolution." I attempt to identify what institutions have to be evolved for satisfying the basic requirements for technology diffusion in agriculture, and to infer what forces were responsible for inducing such institutional evolution.

I

DIFFUSION MODELS AND THE GREEN REVOLUTION IN ASIA

In this section I shall review the models of technology diffusion in agriculture that have influenced the formulation of agricultural development policy for the past several decades, with special reference to the "green revolution" in Asia. This will clarify the nature of the green revolution as a diffusion process, and, at the same time,

[3] P. A. Samuelson, "The Pure Theory of Public Expenditure," *Review of Economics and Statistics*, XXXVI (November 1954), 387-89; "Diagrammatic Exposition of a Theory of Public Expenditures," *Review of Economics and Statistics*, XXXVII (November 1955), 350-56; and "Aspects of Public Expenditure Theories," *Review of Economics and Statistics*, XL (November 1958), 332-38. R. A. Musgrave, *The Theory of Public Finance* (New York: McGraw-Hill, 1959).

will clarify the conditions for the diffusion of agricultural technology within the Asian context.

The traditional approach to the diffusion of technology in agriculture, primarily by rural sociologists, has focused on the impact of communication and sociocultural resistance to innovation within the farm community on the pattern of diffusion over time and across space.[4] There has been particular emphasis on understanding how the different sociological characteristics of adopters create a spectrum ranging from innovators to laggards and how these characteristics determine the means of communication that are most effective in accelerating the rate of diffusion.

This approach, when applied to less developed economies in Asia, tended to emphasize the lack of communication and the sociocultural barriers to diffusion in the "tradition-bound" peasant community. This led to a policy proposal for implementing the extension and community development programs, which aimed at assisting peasants in transforming themselves into rational resource allocators, responsive to economic incentives.[5] It was considered that the apparent productivity gap in agriculture between the developed and the less developed countries could be closed by such means. Thus, what Albert Moseman has called "extension bias" became pervasive in agricultural development policy in the 1950's.[6]

Rather disappointing results of the extension-biased programs in the 1950's called for a reflection on the premises of the sociological model of diffusion. Increasingly it has been recognized that agricultural technology is constrained by ecology, and that there are few technologies developed in the advanced countries, in temperate zones, which can be directly transferred to the less developed countries in the tropical and sub-tropical zones.

The new view of agricultural development, which found its most vigorous statement in Theodore Schultz's book, *Transforming Traditional Agriculture,* postulates that (a) peasants in poor agricul-

[4] For a review of diffusion studies by rural sociologists see G. M. Beal and J. M. Bohlen, *The Diffusion Process* (Ames: Iowa State Agricultural Experiment Station, Special Report No. 18, March 1957); and E. M. Rogers, *Diffusion of Innovations* (New York: The Free Press of Glencoe, 1962).

[5] The theory behind this approach may be called the "diffusion model" of agricultural development. See Yujiro Hayami and V. W. Ruttan, *Agricultural Development: An International Perspective* (Baltimore: Johns Hopkins Press, 1971), pp. 36-39.

[6] A. H. Moseman, *Building Agricultural Research Systems in the Developing Nations* (New York: Agricultural Development Council, 1970), pp. 70-72.

tural areas are rational resource allocators, responsive to economic incentives, and (b) they remain poor because modern high pay-off inputs are not made available to them.[7] A component of the new view is the "economic" model of diffusion, which explains the diffusion process mainly in terms of the relative profitability of new technology as compared to the old.[8] This implies a policy which emphasizes the critical importance of adaptive research in the interregional transfer of location-specific agricultural technology.[9]

The rise of the new view nearly coincided with the dramatic rise in the potential of food cereal production in tropical and sub-tropical Asia since the mid-1960's, the so-called "green revolution."[10] The core of the "revolution" was the development and propagation of high yielding varieties (HYV) of food cereals, rice and wheat, adaptable to local ecologies. The new HYV's are designed to be high yielding in response to high levels of inputs: the design of sturdy shortstemmed plant types capable of carrying the heavy burden of grains resulting from heavy doses of fertilizers with intensive controls of insects, pests and weeds, when planted in fields which have an adequate supply of water.

The varieties that possessed such characteristics had existed in temperate-zone developed countries, but their transfer to the tropics had been prohibited by different ecological conditions. The transfer was first made possible when locally adaptable varieties were developed according to the prototype existing in a different ecological zone, through coordinated adaptive research by international teams of scientists, particularly those in the International Center for Corn and Wheat Improvement (CIMMYT) in Mexico and the International Rice Research Institute (IRRI) in the Philippines.[11]

The dramatic speed with which the new HYV's were diffused among peasants in South and Southeast Asia has demonstrated the power of the "economic" model of diffusion as well as the new view of agricultural development. However, the contribution of the HYV's

[7] T. W. Schultz, *Transforming Traditional Agriculture* (New Haven: Yale University Press, 1964).

