【調査】

Technological Change in Agricultural Production and Its Impact on Agrarian Structure——A Study on the So-Called Green Revolution

I. *Introduction*

This paper attempts to explore a central direction of the changes in the agrarian structure in the countries of South and Southeast Asia that have been taking place since the late 1960's as a result of the so-called Green Revolution (hereafter abbreviated GR).[1] Since, however, the explorations will be made under certain restricted assumptions and because these assumptions are closely related to my broad framework of analysis on the integral process of GR, comments are in order with respect to this framework.

First of all, it emphasizes interactions among three essential variables: *technology, agrarian structure* and, as an intermediary between the two, the *factor endowments* of the society. A technology in this framework is defined as the mode of combination of the factors and inputs in production in a specific pattern, and the technological change as a shift of it from one specific pattern to another. A technology is assumed to be stable (or unstable) if, under a given agrarian structure and given resource endowments of a particular society, it assures (or does not assure) to the members in each stratum of the society that level of output and income which they feel satisfactory or at least tolerable. Similarly, a stable (or unstable) agrarian structure could be conceptualized by interchanging the relation between the technology and the agrarian structure in the above assumption. It follows that the stability of a technology is not obtainable unless the stability of an agrarian structure is attained. When either a technology or an agrarian structure is unstable, it may be assumed that the interactions between the technology and the agrarian society continue until some stable equilibrium between the two is finally attained. Assessed in terms of such a notion, GR, being an exotic technology at least in its inception, is very likely to be an unstable technology and, hence, is surmised to bring about changes in the existing agrarian structure. It is also surmised that in the process of these changes, the changing agrarian structure is likely to induce some changes in the pattern of the factor and input combination initially introduced.

Three spesific assumptions that will be made for pursuing the study according to this framework are as follows:

(1) We assume rather heroically that the agrarian structure in those countries under the impact of GR is undergoing changes solely as a result of GR. In other words, the agrarian structure prior to the introduction of GR had been stable side by side with the then existing technologies.

(2) We assume that the exotic technology of GR has been introduced once for all: Hence, present and future changes in the agrarian structure and, also, resultant changes in this exotic technology are all considered to occur in the process in which the agrarian structure that had been made unstable by the initial and once-for-all introduction of the exotic technology will be brought to a new state of stability.

(3) We assume that the technology underlying GR is characterized by the recommended doses of factors

1) A voluminous amount of literature has appeared on GR, among which ADB [1], IRRI [14] and Brown [5] are important for general account. I myself published a book and an article in English in [17, 18], on which I have heavily drawn for empirical evidence of the discussion in this paper.

and inputs issued by the Government or research organizations.

In the following, Section II gives our summerized observations regarding the technology of GR and Section III a stylized pattern of the initial agrarian structure. Sections IV to VI study the impacts of the new technology upon the agrarian structure as well as the counteracting impacts of the latter upon the former. Throughout these sections, studies are hopefully made simplified by contrasting the events under GR to the prewar experience of Japan and Taiwan under similar technological changes.

II *Types of Technological Changes*

In this section which aims at presenting our summarized observations regarding characteristics of the technological change under question prior to studying its impact upon the agrarian structure, at least three aspects must be touched on. *One*: technical properties of the technological change when a variety of factors and inputs that are required in combination in each of the existing and new technologies are viewed as they are. *Two*: technical properties of it when a variety of these factors and inputs are viewed in terms of three factors of production: land (L), labor (N), and capital (K). *Three*: the economic process in which the society moves from the existing technology to the new one.

One: From the economists' way of abstraction, a specific technological change may be viewed by emphasizing certain aspects of technical properties of those factors and inputs which play a role of strategic importance in bringing about the technological progress. Thus, Professor Schultz [29] conceptualizes "modern (material and human)" and "traditional" inputs. From a somewhat different point of view, *biological* and *mechanical* innovations are sometimes contrasted.[2] I myself have emphasized the importance of the role of flood control, irrigation and drainage both in itself and as a prerequisite of biological innovation.[3] The innovation enabled by their role may be called here *hydrological* innovation. In the light of these concepts, the technologies of agricultural production that had been prevalent in Asia before the advent of the Green Revolution may be classified into three patterns[4]. Since these cross-section patterns seems to be convertible to the stage-wise patterns, these patterns are named here Technology Stages I, II and III:

Stage I Agricultural production adapts itself to flooding or simply to the natural supply of rainfall (pre-hydrological innovation). The predominant part of agricultural production in South and Southeast Asia is still in this stage.

