Food and Agriculture Problems in East Asia

by

Keijiro Otsuka

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Economic and Social Research Institute

—Contents—

1. Introduction

The East Asian economy has achieved what can be termed “miraculously” rapid growth in the last 30 years or so (World Bank 1993). Although it slowed down temporarily in the closing years of the 1990s due to the monetary crisis, the economy is highly likely to get onto a long-term growth path again, as its fundamentals are unaffected by the crisis.

The agriculture sector did not lead the economic growth in East Asia, but it supported the growth through the realization of the “green revolution” that began in the late 1960s. Traditional varieties that are grown by traditional methods, such as rice, corn and wheat, are pest resistant, like weeds. But they are fatally flawed in that they easily fall down when ears increase their weight, as their stems are tall and thin. The green revolution refers to the explosive increase in rice and other grain yields in tropical Asian regions through the development and spread of modern varieties that have low and thick stems and are responsive to the use of fertilizers. The green revolution not only helped head off the food crisis that was a main source of concern in Asia until around the mid 1960s but also ensured food security through supply shift in excess of demand, bringing great benefits to consumers, including urban workers, through the long-term downtrend of grain prices.[1] In particular, the poorest segment of the population, whose ratio of food expense to total consumption expenditure is high, benefited much from the green revolution (Otsuka 2001). Declines of grain prices also contributed greatly to the preservation of natural resources, as it weakened incentives for expanding arable land through deforestation (Otsuka and Place 2001).[2]

Roughly speaking, grain production in tropical Asia nearly trippled in the last 30 years thanks to the green revolution (Pingali et al. 1997). Without the green revolution, Asia now would be suffering from food shortage like Africa and would be a food importing region. Importing foods means an outflow of valuable foreign currency and this in turn would hamper the development of the economy as a whole due to restriction on imports of capital goods (Hayami 1997). Despite its importance, the green revolution appears to be underappreciated in Japan. When it comes to the development of new rice varieties, the financial and manpower contribution made by Japan, the leading rice-growing country, is noteworthy as a successful example of Official Development Assistance.

In this paper, I would like to present an outline of East Asia’s food and agriculture problems by reviewing the development process of the green revolution in the last 30 years or so, looking at its outlook and examining its economic significance. Incidentally,

East Asia includes China. However, since foods and agriculture problems in China include many problems particular to that country, such as the land system, I would like to discuss them in another paper.[3]

I will examine the situations that prompted the birth of the green revolution in Section 2 and its development process in Section 3. In Section 4, I will introduce various criticisms of the green revolution and point out that many of the criticisms are based on misunderstanding. I will examine the sustainability of the green revolution in Section 5 and present my conclusion in Section 6.

2. Birth of the Green Revolution

The development of any industry is based on technological innovation. In this sense, agriculture is no exception. However, promoters of technological innovations differ between the manufacturing industry and agriculture. In the manufacturing industry, the main promoters are private corporations, or as Schumpeter put it, entrepreneurs. In agriculture, public research institutions are important promoters of new technology development. This is the big difference between the manufacturing industry and agriculture.

The difference of promoters between the two sectors can be attributed to the following reasons. In the manufacturing industry, new technological knowledge can be taken possession of by dint of industrial property right or its benefits can be internalized as a corporate secret to a considerable extent. Of course, there are cases where persons other than the developer can enjoy the benefit by, for instance, imitating the technology. Still, the enterprise that creates innovative technology can receive many of the economic benefits deriving from the technology. In contrast, in the case of new agriculture technology, particularly in the case of new varieties, farmers can reproduce the improved varieties. For this reason, developers of new varieties cannot reap the benefits deriving from the development.[4] In other words, technology imitation is quite easy in the case of development of new varieties. If technological imitation were easy in the manufacturing industry, private corporations would lose interest in developing new technology. It is for this reason that, in the case of agriculture, public research institutions are in charge of development of new varieties.[5] On this point, there is no difference between advanced countries and developing countries.

Another important characteristic of agricultural technology is that its effect is largely determined by the production environment. Good varieties grown in temperate regions do not produce high yields in tropical regions. Therefore, an important research theme

in the 1960s was to develop high-yielding varieties suitable for tropical regions by crossing high-yielding varieties in temperate or sub-temperate regions with varieties suitable for tropical environments. The first modern varieties IR 8 developed by the International Rice Research Institute (IRRI) in the Philippines in 1966 was developed by crossing a Taiwanese high-yielding varieties with Indonesia's traditional varieties. The International Maize and Wheat Improvement Center (CIMMYT) in Mexico, in its initial crossing of wheat, used Norin No. 10, a high-yielding varieties developed by Japan before the war.[6] As will be discussed in the next section, development of new varieties is now promoted by taking pest resistance and environmental suitability into account.

Modern varieties developed in this way have the important characteristic of being cross-border "international public goods." That is to say, a variety developed by one country spreads across national borders and brings benefits to other countries. This is especially true in well-irrigated countries, as micro production environments are similar. In fact, IR 8 has spread from the Philippines to other Southeast Asian countries and South Asia countries like India.[7] Moreover, breeding and cultivation technologies also have an element of being international public good. That is, there are cross-border external economies in the development of modern production methods. If there are external economies in the technological development aimed at developing modern varieties, it cannot be justified from the viewpoint of economics to leave the development to each country's research institutes. This is because each research institute tends to conduct experiment and research activities with only its country's interest in mind, resulting in socially expenditure for experiments and research. Professor Theodore Schultz of Chicago University, the doyen of agricultural economics, accurately recognized this point in the 1950s, calling for establishing international insufficient research institutes for agricultural development of developing countries in tropical regions. In response to his argument, the Rockefeller Foundation and the Ford Foundation established the IRRI and CITTYT in the early 1960s. The experiment and research activities at the institutes resulted in the development of modern varieties in the second half of the 1960s.[8] It can be said that the design of institutional arrangements based on such economic insight and the application of modern scientific knowledge to developing countries led to the realization of the green revolution.

3. Development Structure of the Green Revolution

In tropical Asia, modern varieties of not only rice but also wheat and maize have

been developed and have helped increase yields in wide-ranging regions. In the following analysis, I would like to discuss mainly rice, which is the most important grain in Asia and about which I have been studying for a long time. Incidentally, there is no big difference between the production of rice and that of other gains, other than the fact that irrigation is essential for paddy rice production.

(1) Understanding of the effect of modern varieties

Before studying changes in paddy rice production in Asia, I would like to examine the characteristics of modern varieties using a production function. Figure 1 shows variety-by-variety yield functions, with the horizontal axis being fertilizer input per land and the vertical axis production volume per unit of land area (hereinafter referred to as "yield").[9] Although it is omitted in Figure 1, the location of the yield curve is largely determined by the production environment. In the case of modern varieties, in particular, productivity varies greatly depending on the availability of irrigation water. However, for the sake of simplicity, the impacts of bad environments on yield are ignored in the following discussion.