[8] For a typical example see Zvi Griliches, "Hybrid Corn: An Exploration in the Economics of Technological Change," *Econometrica*, XXV (October 1957), 501-22.

[9] Hayami and Ruttan, *Agricultural Development*, pp. 174-82.

[10] For a popular introduction to the green revolution see L. R. Brown, *Seeds of Change* (New York: Praeger, 1970).

[11] See Hayami and Ruttan, *Agricultural Development*, pp. 182-90.

to aggregate food production in the area has not been as dramatic as originally expected. Diffusion of the HYV's has been confined to irrigated areas, which are a minor portion of total arable land area. Moreover, even in the irrigated areas, the yields of the HYV's have not been so dramatic in actual farm fields as in the fields of experimental stations. While the new varieties from IRRI produce three to five times as much as traditional varieties, their yields in farm fields are usually less than thirty percent of those of the traditional varieties.

Such a poor performance of the HYV's in the actual farm fields has been accounted for by a number of factors including the inadequate controls of weeds and pests. It is generally agreed, however, that insufficient water control is the most critical constraint. In South and Southeast Asia, even in irrigated areas, minor laterals are often insufficient and drainages are rarely built; thus, the exact water control required for the HYV's can hardly be expected. As explained previously, the new HYV's were developed according to the prototype in the temperate-zone. The prototype had been developed within the favorable environmental conditions with irrigation systems that allowed highly precise water control.

A basic requirement for sustaining the momentum in the interregional transfer of the seed-fertilizer technology that led to the green revolution should be large-scale investments in research to adapt the HYV's to the environmental conditions in tropical Asia as well as in irrigation facilities in order to transform the environmental conditions.

II

DEVELOPMENT AND DIFFUSION OF RICE TECHNOLOGY IN JAPAN

The critical role of adaptive research and irrigation infrastructure in the diffusion of a rice technology in the form of fertilizer-responsive high-yielding varieties is demonstrated more clearly by the history of rice economy in East Asia. The development and diffusion of the HYV's, though of a recent origin in South and Southeast Asia, has been a major factor in accounting for agricultural growth in Japan since the last quarter of the nineteenth century. This process was transferred to overseas colonies, Korea and Taiwan, during the inter-war period.

Why did this process originate in Japan? The answer should be

sought in the conditions of factor endowments, including environmental factors, that were conducive to such development. At the beginning of modern economic growth at the time of the Meiji Restoration (1868) Japan was already densely populated; arable land area per capita of population and per farm worker was only one fifth and one third of one hectare respectively. Since the possibility of expanding cultivation frontiers was largely exhausted (except in Hokkaido), the marginal cost of increasing cultivation area should have been steeply sloping.

The fact that the unfavorable endowment of land represented the major constraint on agricultural production during the early period of modern economic growth in Japan may be inferred from Figure 1, which shows the movements in the prices of factors of agricultural production. From the 1880's to the 1930's the price of arable land rose, not only relative to the prices of reproducible inputs such as fertilizers and farm machineries, but also relative to the farm wage rates. Such price movements should reflect the highly inelastic supply of arable land area relative to the other factors of agricultural production, which faced with the expanding demand for farm products in the course of industrialization and economic growth.

In such a situation it was natural that agricultural development efforts were directed toward saving arable land area through the substitution of land by fertilizers which are, by nature, substitutes for land, and which prices were declining sharply as shown in Figure 1. The fertilizer-responsive HYV's were the means of facilitating the substitution of fertilizers for land.[12]

The environmental conditions were also favorable to the development and diffusion of these HYV's. Even at the beginning of the Meiji Restoration almost one hundred percent of the paddy fields in Japan were irrigated, although the water supply was not necessarily sufficient and appropriate drainage was lacking in many cases. These irrigation systems were built during the long and peaceful Tokugawa period, primarily by communal labor under the encouragement of feudal lords.

In fact, an attempt to select better seed varieties and to apply commercial fertilizers in the forms of fish meal and oilseed cakes

[12] For the process of factor substitution involving technical change in response to changes in relative factor prices seo Hayami and Ruttan, *Agricultural Development*, pp. 111-35.