Stage II Agricultural production is based on the control of water; but, irrigation is done mainly for making up for deficiency and untimely rainfall (hydrological innovation). Agricultural production in almost all irrigated land in South and Southeast Asia belongs to this stage.

Stage III Agricultural production is based on the artificial control of the supply of water (a new stage of hydrological innovation) and, moreover, on the varietal improvement of seeds combined with the increased application of fertilizer (biological innovation). This stage may be sub-divided into two: one using mainly traditional inputs and the other using mainly modern inputs except mechanical tracting power. In South and Southeast Asia, this stage can be found only in a few scattered areas. In Northeast Asia, however, agriculture in Japan since the turn of this century and in Taiwan and Korea since the 1930's seem to have already reached this stage. (We leave aside here the case of Japan's agriculture for the past 15 years, which has certainly entered a

2) The meaning of biological innovation will become clear shortly in connection with the definition of Technological Stage III. Professor Johnston [20] calls this "seed-fertilizer revolution," and Professor K. Ohkawa "biological-chemical innovation." "Mechanical innovation" denotes the innovation brought about by introducing mechanical tracting power. For an interesting study contrasting biological and mechanical innovations, see Hayami and Ruttan [12].

3) This is discussed in [16, Ch. 2] by extensively using cross-section and historical data in Asia.

4) [16, pp. 71–78].

involving mechanical innovation).

GR has appeared with the aim of applying itself to the countries in South and Southeast Asia, hence to agriculture in Stages I and II. Essentially, it purports to be a biological innovation based predominantly on modern inputs; it has in it even an element of mechanical innovation. Of course, it requires as prerequisite a hydrological innovation. Though very artificially and hypothetically, we distinguish it stagewise by calling it Stage IV technology. Hereafter, we are going to examine this technology by contrasting the technological change from Stages I and II to IV with that from Stages I and II to III.

Two: Technical properties of a technological progress is here evaluated in terms of what Murray Brown calls four characteristics of the abstract technology [5, pp. 12–26]: (1) the efficiency (the rate of shift in production function), (2) the degree of technological economies of scale, (3) the degree of factor intensity and (4) the ease with which one factor of production is substituted for another. With regard to (1), there seems to be no question that the rate of shift in production function is much larger between the production functions representing Stages I and II and Stage IV, respectively than between the production functions successively appeared in the process of shift from stages I to III[5]. Regarding (2), the technological changes based on biological innovation are often said to be scale-neutral. This must be qualified when hydrological innovation as the prerequisite is taken into consideration. In the case of shift from Stages I and II to IV, further possibilities in which technological changes involve scale economies arise, in particular in connection with the requirement of technically articulate field structure and equipments for irrigation, power-tillers and tractors, threshing and milling machines and even technical skills.