First, with regard to traditional varieties, Figure 1 shows that the location of their yield functions is not only low reflecting their low yield potential but also absolutely declining if fertilizer input exceeds a certain amount. This indicates that since traditional varieties tend to lodge, increased fertilizer input does not lead to an increased yield. Moreover, since traditional varieties have less soil-nutrient absorption capacity, they tend to yield less than modern varieties when no fertilizer is used.

Since modern varieties have been developed by removing the defects of traditional varieties and by enhancing fertilizer responsiveness, their yield functions stand at locations higher than that of traditional varieties. What I want to emphasize here is that the modern variety does not refer to a single variety but that many superior varieties have been developed with time. In this paper, modern varieties are roughly classified into first-generation, second-generation, and third-generation categories in accordance with Otsuka et al. (1994s) and Estudillo and Otsuka (2001).

First, I would like to take a look at the first-generation Modern Variety I that was developed in the second half of the 1960s. This type of variety produces a tremendous amount of yield in a pest-free, well-irrigated production environment. In terms of potential yield, there is not a big difference between first-generation varieties and later generation varieties. It is for this reason that IR 8, the first-generation variety, was called "miracle rice." However, the first-generation modern varieties are vulnerable to diseases and pests, and their yields are particularly low in bad environmental conditions.

The Modern Variety I was initially called the “high-yielding.” But since they do not always produce high yields irrespective of production environment, they have come to be called the “modern variety.” As Figure 1 illustrates, the first-generation variety’s average yield curve, which takes into account a decline in yield caused by diseases and pets, stands above that of traditional varieties but below those of the second-generation and third-generation varieties.

Although the use of Modern Variety I spread smoothly, it was beset by a succession of episodes of serious damage caused by diseases and pests. In response, intensive research into plant pest resistance in modern varieties began in the beginning of the 1970s. The research resulted in the development of pest-resistant IR 36 in 1976. The modern varieties developed thereafter are all pest resistant. Figure 1 shows that the yield curve of IR 36 and other second-generation varieties classified as Modern Variety II stands above that of Modern Variety I. A study made in the Philippines shows that the yield gap between Modern Variety I and Modern Variety II is larger than the yield gap between traditional varieties and Modern Variety I (Otsuka et al. 1994a). The development of Modern Variety II not only increased average yield but also contributed to the stability of farmers’ income by stabilizing yields. Incidentally, in the development of Modern Variety II, Modern Variety I was used in crossing in order to achieve high yields.

Though detailed statistics are not available, the growing area of Modern Variety II is believed to have increased to nearly half of the rice paddies in Asia. However, in order to further spread the use of Modern Variety II, it was necessary to enhance its adaptability to delicate differences in environment. In response, research institutes in various countries developed Modern Variety III by taking into account differences in diversified production environments. Many of this type of variety spread to limited areas and have a characteristic of being a local public good. As a result of the development of Modern Variety III, the growing area of modern varieties has increased sharply and their diffusion rate is believed to have approached 70%. The Modern Variety III category includes those whose flavor has been enhanced. Such varieties are priced 10~15% higher than Modern Variety II and their yields are higher in terms of production value, which reflects the difference in quality. Incidentally, in the development of Modern Variety III, Modern Variety II was used in crossing.

As was described above, the green revolution is not a revolutionary change that took place all at once, but rather a long and successive process of improvement. I omitted explanation, but since modern varieties, unlike most of the traditional varieties, are non-photosensitive, cropping in dry season is possible as long as irrigation is available.

Moreover, since they are short-maturing, a third crop is possible in some areas. If their effect on the second and third crops is taken into account, the effect of modern varieties' on increased rice production is enormous.

(2) Production in Asia

Before we make an analysis of rice, I would like to take a look at the changes in food (or grain) production in Sub-Saharan Africa, where the green revolution has yet to take place, and in Asia, where the revolution took place (See Figure 2). During the first half of the 1960s, per-capita food production in Asia was decreasing sharply due to population explosion, extinction of land available for the expansion of arable land, and sluggish production on existing land. After the outbreak of the green revolution, however, food supply began to increase constantly and continuously, with per-capital food production rising nearly 40% in the second half of the 1990s. In contrast, per-capita food production in Africa, where yield per unit of land area has remained stagnant, dropped nearly 20% and shows no signs of improvement. Regional disparities in food production can be explained by the presence or absence of the green revolution.[10]

Next, I would like to examine rice production trend in Asia. Figure 3 shows the quantity of rice production, harvested area, and yield per harvested area (all indexed) in Southeast Asia and South Asia. Rice production in Southeast Asia posted a 4.5-fold increase from 1950 to 2000. During that period, the yield rose 250%, while the harvested area increased only by about 180%. In other words, it is clear that the increase in yield was the driving force behind the increase in rice production. The increase in yield can be attributed to the spread of modern varieties, increased fertilizer input and, to a lesser degree, to the increase in irrigation area (David and Otsuka 1994). Although precise statistical figures are not available, it can be said that the increase in harvested area up to the 1960s was mainly brought about by an increase in cultivated area, while its increase in and after the 1970s was largely due to an increase in planted area during dry season as a result of the introduction of modern varieties. A detailed study of the changes in yield in Southeast Asia reveals that the yield increased at an accelerated rate from the 1970s to the early 1980s but that the growth slackened thereafter. As will be examined in detail later, this suggests that the green revolution is coming to an end in the region.

In South Asia, arable land is less available than in Southeast Asia and paddy field environments are inferior to those in East Asia. In addition, it took a long time to adapt the modern varieties developed mainly in the Philippines to the production

environments in South Asia. Consequently, the increase harvested areas in South Asia has been slower than in Southeast Asia and the increase in yields is lower than in Southeast Asia. What is interesting to note is that yields in South Asia increased at an accelerated rate in the 1980s. This suggests that the green revolution in South Asia picked up several years later than in Southeast Asia.

(3) Yield trend

As was already pointed out, modern varieties are effective in increasing yields particularly in the areas where irrigation is available. Figure 4 illustrates this point by citing the case in the Philippines.[11] The diffusion rate of modern varieties in the Philippines is extremely high. It stood at 66% in irrigated areas in 1970 and has remained at above 90% since 1982. Though the diffusion rate in the areas of rain-fed paddy fields is lower than in irrigated areas, it has stood at 80~90% since 1982 (Estudillo and Otsuka 2002). Figure 4 clearly shows that irrigated areas produce higher yields than rain-fed paddy fields irrespective of the type of varieties.

It also shows that the yield of modern varieties is higher that of traditional varieties and that the yield increased conspicuously from the mid-1970s to the mid-1980s. This suggests that the yield of modern varieties improved gradually, as was illustrated by Figure 1. However, the yield does not show a marked increased after the mid-1980s. This indicates that, in terms of yield, recent varieties in the Modern Variety III category do not have large advantages over the past varieties. This may be mainly due to the fact that room for improvement has practically disappeared as a result of inter-varietal crossing in innumerable combinations.