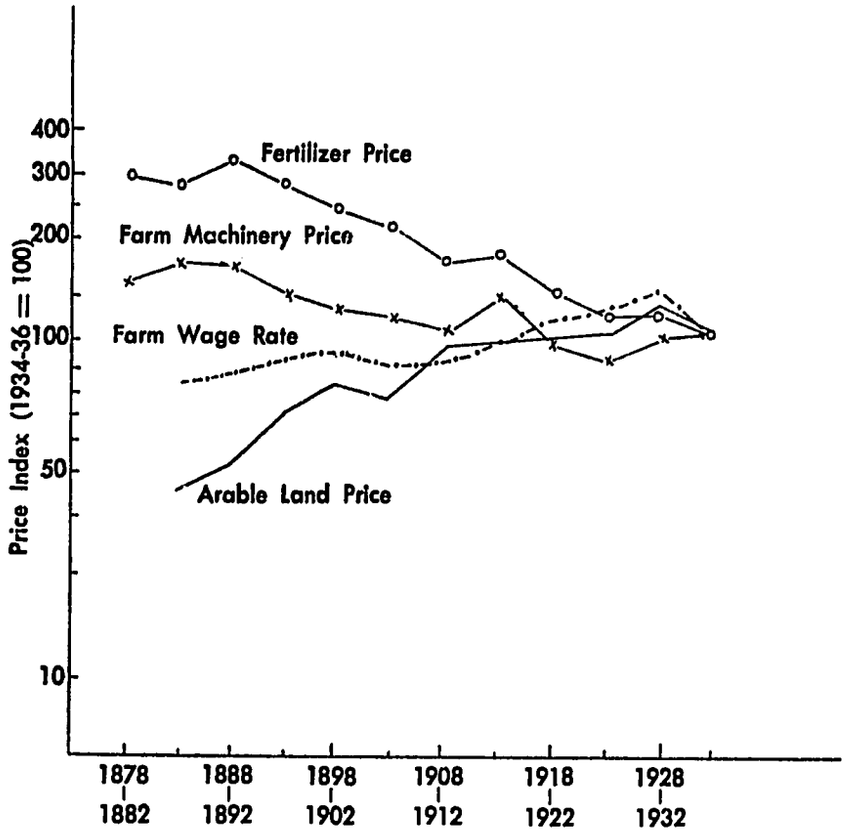

FIGURE 1
INDICES OF THE PRICES OF FACTORS OF AGRICULTURAL PRODUCTION RELATIVE TO THE PRICE OF AGRICULTURAL PRODUCTS (FIVE YEAR AVERAGES, 1878-82 TO 1933-37)

Source: Yujiro Hayami, *Nihon Nogyo no Seicho Katei*, (Process of Agricultural Growth in Japan), (Tokyo: Sobunsha, 1973), p. 34.

had already begun in the late Tokugawa period in such districts as Kinki, where the population density was higher and the irrigation infrastructure was better established.[13] The diffusion of the improved varieties and practices had been constrained by feudalism. Under the feudal system, peasants were bound to their land, and were, in general, not allowed to leave their villages. Neither were they free to choose what crops to plant nor to choose what varieties

[13] See Vol. 1 to Vol. 3 of Nogyo Hattatsushi Chosakai, *Nihon Nogyo Hattatsu Shi* (History of Agricultural Development in Japan) (Tokyo: Chuokoronsha, 1953-1958).

of seeds to sow. Barriers which divided the nation into feudal territories suppressed nationwide communications. Another constraint upon the development and diffusion of the seed-fertilizer technology was the unfavorable product and factor price relationship, especially the prohibitively high price of commercial fertilizers.[14]

With the reforms of the Meiji Restoration, the feudal barriers to diffusion were removed. The nation was united into a modern state, and the peasants were transformed into free decision-makers within the system of capitalism. Nationwide communication was facilitated by the introduction of modern postal service and railways; thus, the cost of information dissemination was greatly reduced. The land tax reform which granted a fee simple title to the farmers and replaced a feudal share-crop tax by a fixed cash tax should increase the farmers' incentive to innovate. Concurrently, the application of modern means of transportation and manufacture to the supply of fertilizers resulted in a rapid reduction in fertilizer prices, and increased the profitability of the adoption of the seed-fertilizer technology.

The farmers, especially of the *gono* class (landlords who personally farmed part of their holdings) vigorously responded to such new opportunities. They voluntarily formed agricultural societies called *nodankai* (agricultural discussion society) or *hinshukokankai* (seed exchange society), which later grew to the Imperial Agricultural Society, a national system of agricultural associations, and searched for high pay-off techniques.[15] The major improved varieties that were diffused in Japan up to the end of the 1920's, such as *Shinriki* and *Kamenoo* varieties, were selected by *rōnō* (veteran farmers from the *gono* class). Applications of such practices as the use of salt water in rice seed selection, improved preparation and management of nursery beds, and checkrow planting were also promoted by them.