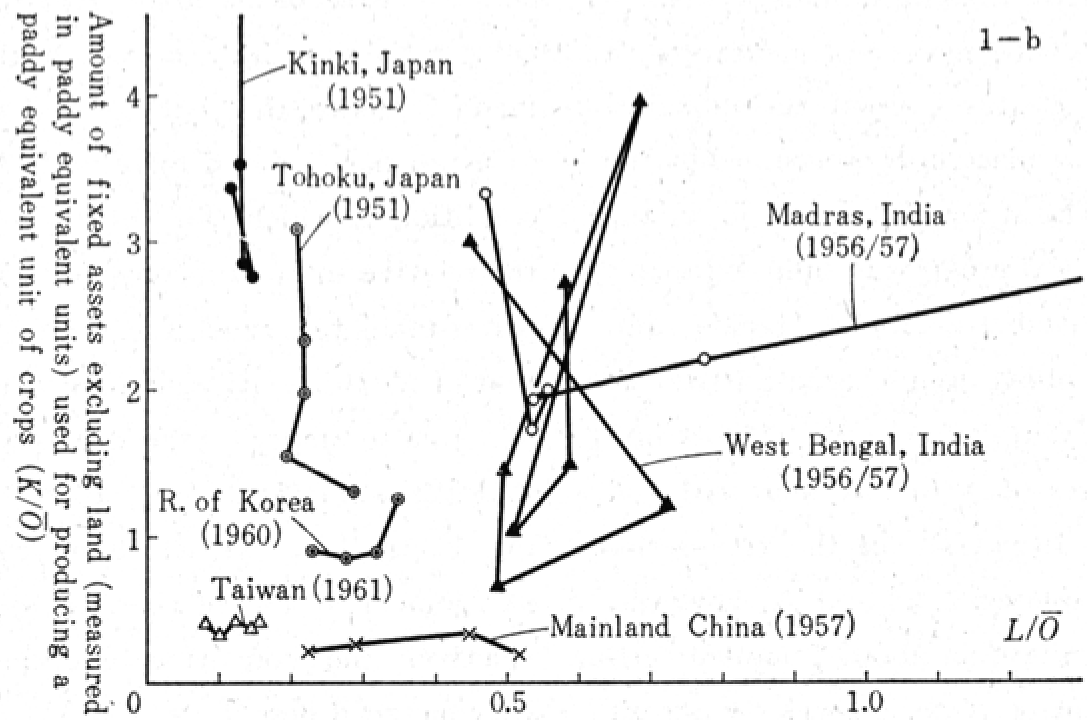
Characteristics (3) and (4) are considered in combination. The former is measured by the factor combination ratios for given relative factor prices and the latter by the partial elasticity of substitution between each pair of the factors of production. First, the shift from Stages I to III is taken up. (i) The factor combination in this shift seems to be biased toward increasing both K/L and N/L for given relative factor prices, resulting from the characteristics of combined hydrological and biological innovations. This seems to be reflected in the relationship shown in Chart 1, though very crudely and necessarily with serious qualifications because of the methods used for dealing with data. (ii) While the empirical studies are yet to be attempted, it may be reasoned that the partial elasticities of substitution both between K and L and between N and L must be positive and become larger with the shift in stages; but the partial elasticity between K and N must be negative in Stage III, indicating that they are complementary. (iii) It follows that, under the conditions in which both hydrological and biological innovations are taking place,[6] the relative distributive shares of both K and N for given relative factor prices tend to be increasing and that of L decreasing with the shift in stages.