This reasoning is clearly supported by data obtained in the “Central Luzon Loop Survey,” a 100~150 sample survey conducted by the IRRI every four years since 1966 (See Table 1).[12] Incidentally, Central Luzon is the major grain belt in the Philippines and a leading rice-growing region that can be called the heartland of the green revolution. The table shows (1) that the diffusion of Modern Variety I in the beginning of the 1970s was drastic, (2) that the shift from Modern Variety I to Modern Variety II in the second half of the 1970s was also rapid, and (3) that the shift to Modern Variety III began in around the mid-1980s. The table also shows (1) that the disparity between traditional varieties and Modern Variety I was small, (2) that the yield of Modern Variety II is clearly higher than that of Modern Variety I, and (3) that the yield-increasing effect of Modern Variety III is weak. Although these kinds of data are not available in other countries, it would be safe to say that similar trends can observed in countries other than the Philippines.

Although data on changes in the diffusion of generation-by-generation varieties are not shown, it is interesting to see the long-term changes in yields per unit of land by country (See Figure 5). We can identify several important findings from the table. First, an increase in yield began earlier in the Philippines and Indonesia than in the other countries and the yield began to slow down in the two countries in the 1980s. This indicates that the green revolution first began in the Philippines, that the production environments in Indonesia are similar to those in the Philippines, and that the potential of the green revolution was depleted in both countries in the 1980s. Incidentally, the main reason why the yield in Indonesia is much higher than in the Philippines is that the latter often suffers damage from typhoons. Second, it can be pointed out that in Sri Lanka, where the irrigation rate is high, both the beginnning and end of the green revolution came early, as was the case in the Philippines and Indonesia. Third, in Vietnam, Bangladesh, and India—the three countries where the green revolution began late—yields continued to increase even in the 1990s. This is evidence that the green revolution, accompanied by cross-border technology transfer, gradually improved the paddy rice yield of the whole Asia. If these processes are taken into account, it can be said that the green revolution has so far been sustainable.

However, as Otsuka (2000) has pointed out, the potential of the green revolution in Vietnam and South Asia will be depleted sooner or later and the yield will begin to slow down as it did in Southeast Asia. If that is the case, the balance between rice supply and demand will become tight again.

(4) Changes in rice prices

It is wrong to say that, “Progress in agricultural technology will increase farmers’ income.” Generally speaking, demand for farm products is stagnant as it is inelastic to income. It is also inelastic to prices. Therefore, once supply increases sharply, a price declines sharply. This is particularly true of grains that are stable foods, like rice.[13] A good case in point is the collapse of international rice prices caused by the green revolution.

Figure 6 shows a long-term trend of international rice prices by using the prices of rice produced in Thailand. It is true that the international market for rice is not competitive, as many countries often intervene in the market. But it is also true that prices of Thai rice have a major impact on the pricing of rice produced in other countries. Figure 6 clearly shows that except for the period from 1973 to 1974, when rice prices soared due to speculation, rice prices had remained stable in real terms before the green revolution and that they began to decline sharply and consistently

thereafter. It would be hard to understand this trend without taking the effect of the green revolution into account (Pingali et al., 1997: Kikuchi, 2002).

A drop in rice prices would reduce living costs, bringing benefits to urban consumers and workers. If workers are willing to work at lower nominal wages, it would reduce labor costs and stimulate industrial development (Hayami 1997). In this way, the green revolution has a positive impact on the development of the economy as a whole. However, if rice prices drop in real terms, it would inflict loss on farmers as a whole. For farmers who adopted modern varieties, the net effect is not necessarily clear, as the use of modern varieties reduce costs (David and Otsuka 1994). The question is what happens to farmers who are engaged in production under unfavorable production environments where the adoption of modern varieties is not advantageous. Since these farmers do not enjoy the benefits of technological progress at the time when the prices of their products decline, their living standards would get worse. If they want to avoid this, the labor force has to move to cities or regions that are faring well as a result of the adoption of modern varieties. Incidentally, the adoption of modern varieties increases labor demand, especially for simple tasks such as weeding and harvesting in which poor people can take part. But the increase would not be a dramatic (Otsuka et al., 1994a; Otsuka, 1995). In order to bring benefits to the rural population suffering from a loss at least temporarily, it is hopeful that the green revolution leads to industrialization. Unfortunately, there are no persuasive study showing to what extent it has been achieved.

4. Criticisms of the Green Revolution and their Counterarguments

As was outlined in the previous section, the green revolution has brought about a revolutionary change to the agriculture in Asia. However, we often hear unfounded criticism, mainly from NGOs, regarding the outcome of the green revolution. Therefore, I would like to take up such criticisms and respond to them from my perspective in this section.

A criticism made in the initial stage of the green revolution was that since new varieties require chemical fertilizers and other chemical inputs, only rich landlords and large farmers capable of purchasing new inputs would benefit from the green revolution and that peasants and small farmers who are unable to purchase and adopt new varieties would not benefit at all (David and Otsuka 1994).[14] If the criticism is correct, it would mean that the green revolution has a negative effect of expanding income disparities within rural communities. In reality, however, such instances were not confirmed in the

1970s (Hayami and Kikuchi 1982) and even in the 1980s (David and Otsuka 1994). This is because even small farmers and peasants actively adopted new varieties, as the increase in income brought about by the adoption of new varieties more than offset the costs for purchasing new varieties.[15] In addition, the fact that the suppliers of purchase factors, such as retailers of fertilizers, sold fertilizers on credit under deferred payment arrangements may have contributed to the adoption of new technologies by petty farmers. If there is a disparity between large farmers and small farmers, it is a converse relation of the former being inefficient and the latter being efficient (Otsuka 2002).

The second criticism was that since the green revolution induced increased input of chemical fertilizers and other chemical inputs, primarily fertilizer manufacturers and agricultural chemical companies benefited from the revolution. There is some truth in this argument. But we should not forget that farmers increased inputs because they judged that doing so would bring more benefits than its cost. We should not also forget the basic principle that without increased input of fertilizers an increased yield cannot be expected. If organic fertilizers, such as compost, are to be used, large application of chemical fertilizers would not be necessary. However, it was farmers themselves who chose chemical fertilizers.[16] It is true that agricultural chemicals caused serious damage and injured farmers' health (Pingali et al. 1997), but the situation has been improved considerably thanks to the development of modern varieties that have strong pest-resistance and the diffusion of integrated pest management. Some people make the criticism that heavy application of chemical inputs has degraded the soil, resulting in decreased yields. But such trend has not been observed statistically (Estudillo and Otsuka 2001). Judging from yields and productivity, it would be safe to say that the green revolution has so far been sustainable.