The diffusion of those *rōnō* varieties and related practices was initiated within the western part of Japan, which included the most advanced agricultural districts such as Kinki and northern Kyushu. Later, beginning in the first decade of this century this process was transmitted to the relatively backward eastern part of Japan.[16] Such

[14] *Ibid.*
[15] Vol. 3 of *Nihon Nogyo*, pp. 219-386.
[16] Yujiro Hayami and Saburo Yamada, "Technological Progress in Agriculture," in Lawrence Klein and Kazushi Ohkawa, (eds.), *Economic Growth: The Japanese*

sequences in the interregional diffusion were reflected in the earlier spurt of rice yield in western Japan followed by the spurt in eastern Japan, shown in Figure 2.[17] Indeed, the regional sequences in the spurt of rice yield in Figure 2 are consistent with the pattern in the diffusion of the *rōnō* varieties as shown in Figure 3.

It must be emphasized that this is not a simple diffusion of seeds or practices, but rather the diffusion of the concepts and the methods of improving seed varieties and cultural practices suited for the local environment. Also, it involved the process of the assimilation of environmental conditions for rice production in the East to those in the West by improving the irrigation and drainage systems.

The public sector played a critical role in this process of the development and diffusion of seed-fertilizer technology. Shortly after the Meiji Restoration, the government tried to modernize Japanese agriculture toward the large-scale mechanized farming of the Anglo-American type by importing Western farm machinery, crops, and livestock, and by inviting instructors from Britain and the United States. This policy of direct "technology borrowing" proved unsuccessful because of differences in both climatic and economic conditions. During the 1880's, the government quickly shifted to a strategy of agricultural development with the emphasis on raising yields of traditional food staples, above all, rice.[18]

Toward this goal, it attempted to screen and tailor Japan's indigenous techniques by modern agricultural sciences from Germany (soil science and agricultural chemistry of the Liebig tradition). In 1881 British agricultural instructors in the Komaba Agricultural School (later designated the University of Tokyo College of Agriculture) were replaced by German scientists. In 1885 the Itinerant Instructor System was established, in which the instructors traveled throughout the country holding agricultural extension meetings. The government employed as instructors not only the graduates of the Komaba School but also veteran farmers (*rōnō*) in order to combine the best practical farming experience with the new scien-

Experience since the Meiji Period (Homewood, Ill.: Richard D. Irwin, 1968), pp. 135-61.

[17] See *ibid.* for the quantitative analysis of the diffusion process that resulted in the regional patterns of rice yield increases as shown in Figure 2.

[18] For the early experience with technology importation and the subsequent policy reorientation, see Hayami and Ruttan, *Agricultural Development*, pp. 153-64, and Takekazu Ogura (ed.), *Agricultural Development in Modern Japan* (Tokyo: Fuji Publishing Co., 1963).