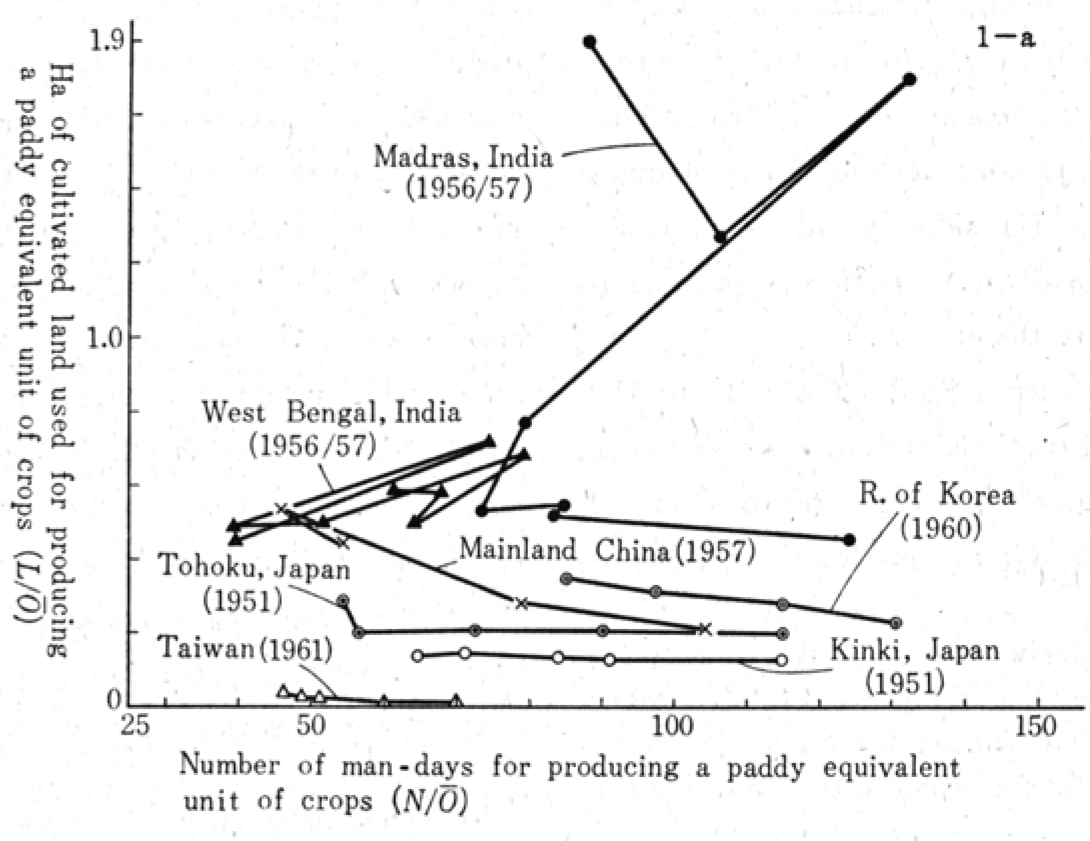
Two comments are in order. One is that the competitiveness or complementarity of K in relation to L

5) Although per hectare yield of rice is by no means a relevant indicator, the following facts about it may be shown for substantiating this. In the Philippines, a well known new variety of rice IR-8 hybridized at the International Rice Research Institute has a per hectare yield capacity of paddy of 6 tons in the wet season or 9 tons in the dry season. This has appeared against the prevailing situation where per hectare yields in the irrigated land is on the average 1.8 tons. In the process of shift from Stages I to III, perhaps the most remarkable increases in rice yields ever attained at one point of time seem to be about 50% in prewar Korea and about 30% in prewar Taiwan (both by introduction of Japanese varieties; in Taiwan, the introduced Japanese varieties of rice by naturalization have been called *Pong Rai* [18, pp. 24–25]. The Japanese experience in this regard was far more modest [13, pp. 128–134].

6) Namely, under the condition in which L becomes relatively scarce as compared with N and K and, hence, the relative prices of L to both N and K rises. This condition is nesessary if, for instance, the shift in the production function takes place in such a way as shown by Q_{I} (Stage I) and Q_{III} (Stage III) in Fig. 1 below. In this case, this condition indicates that the economically relevant sections of Q_{I} and Q_{III} are those lying on the right of α and β in 1–a and on the left of γ and δ in 1–b.

Chart 1 Relationships between Land (L), Labor (N) and Capital (K) in Cross-section Data by Country and by Size of Farm Household——Asia





Sources: Original sources, which are farm management surveys of each country, are the same as used in [16, Chart 3–3, pp. 230–321] and cited in the same place.

Notes: While the two charts are drawn as if they are isoquant maps, they are actually not. First, each plot of the broken line representing each country corresponds to the average value of the variables concerned for each size class of holdings, which is derivable from the farm management surveys for the farm households. (In general, the smaller the size class, the value of $N/\bar{O}$ is larger and that of $L/\bar{O}$ smaller.) Second, in Chart 1–a $K/\bar{O}$ is not kept constant and in Chart 1–b $N/\bar{O}$ is not kept constant. However, the location of each of these broken lines is expected to suggest at least crudely the economically effective section of the isoquant.