Observing that the farmers who have adopted modern varieties are not necessarily better off, some specialists and NGO staff well versed in actual situations in rural Asian communities doubt that the green revolution has increased farmers' income. This argument is empirically correct. This is because the technological progress in agriculture does not directly lead to benefits for farmers, as the principle of "banner crop beggars" is at work. If only one small country adopts modern varieties, the resulting increase in supply would not have a major impact on the international prices of the crop. In that case, farmers in the country adopting new varieties would gain pecuniary profits from the effects of the yield-enhancing new varieties. However, if, for instance, a sharp increase in rice supply takes place simultaneously in many of the Asian countries growing on rice, the international prices of rice would decline and farmers are highly likely to suffer loss in income just as in the case of banner crops. It is for this

reason that the international prices of rice have kept declining, as we examined in Figure 6. But this is not unique to the green revolution. As far as staple grains are concerned, the basic fact is that the benefit of technological development does not accrue to farmers due to price inelasticity of demand. Therefore, I would have to say that persons criticizing the green revolution on the ground that it does not lead to increased farmers' income are barking up the wrong tree.

Stated another way, the biggest beneficiaries of the green revolution are consumers of grains. In particular, poor households with relatively high expenditure on grains reaped vast welfare gains from a decline in grain prices (Binswanger and Quizon, 1989). Landless workers, who constitute the poorest segment of the rural population, are also consumers of rice and they also benefited from the price reduction. Therefore, there is little doubt that the green revolution has contributed greatly in the reduction of poverty in Asia. The deep-rooted criticism of the green revolution is that it has widened the income disparity between regions with favorable production environments and those with unfavorable production environments. As I have already pointed out, modern varieties produce high yields in well-irrigated areas and well-drained rain-fed paddy fields. On the other hand, the adoption rate of modern varieties is extremely low in sloping land exposed to dry weather and in downstream regions of great rivers (David and Otsuka, 1993). There are sufficient grounds for the argument that since the income of farmers in such areas or regions is lower than that of the farmers in areas of favorable production environments in the first place, the green revolution has widened the disparity. But the oft-expressed criticism that "the green revolution ignored poor areas" is not necessarily appropriate. As a comparative study made by David and Otsuka (1994) shows, there were interregional movements of small farmers and landless workers from regions with unfavorable production environments to regions with favorable production environments following a temporary rise in wages brought about by the green revolution in favorable production regions. The migration not only raised the income of the migrants but also eased the population pressure in unfavorable regions, resulting in increases in the income of the people who remained in the regions. In fact, according to the above study that analyzed situations in six countries in tropical Asia, there was almost no wage disparity among the regions. Since the Small farmers and landless workers who migrated belong to the poorest segment of rural population, we should consider that the green revolution indirectly conferred benefits to them.

However, given the fact that the inter-regional migration of labor is accompanied by financial burden and emotional pain, we cannot deny the validity of the argument that the green revolution has widened the regional disparity of economic welfare. But this

does not immediately mean that high-yielding varieties should be developed for regions with poor production environments. This is (1) because it is difficult to develop high-yielding varieties for such regions with conventional breeding technology and (2) because, even if such a variety was developed, the adoption areas of the variety would inevitably be limited due to the diversity of the unfavorable production-environments. Consequently, the total impact of the green revolution on production increase would be minimal and the green revolution would lose its revolutionary nature (David and Otsuka, 1993). If we dissolve the poverty problem in such regions, given the present circumstances, we should invest in infrastructure and human capital, such as education, rather than striving to develop new rice varieties.

5. Sustainability of the Green Revolution

So far, the green revolution has been judged to be sustainable. In reality, however, yields show signs of peaking out and it is not clear whether we can maintain the current level of production and further enhance productivity. In other words, as far as rice cultivation is concerned, it is no exaggeration to say that the green revolution based on the conventional breeding technology, or the potential of the new technology born in the Philippines in the second half of the 1960s, has finally faded away after spreading to India and other South Asian countries (Otsuka 2000). In this sense, the sustainability of the green revolution has been almost lost.

In addition, the world is concerned about a possible serious water shortage in third world countries due to urbanization and industrialization. Moreover, it is anticipated that there will be a shift to feed crop production in paddy fields in response to growing demand for livestock products and that arable land will decrease due to urbanization. In order to ensure enough supply to meet demand for grains under such disadvantageous conditions [17], it is necessary to create a new of “second green revolution” to produce higher yields by using limited water resources.

The basic strategy to overcome water shortage is to develop the technology that would increase yield per unit of natural resources used including land and water. A promising short-term measure is developing hybrid rice. The development has already started and a promising hybrid rice that produces a yield of 15~20% higher than the modern varieties has already been developed and used on farm fields. A longer term measure is to develop new varieties by utilizing biotechnology. It is possible to develop new varieties equipped with strong pest resistance by using recombinant DNA technologies. Experiments and research in this direction are now under way. Since

damage by disease and pests is conspicuous in the regions with favorable production environments, the development of new varieties would make it possible to produce more rice with less agricultural chemicals. It would help ease the conventional criticism of the green revolution on the ground of increased use of agricultural chemicals.

At the same time, it has become increasingly clear that cultivating drought-resistant rice in dry weather is possible by using biotechnology. If this proves to be successful, it would be possible to respond to the criticism of the green revolution on the ground of the widening regional disparity in income. The development of drought-resistant varieties should also help conserve irrigation water. If a water-saving farming method is established for irrigated regions, it would ease the problem of water shortage in the future.

If it is possible to maintain or increase rice production with less irrigation water and farm land, it would make it possible to prevent grain prices from rising and even reduce them. If grain prices are at a low level, it would help reduce the poverty and environmental disruption, such as deforestation aimed at the expansion of farm land.

In a nutshell, the second green revolution is expected not only to realize “an increase in food production => a decline in grain prices => reduction of poverty” but also to increase production efficiency in regions with unfavorable production environments and contribute to the improvement of environmentals. Then, is it feasible? Under the present circumstances, the answer is neither “no” nor “yes.” Not “no,” because the technical feasibility of realizing the second green revolution has increased. But it does not mean “yes,” because it requires a massive amount of investment and because investment in agricultural research has been drastically reduced. However, as long as development of agricultural technology hinges on investment, we have to invest in order to realize gains. As long as investment keeps decreasing, we cannot expect sufficient returns.

The main reasons behind the decrease in agricultural investment are a downtrend of grain prices that lowers returns on research investments in agricultural technology. They are compounded by a sharp cut off in official development assistance because of the sluggish Japanese economy and the worsening financial budget. Judging from the current situation, investments in agricultural research will continue to decline unless a serious water or food shortage breaks out and the situation will plunge into a serious crisis. However, as was described in Section 2, agricultural technology produced by research has a strong nature of being “international public good” and investment is destined to be excessively small from a global viewpoint. In order to properly cope with new problems, such as the water shortage, which is reflected in increasing scarcity of water in many areas in recent years, we should go back to the starting point and reaffirm

the importance of investment in agricultural research.