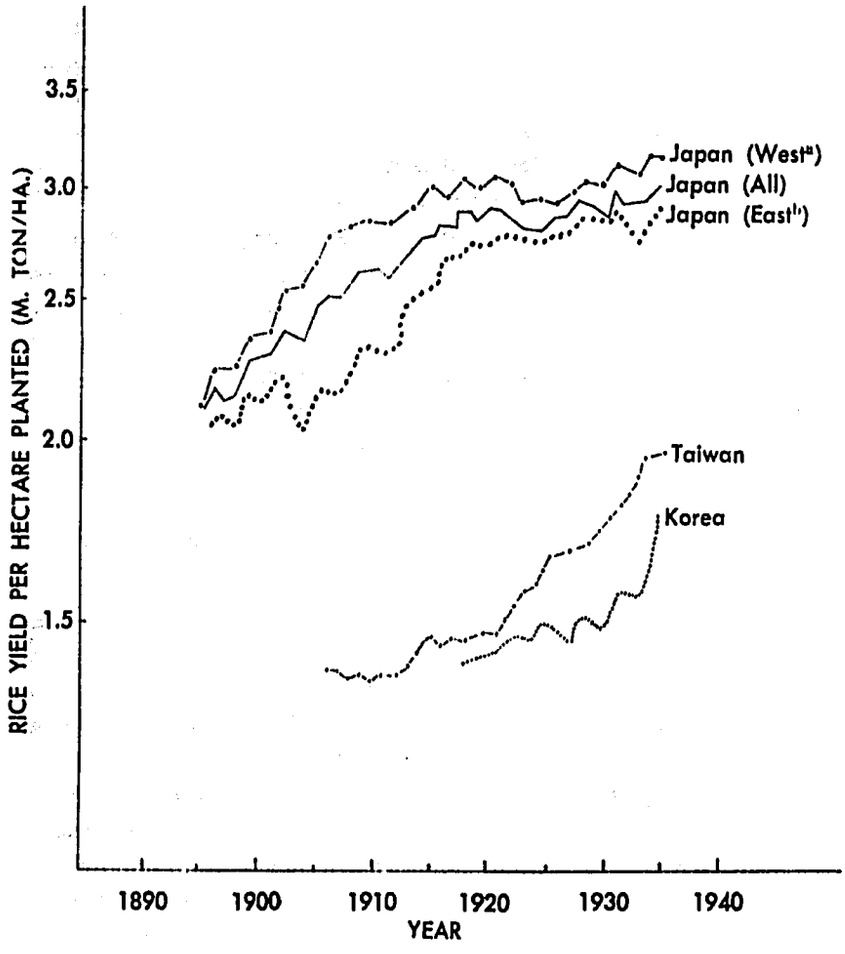

FIGURE 2
RICE YIELDS PER HECTARE PLANTED FOR JAPAN, TAIWAN AND KOREA
FIVE-YEAR MOVING AVERAGE, 1895-1935

[a] Western prefectures: Toyama, Ishikawa, Fukui, Gifu, Mie, Shiga, Kyoto, Osaka, Hyogo, Nara, Wakayama, Tottori, Shimane, Okayama, Hiroshima, Yamaguchi, Tokushima, Kagawa, Ehime, Kochi, Fukuoka, Saga, Nagasaki, Kumamoto, Oita, Miyazaki, Kagoshima.

[b] Eastern prefectures: Aomori, Iwate, Miyagi, Akita, Yamagata, Fukushima, Ibaragi, Tochigi, Gunma, Chiba, Saitama, Tokyo, Kanagawa, Niigata, Nagano, Yamanashi, Shizuoka, Aichi.

Sources: Nobufumi Kayo, (ed.), *Nihon Nogyo Kiso Tokei*, (Basic Agricultural Statistics of Japan), (Tokyo: Norin Suisangyo Seisansei Kojo Kaigi, 1958); Taiwan Government-General, *Taiwan Nogyo Nenpo*, (Yearbook of Taiwan Agriculture), (Taipei), various issues; Korea Government-General, *Nogyo Tokeihyo*, (Agricultural Statistics), (Seoul), various issues.