and N depends on the categories of K. Thus, the irrigation and other water control facilities are complementary with N, but are competitive with L. The same applies to fertilizer. Agricultural machinery and implements (together with drought animals) are sometimes competitive and sometimes complementary with both L and N. Yet, in the present technological change, the predominant place in K is occupied by the first two categories. The second comment is on the experience of technological progress in prewar Japan's agriculture. While the studies in it which tackle sufficiently with all of the above four characteristics are few, it seems certain that between the 1890's and 1930's the relative shares of N and K increased and that of L decreased.[7] Inspection of the time-series data of the actually employed L, N and K, however, indicates that, as a peculiar fact about Japanese agriculture, the substitution of K for N was significant throughout the same period. The major categories of K which made possible this substitution were a variety of labor replacing implements. Irrigation investment, which had been done largely prior to the Meiji era, seems to have played a relatively minor role. This suggests that prewar Japan's technological changes occurred within Stage III side by side with rapid industrialization and a constant outflow of the agricultural labor force into the cities.

Next, in the shift from Stages I and II to IV, which is characterized by the simultaneous occurrence of hydrological, biological and even some mechanical innovations with required inputs predominantly "modern," the factor combination seems to be biased toward increasing N/L, K/L and K/N for given relative factor prices. The relations between K and N may be different from the previous case: because of the characteristics of mechanical innovation, the force of competitiveness may outweigh that of complementarity.[8] Hence, the partial elasticities of substitution seem all positive and increasing. As a result, on the condition in which this shift will become profitable, the relative share of income for given relative factor prices tends to become the largest in K: then comes that of N: the relative share of L tends to decrease.

As a summary of the discussions with regard to characteristics (3) and (4) of technological changes, Fig. 1 may be shown which indicates a hypothetical locational relations of the isoquants representing respectively the production functions of the stages we are concerned here.[9]

Three: In the above, we were concerned with the technical properties of technological changes, although, when the changes in the factor combination and distributive shares were discussed, we assumed (1) competitive markets of factors and products and (2) constancy of the relative factor prices of factors and products. It should be noted, however, that the actual process of technological change in the society does not correspond to the shift from the equilibrium point of an existing production function to the equilibrium point of a new production function in the above assumptions. The actual process is a disequilibrium process brought about by the advent of a new production function in a society where an old production function prevails. Assuming still the competitive markets and, with it, the agrarian society consisting of identical

---

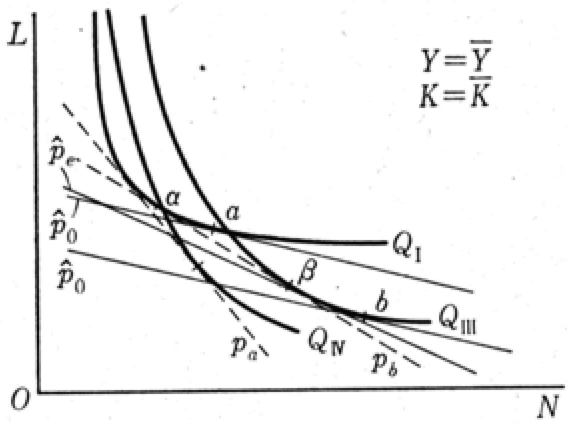
7) This finding is derived by using the time series data [35] of the national total figures of L, N (number of gainful workers), K (not completely covered), wages, land rent, the prices of capital goods and the rate of interest.

8) Two reservations with regard to mechanical innovation in GR are necessary. One: Even mechanical innovation has a property that is complementary with N, as is exemplified in the cases where it makes possibles timely ploughing and with it a double cropping [3] [15]. Two: To what extent the mechanical innovation is separable from the essential ingredients of the GR is, in fact, a yet unsolved question. This is related to assumption (3) of Section I. Johnston and others [20] assume the separability.