6. Conclusion

In economies at an early stage of development, the proportion of working population engaged in agriculture accounts for more than 50%. In order to achieve economic development at this stage, it is necessary to enhance the efficiency of the agriculture sector. In East Asian countries located in the tropics, the productivity of rice and other grains increased dramatically thanks to the green revolution, supporting the development of the economies as a whole. More specifically, (1) the green revolution increased grain supply and reduced their prices, resulting in enhancement of the economic welfare of poor people, mainly urban workers, (2) the excess workers created as a result of increased efficiency in agriculture moved to cities and this helped accelerate industrialization, and (3) labor demand for landless workers, who constitute the poorest sector of farm population, increased, though not so dramatically, and this helped improve their economic conditions to some extent. Conversely, if the green revolution had not taken place, grain prices would have gone up, the standard of living of workers would have declined, and a large pool of workers would have been retained in farm villages, resulting in a slow down of economic growth.

As just described, the green revolution had an important role in supporting economic growth. But the significance of its effect is not generally appreciated. This largely stems from disregard of the results of the lack of sound empirical economic analysis. In particular, the fact that a rise in agricultural productivity brings benefits to consumers through lower grain prices is often ignored. But the overall downward trend of rice prices that we observed cannot be understood without taking the outcome of the green revolution into account. It will become increasingly important for policy makers, leaders of NGOs that play important roles in solving development problems, and economists to exchange views on proper assessment of the green revolution.

Before concluding this article, I want to stress the following points. The outcome of agricultural experiment and research activities has a strong nature of being “international public good” and therefore investment in such activities tends to be too little viewed from international community as a whole. At the time when biotechnology is put to practical use, returns on investment in public agricultural research should have increased. It is highly likely that the current decrease in such investment has resulted in gross underinvestment. The “second green revolution” holds the promise of not only resolving the problems of poverty but also harmonizing environmental improvement

and economic growth, leading to the realization of “sustainable agricultural development.” I look forward to sensible discussions on the role and impacts of agricultural development by all parties interested in sustainable agricultural and economic development.

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Table 1 Changes in Paddy Rice Varieties and Rice Yield in Central Luzon, 1966~1998 (Rainy season)

	1966	1970	1979	1986	1994	1999
Variety adoption rate (%)						
Traditional varieties	100	34	0	0	0	0
Modern Variety I		66	8	1	0	0
Modern Variety II			92	38	6	0
Modern Variety III				61	94	100
Yield (ton/ha)						
Traditional varieties	2.3	2.4				
Modern Variety I		2.6	2.8			
Modern Variety II			3.6	3.5	4.6	
Modern Variety III				3.6	3.9	3.4