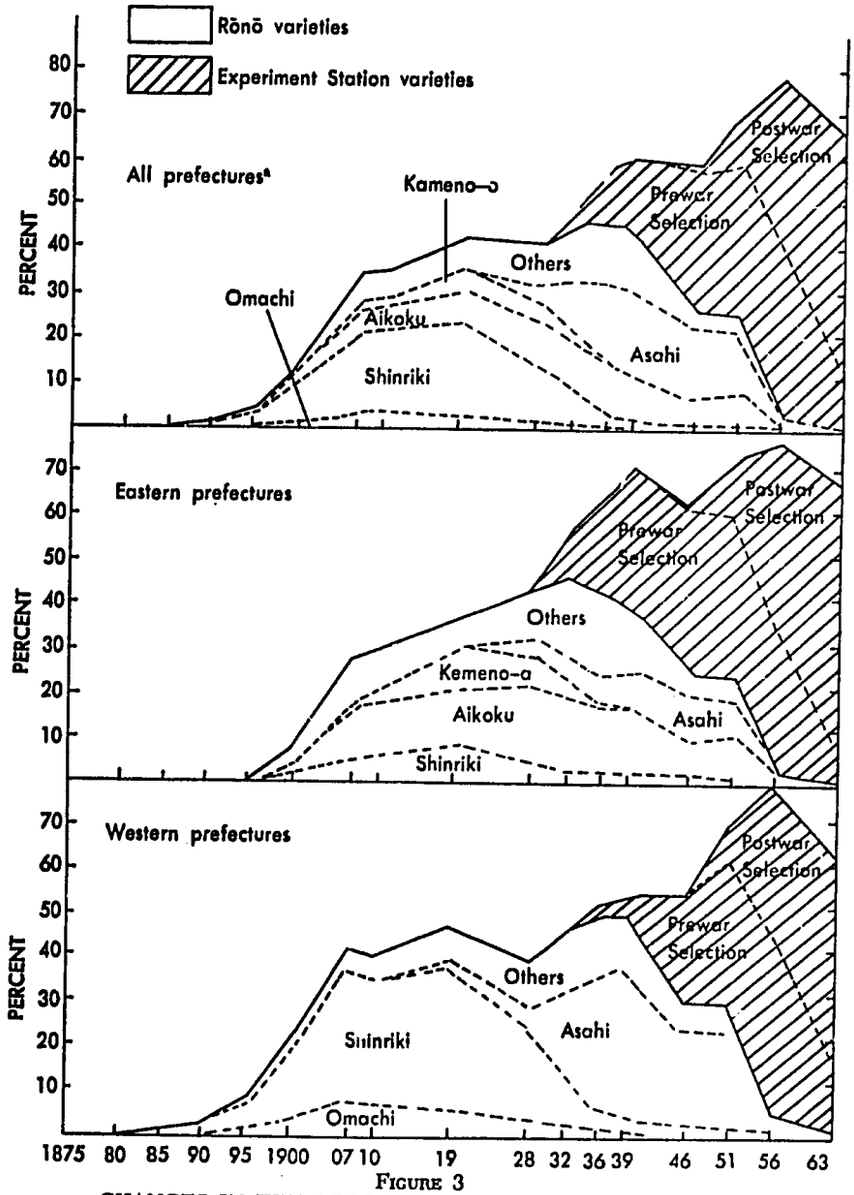

FIGURE 3

CHANGES IN THE PERCENTAGE OF AREA PLANTED IN IMPROVED VARIETIES TO TOTAL AREA PLANTED IN RICE, JAPAN, 1875-1963

[a] Regional breakdowns are the same as for Figure 2.

Source: Yujiro Hayami and Saburo Yamada, "Technical Progress in Agriculture," in Lawrence Klein and Kazushi Ohkawa, (eds.), *Economic Growth: the Japanese Experience since the Meiji Period* (Homewood, Ill.: Richard D. Irwin, 1968), p. 152.

tific knowedge of the inexperienced college graduates. In contrast with the earlier emphasis on the direct transplanting of Western technology, the itinerant instruction system was designed to diffuse the best seed varieties already in use by Japanese farmers and the most productive cultural practices used in the production of Japan's traditional staple crops, rice and barley. In order to provide better information for the itinerant lectures, the Experiment Farm for Staple Cereals and Vegetables was set up in 1886, which was further strengthened and designated the National Agricultural Experiment Station in 1893. Also, prefectures began to set up local experiment stations. This trend was accelerated with the Law of State Subsidy for Prefectural Agricultural Experiment Stations in 1899.

The initial research conducted at the experiment stations was primarily at the applied end of the research spectrum. The major projects were simple field experiments comparing the various varieties of seeds or various husbandry techniques (for example, check-row planting of rice seedlings versus irregular planting). Facilities, personnel and, above all, the state of knowledge did not permit conducting research beyond simple comparative experiments.

Nevertheless, such experiments provided a basis for the rapid rise in agricultural productivity during the later years of the Meiji period, because of the existence of substantial indigenous technological potential which could be further tested, developed, and refined at the new experiment stations and a strong propensity to innovation among farmers with whom the research workers interacted effectively.

Experiment station research was successful in testing the results of farmer innovation. The *rōnō* techniques were based on experience in the specific environments where they were originated. They tended to be highly location-specific and to require modification when transferred to other localities. Simple comparative tests effectively screened the *rōnō* techniques, thereby reducing the cost of search for technical information by farmers. Slight modification and adaptation of indigenous techniques on the basis of experimental tests often gave them universal applicability.

The government also assisted in the modification of environmental conditions through the improvement in land infrastructure. Land improvement, by nature, requires a large lump-sum investment and the cooperation of the farmers and landowners in the

area the project covers. Since the early Meiji period (even from the feudal period) the land improvement projects, including the construction of irrigation and drainage facilities and the replotment of irregular small-sized paddy fields into a more efficient shape, had been undertaken through the initiative of the landlords. However, the scale of the projects had been limited because of the difficulties both in getting the consent of people concerned in wider areas and in securing a sufficient amount of long-term credit.

In order to facilitate the land improvement projects the government enacted the Arable Land Replotment Law in 1899 (revised in 1905 and 1909). Under this law (a) participation in the project was made compulsory upon the consent of more than two thirds of those landowners who owned more than two thirds of the arable land in the district concerned, and (b) a legal person status was given to the associations of land improvement projects so that they could receive credit.[19] Also, the government established the Japan Hypothec Bank in 1897, which aimed to advance long-term credit for land infrastructure investments. Both local and central governments promoted the land improvement projects by giving subsidies through agricultural associations.

Improvement in land infrastructure, especially in drainage facilities, was a critical condition for the eastward diffusion of the seed-fertilizer technology, as discussed above. The improvement in drainage enabled the full exploitation of fertilizer response capacity of the HYV's. It also facilitated the introduction of horse plowing. Deep plowing by animal power and improved plows contributed to an increase in the application of fertilizers and in the productivity of the land.

III

TRANSFER OF RICE TECHNOLOGY TO KOREA AND TAIWAN

By adequately screening and tailoring veteran farmers' varieties and practices by rather simple experiments, Japan was able to exploit the substantial indigenous technological potential in agriculture. Domestic rice production was able to supply about 95 percent of domestic consumption during the period of the big spurt in industrialization between the Russo-Japanese War (1904-05) and World War I. The technological potential was being exhausted,

[19] Vol. 4 of *Nihon Nogyo*, pp. 213-32.

however, since it was being exploited in the absence of a supply of new potential. As already mentioned, the experiment stations in their early days contributed to agricultural productivity growth by exploiting indigenous potential rather than by supplying new potential. The national experiment station gradually moved to conduct more basic research, including original crop breeding projects both by cross-breeding (1904) and by pure line selection (1905). Results of major practical significance lagged, however, for more than two decades.[20]

The exploitation of indigenous potential and the lag in scientific research in supplying new potential, when confronted with the expansion of demand due to World War I, resulted in a serious rice shortage culminating in the *Kome Sodo* (Rice Riot) in 1918, which swept over all the major cities in Japan.

Japan was then faced with a choice between high rice prices, high cost of living, and high wages on the one hand and a drain on foreign exchange by large-scale rice imports on the other. The reaction of the government was to increase rice imports from Taiwan and Korea by developing rice production in these colonies by means of transferring the rice technology of Japan.[21]

Major difficulties in transplanting the seed-fertilizer technology developed in Japan to the overseas territories were caused by the differences in environmental conditions. Climatic difference is particularly large between Japan (in a temperate zone) and Taiwan (located in a sub-tropical zone), and this difference prohibited the direct transfer of Japanese varieties to Taiwan. More critical was the lack of irrigation infrastructure. According to the observation of Seiichi Tobata and Kazushi Ohkawa, "The first technical condition of rice production is nothing but water control. But paddy field in Korea is so-called 'rain-fed' paddy field, . . . accordingly marshy paddy field with drainage difficulty, which is considered of low quality in Japan is considered good paddy field. . . Who would dare to apply fertilizers under such conditions?"[22] It was natural that a high investment priority was placed on irrigation when the Rice Development Program was launched in Korea in 1920. The agricul-

[20] Hayami and Ruttan, *Agricultural Development*, pp. 160-62.

[21] For the motivation process of transferring the Japanese rice technology to Taiwan and Korea, see *ibid.*, pp. 198-212.

[22] Seiichi Tobata and Kazushi Ohkawa, *Chosen Beikoku Keizairon* (A Treatise on Rice Economy in Korea), (Tokyo: Nihon Gakujutsu Shinkokai, 1935), pp. 2-3.

tural development expenditure increased from a 1915-1919 total of 3.5 million yen to a 1920-1924 total of 18.6 million yen, and the major share of this increase was accounted for by the increase in the expenditure for land improvement projects which jumped from only 0.3 million to as much as 12 million yen.[23]

When the Rice Development Program was initiated, irrigation infrastructure in Taiwan was relatively more advanced than in Korea. This was primarily because annexation of Taiwan occurred a decade earlier than Korea, so that investment in infrastructure in general was earlier in starting, and, also, because irrigation had been developed from the early days of colonization to promote sugar cane production. On the basis of relatively advanced irrigation infrastructure, when the Japanese rice varieties adaptable to tropical Taiwan climate (so-called "Ponlai varieties") were developed at the Central Research Institute of the Government-General, they were diffused among Taiwan farmers at a dramatic rate. Areas planted with the Ponlai varieties grew from only 400 hectares in 1922 to 131 thousand hectares in 1930, and to 296 thousand hectares (almost one half of the total rice area) in 1935. Corresponding to the spread of the Ponlai varieties, the average rice yield in Taiwan began a sharp rise from the mid-1920's (Figure 2).

In Korea, constrained by poor irrigation infrastructure, the development and diffusion of fertilizer-responsive high-yielding varieties comparable to the Ponlai varieties lagged almost a decade behind Taiwan. However, as irrigation systems were constructed according to the Rice Production Development Program, the HYV's began to be introduced from Japan and, also, to be developed at the experiment station in Korea. As those varieties were diffused during the 1930's, average rice yields in Korea began to catch up with those in Japan and Taiwan (Figure 2).

IV

HISTORICAL PERSPECTIVE ON ASIAN DEVELOPMENT

From the review of historical experience in Japan, Taiwan and Korea, it should be clear that the diffusion of seed-fertilizer technology in rice production in Japan since the early Meiji period and its transfer to Taiwan and Korea during the interwar period were

[23] Kuro Kobayakawa, ed., *Chosen Nogyo Hattatsushi: Seisakuhen* (History of Korean Agricultural Development), (Tokyo: Yukokyokai, 1959), pp. 27-28.

essentially the same process as the "green revolution" in Asia today. The process involved (a) adaptation of a biological technology to different environmental conditions, and (b) assimilation of the environments to those in which the technology was originated.