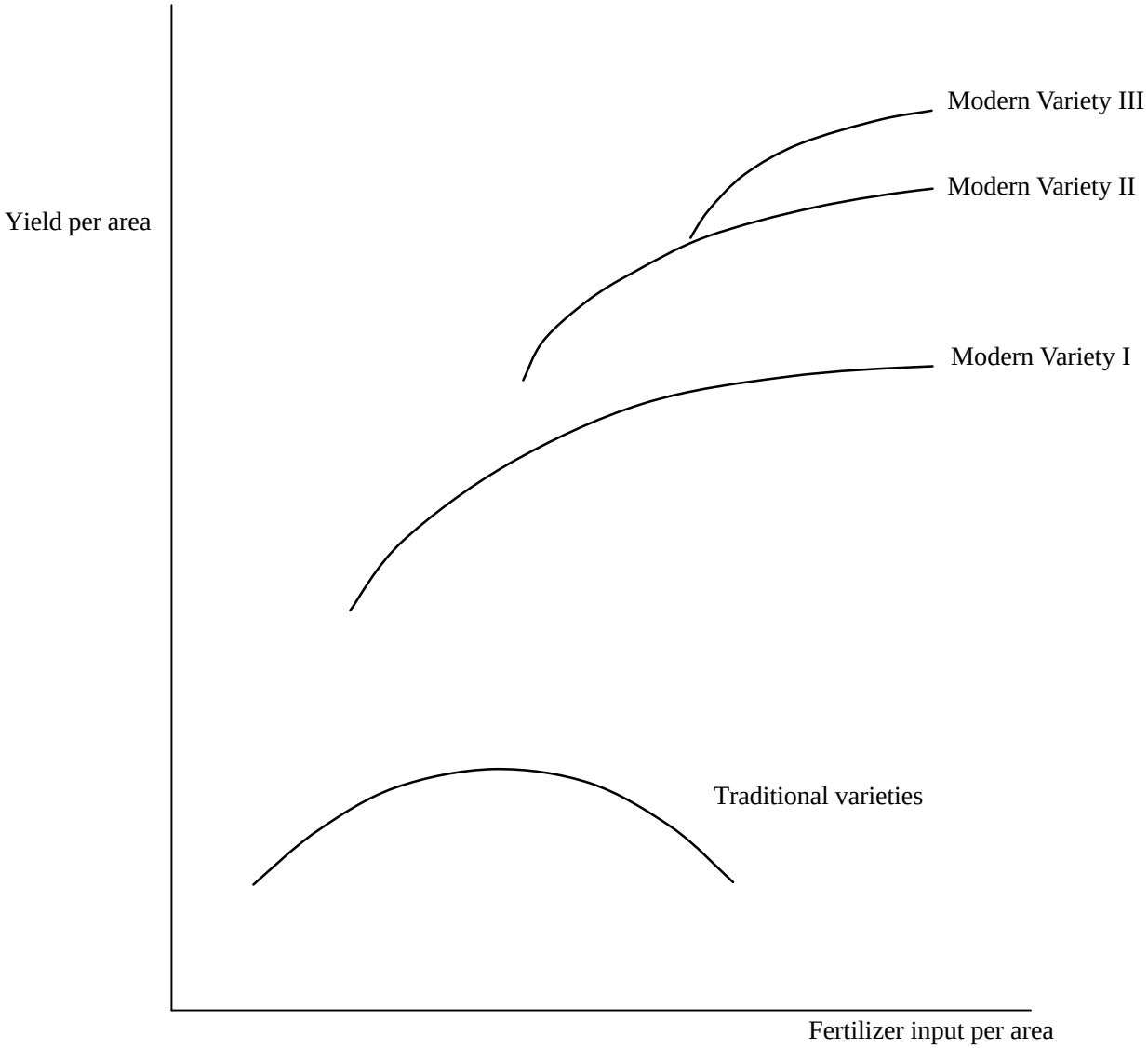


Figure 1 Exemplification of Variety-by-Variety Yield Function

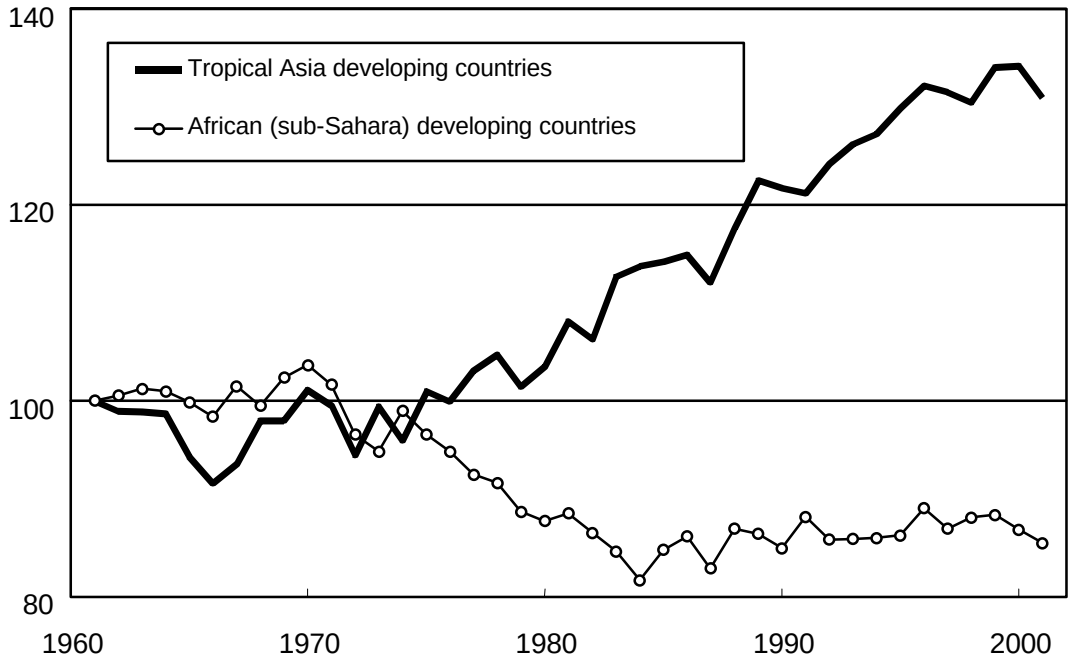


Figure 2 Changes in Per-Capita Food Production in Tropical Asian and African Countries
Index (1961 = 100), 1961-2001

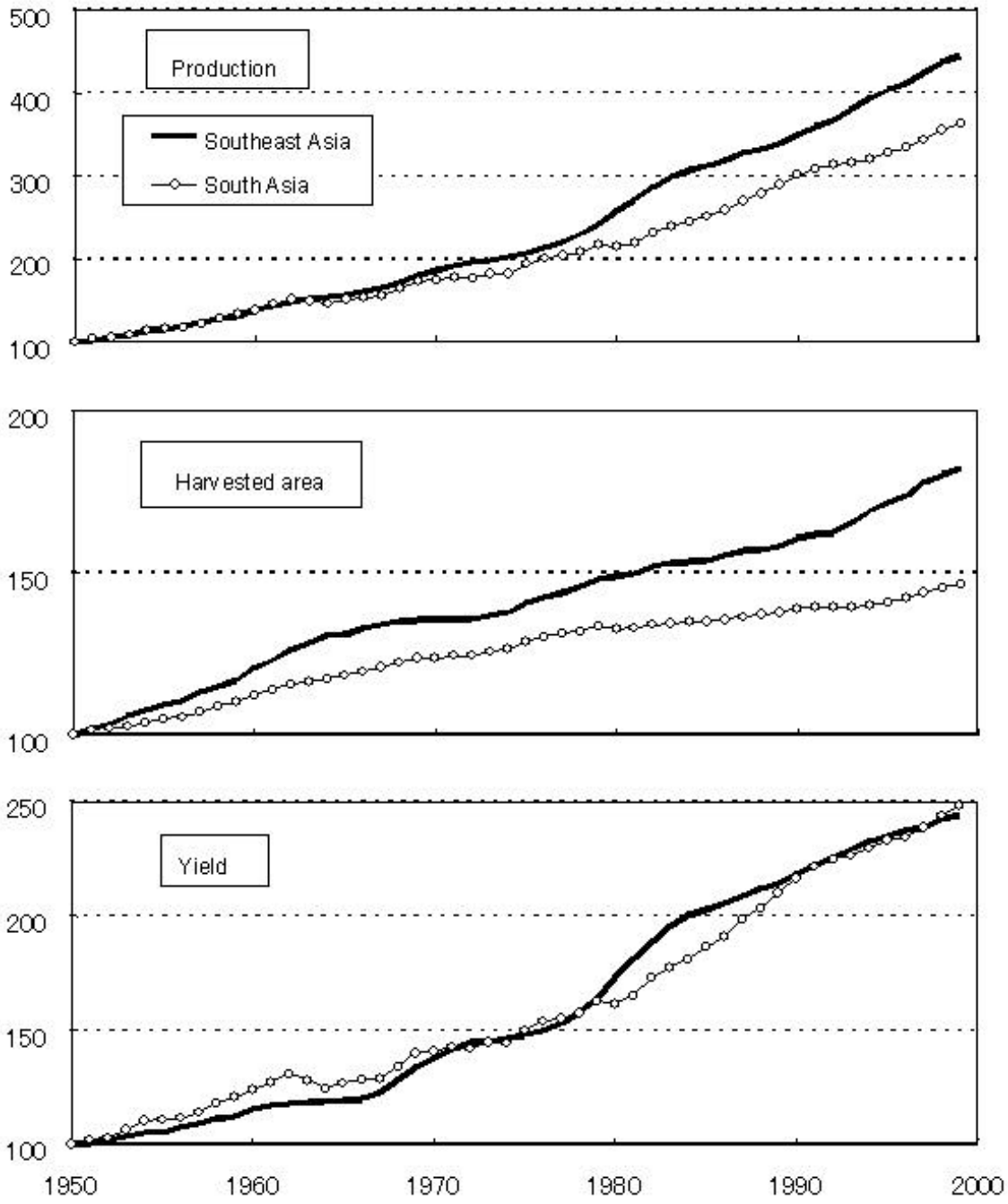
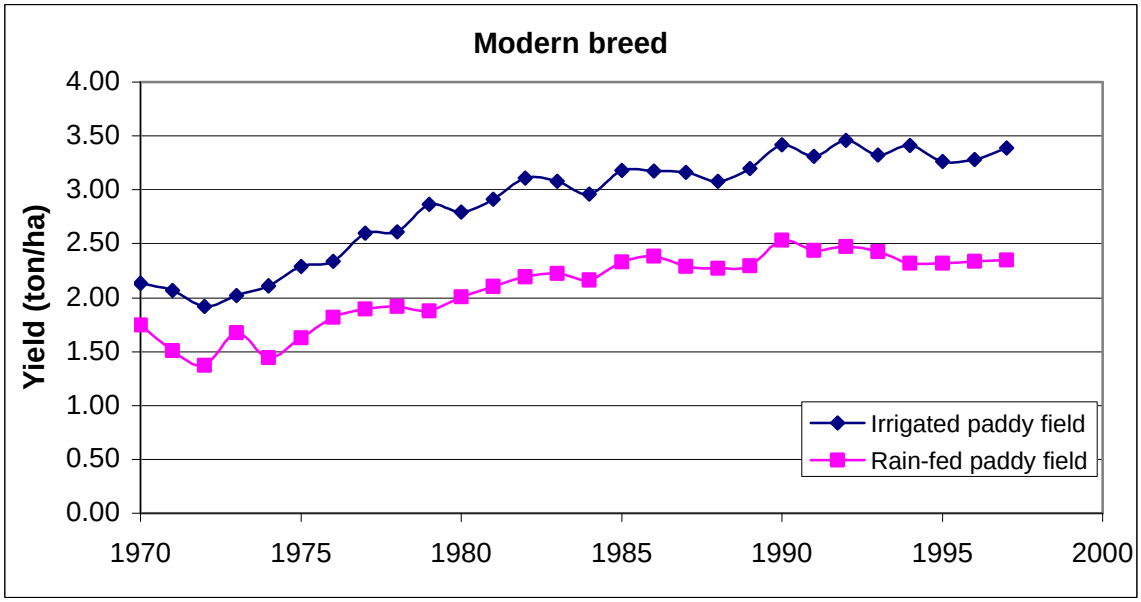