The success with which the fertilizer-responsive high-yielding varieties were diffused in Japan can now be identified as the development of appropriate institutions to organize adaptive research and land infrastructure improvement. Evolution of such institutions into the national-prefectural experiment station network and the nationwide organization of agricultural associations established the conditions for the diffusion of the seed-fertilizer technology. If there were no such institutional development, sustained growth in land productivity in Japanese agriculture during the Meiji period could hardly have been expected, and agriculture would not have been able to meet the requirements of the nonagricultural sector for food and materials in the early period of modern economic growth.

However, it must be remembered that, in compensation for an unfavorable land endowment relative to population, Japan was favored by the initial endowment of a well-developed irrigation system. Increases in rice output and productivity during the Meiji period were based on this inheritance from the feudal regime. Although significant investments were made in the improvement in land infrastructure, primarily drainage facilities, resource requirements were relatively small for the diffusion of the seed-fertilizer technology. This made possible a resource outflow from agriculture for financing industrialization.

Such a prerequisite as irrigation infrastructure for the diffusion of the seed-fertilizer technology did not exist in Taiwan and Korea when it was attempted to develop rice production in these overseas territories in order to mitigate a rice shortage in Japan. This "missing prerequisite" was supplied by the large-scale public investment in irrigation. Organization of farmers into irrigation associations was enforced by the power of colonial governments, while utilizing indigenous rural community structures such as the *Pao Cha* system in Taiwan.

The dramatic diffusion of the HYV's in tropical Asia since the mid-1960's was first made possible by adaptive research at the new international research centers, which developed the HYV's adaptable to tropical ecology according to the prototype varieties in Japan and Taiwan. However, it should be recognized that there has been

a significant increase in irrigation investment since the late 1950's in the countries in Southeast Asia (Ceylon, Malaysia, the Philippines and others)—the countries characterized by the higher rates of diffusion of the HYV's in the "green revolution."

It should also be recognized that behind the acceleration in irrigation investment there was population pressure against land. Countries in Southeast Asia had traditionally been endowed with a rich supply of unexploited land resources. But, as population grew at the explosive rate of nearly three percent per year since World War II, the slack land resource began to be exhausted. In such situations there developed a need to augment land by constructing irrigation infrastructures.

In the Philippines, for example, during the 1950's agricultural output grew at the high rate of more than four percent per year, a rate which was primarily brought about by parallel increases in arable land area and in the agricultural labor force.[24] Toward the end of the 1950's, however, expansion of the cultivation frontier stopped and the deterioration in the land/man ratio began. This was the time when government investment in irrigation systems was accelerated.[25] As irrigation systems were expanded during the 1960's, the HYV's were developed at IRRI and BPI (Bureau of Plant Industry) and were diffused rapidly in irrigated areas in Luzon. These were the same sequences of agricultural development that Taiwan and Korea had experienced during the interwar period.

There exist wide variations in the relative endowments of land and labor among countries in Southeast Asia today. However, if the present rate of population growth in the 2.5 to 3 percent range continues, population pressure in the rural sector will soon lead to the deterioration in the land/man ratio, at least in the short run, even in the countries richly endowed with slack land resources. It would then become inevitable that those countries follow the path of agricultural growth which the Philippines began to take in the 1960's. Institutional arrangements for organizing public investments in irrigation and adaptive research should be required for counteracting

[24] Cristina Crisostomo and Randolph Barker, *Growth Rates of Philippine Agriculture, 1948-1969*, a paper prepared for the Conference on Agricultural Growth in Japan, Korea, Taiwan, and the Philippines, at the East-West Food Center, February 6-9, 1973 (mimeographed).

[25] Cristina Crisostomo, W. H. Meyers, T. B. Paris, Bart Duff, and Randolph Barker, "The New Rice Technology and Labor Absorption in Philippine Agriculture," *Malayan Economic Review*, XVI (October 1971), 117-58.

population pressure by means of the diffusion of seed-fertilizer technology. Since population pressure in the countries in Southeast Asia today is much stronger than in Meiji Japan (about one percent per year) and in Taiwan and Korea during the interwar period (2 to 2.5 percent), there is a real danger that the increase in land productivity may not be able to compensate for the decrease in land/man ratio, unless massive investments in irrigation and research are made.

Agricultural growth in the Philippines and other developing countries in Asia does not seem likely to be "capital-cheap" as it was in Japan, which inherited from the feudal period a well-developed irrigation infrastructure. Rather it appears likely that those countries would have to invest in irrigation on a larger scale and at a faster rate than Taiwan, and against a stronger population pressure, if they are to attain the growth in agricultural output consistent with the expanding demand for farm products from the developing economies. Capital requirements for agricultural growth at such a rate may even exceed the limits that governments in those countries would be able to mobilize with present institutional structures. The development and diffusion of a land-saving technology in agriculture consistent with the economic development goal in South and Southeast Asia will require institutional innovations both in the form of international cooperation and in the form of internal organization for the purpose of mobilizing indigenous resources.

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