Figure 3 Changes in Rice Production, Harvested Area, and Yield per Land Area in Southeast Asia and South Asia
Five-year moving average (Index: 1950 =100), 1950~1999



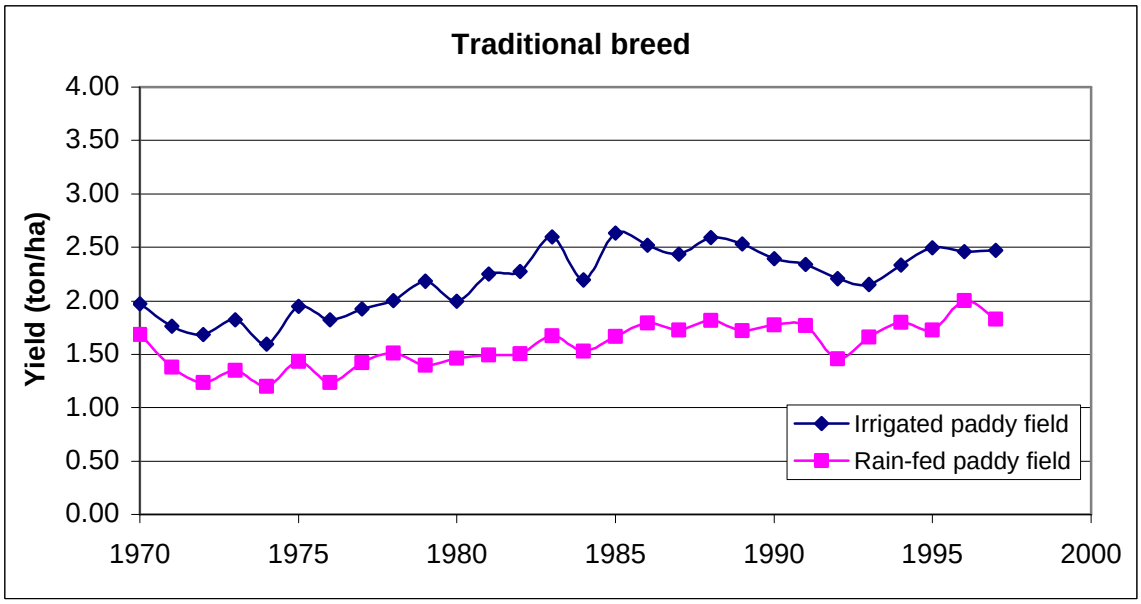


Figure 4 Changes in Yield in the Philippines by Type of Variety and by Production Environment, 1970~1979

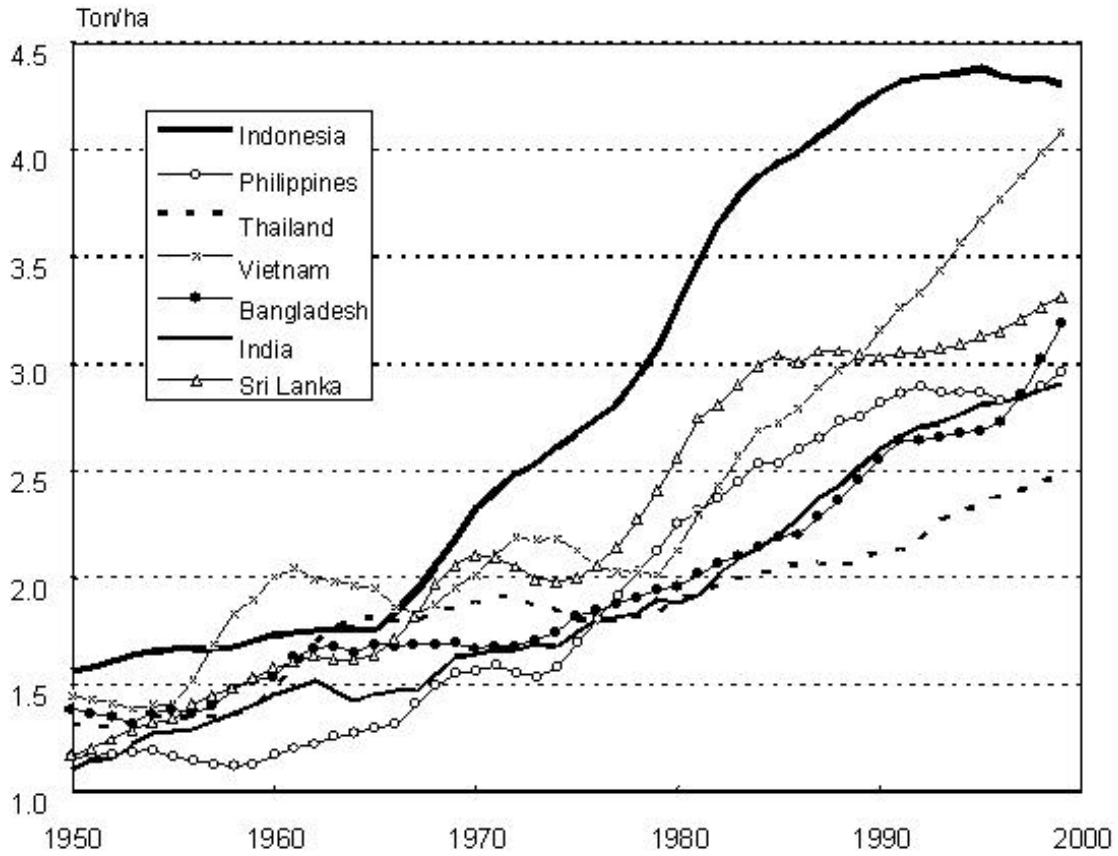


Figure 5 Changes in Rice Yield in Major Rice-Growing Countries in Tropical Monsoon Asia, 5-year moving average, 1950~1999

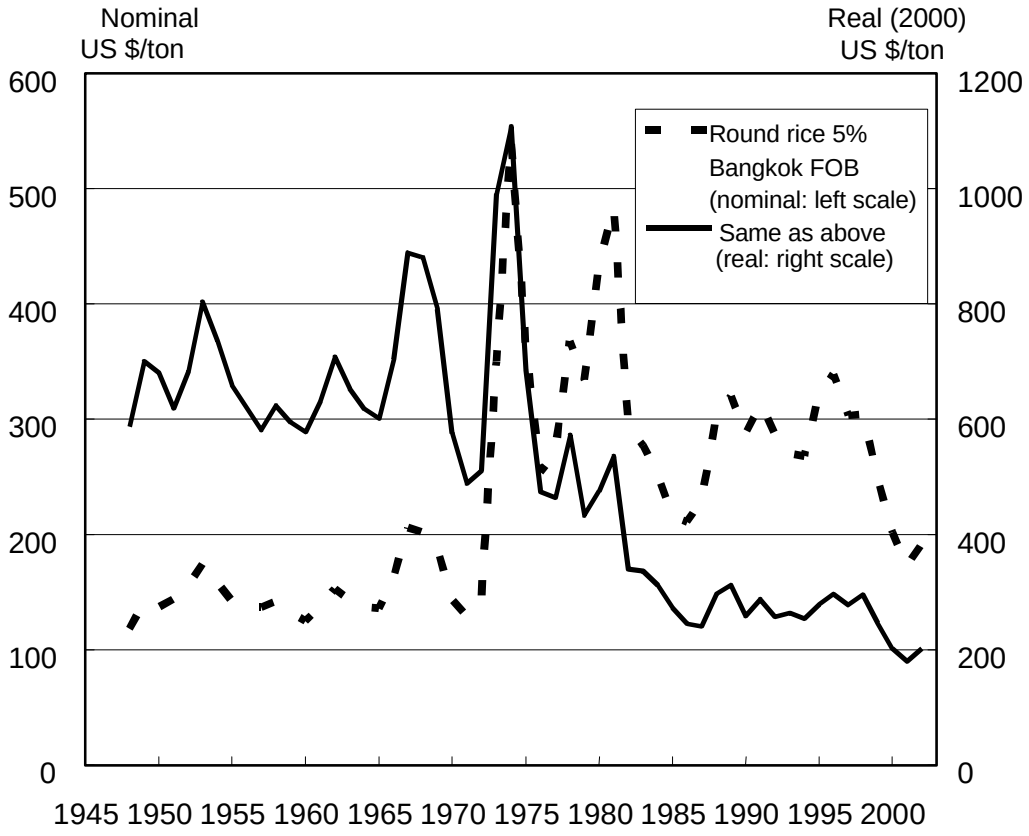


Figure 6 Trend of International Rice Prices, 1948~2002

Footnotes

* In writing this paper, this author received the full support of Mr. Masao Kikuchi. Figure 2-3 and 5-6 are reprinted from Kikuchi (2002). I want to take this opportunity to say thank you to Mr. Kikuchi. Needless to say, the responsibility for the contents of the paper rests with me.

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[1] The green revolution does not necessarily enrich farmers. This is because demand for rice and other staple grains is price inelastic. The cost will decrease if the supply curve shifts to the rightward, but since the price falls sharply, the producer is highly likely to suffer a net loss. The biggest beneficiaries of the green revolution are consumers. They enjoy an enormous amount of consumer surplus from a decline of grain prices.

[2] This is in stark contrast to the situation in sub-Saharan Africa where deforestation to expand arable land prompted by sluggish food production on existing arable land, and overgrazing have aggravated desertification. In this region, many people are suffering from malnutrition and a dry weather may cause a hunger problem.

[3] With regard to agriculture problems in China, this writer and Professor Scott of University of California are jointly working on an essay to be published possibly this autumn.

[4] However, in the case of hybrids, such as improved seeds of corn and vegetables, the main entity of technological development is a private corporation, and as such seeds cannot be produced in-house.

[5] Even in the case of hybrids, many of the varieties utilized by private corporations are developed by public experiment and research institutions.

[6] Although the International Maize and Wheat Improvement Center is located in Mexico, the modern varieties developed by the institute have proved effective mainly in South Asia.

[7] This writer recently observed that the IR series of varieties developed in the Philippines are being cultivated and producing high yields in well-irrigated regions in Africa, such as Ghana and Kenya.

[8] Thereafter, the Consultative Group for International Agricultural Research (CGIAR) was established in 1971. CGIAR has come to be managed with the support of not only from the Rockefeller and Ford foundations but much more importantly from international organs, such as the World Bank (Hayami and Ruttan 1985). At present, 15 international agricultural research institutes are in operation.

[9] Although the fertilizer reaction function is nothing but a production function, inputs of labor, capital, etc. are ignored here for simplification.

[10] The green revolution did not take place in Africa because Africa' production environments are by far poor as compared with Asia's. However, it is true that research and development investment made in Africa was too small. This writer believes that it is possible to start the green revolution in Africa, if the appropriate investment is made.

[11] The Foundation for Advanced Studies on International Development, to which this writer belongs, has been collecting data similar to those in the Philippines by implementing an international joint project dubbed "The Green Revolution in Asia and

its Applicability to Africa" for 2002-2003.

[12] It is extremely unusual that detailed information on farming and farm household income have been consistently collected from the days before the outbreak of the green revolution until the present. It is also an unusual case where varieties can be classified by generation.

[13] In Japan, per-capita consumption of rice was about 130 kilograms in the 1960s, but it had dropped to less than half of that amount. Rice has become inferior goods in other Asian countries as well.

[14] If increased production by rich people triggers a decline in grain prices, it would reduce income of poor people further. That has, however, never been the case in practice.

[15] There are arguments that peasants, especially sharecroppers, are inefficient and are reluctant to adopt highly efficient new technologies. But there is no empirical evidence supporting such arguments (Hayami and Otsuka 1993).

[16] The IRRI spent a vast sum of money for the development of nitrogen-fixing plants. But the plants were not widely used.

[17] In East Asia, staple food crops like rice are becoming inferior goods. Therefore, the increase in demand is brought about by population growth but not by income growth.