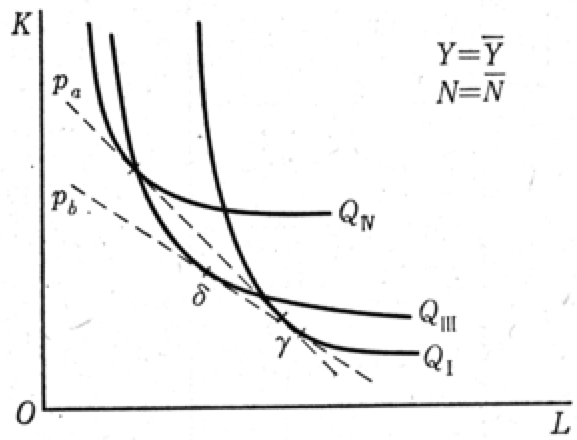
9) The production function representing each stage is shown in the figure by approximating it by a CES production function. Using for the simplicity's sake the CES production function with two factors: $Y=(AX_1^{-\rho}+BX_2^{-\rho})^{-\frac{1}{\rho}}$ where X_i is either L and N or K and L, the characteristics of each of the isoquants Q_{I}, Q_{III} and Q_{IV} are indicated (i) by the size of ρ and (ii) by that of $(A/B)^{\frac{1}{\rho}}$. As is clear, $A^{\frac{1}{\rho}}$ *and* $B^{\frac{1}{\rho}}$ are identical to the distances of asymptotes of the isoquant to both axes when the elasticity of substitution is less than 1 (or $0<\rho<\infty$).

Fig. 1 Hypothetical Production Functions representing Stages I (II), III and IV

1−a



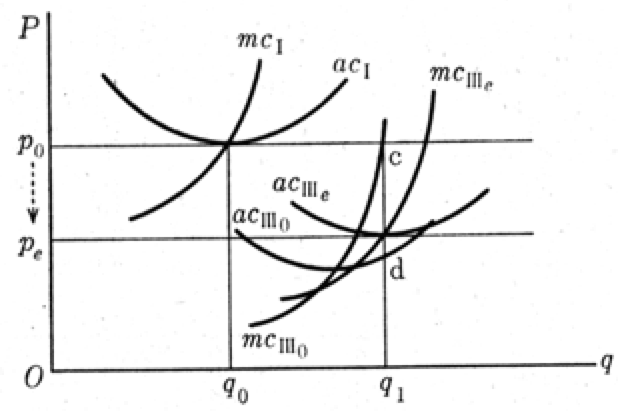
1−b



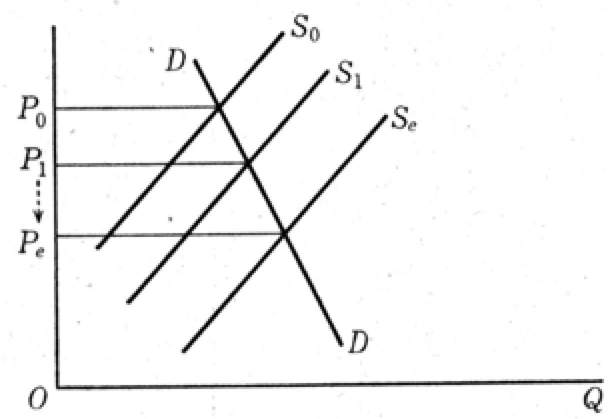
Notes: (1) Each Q's represents the isoquant of the production function $Y=f(L, N, K)$ when Y and any one of the three factors are held constant. (2) Pa and Pb indicate the limits of the relative price lines in the sense that if the relative price of land is cheaper than Pa and Pb, shift from stages I to III or IV is not profitable.

Fig. 2 Hypothetical Process of a Society's Shift in Technological Stages

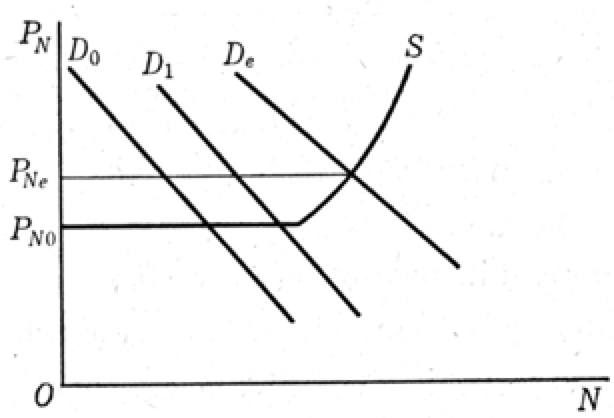
2−a. Average and Marginal Cost Curves of a Farm



2−b. Demand and Supply Curves of a Product



2−c. Demand and Supply Curves of Labor



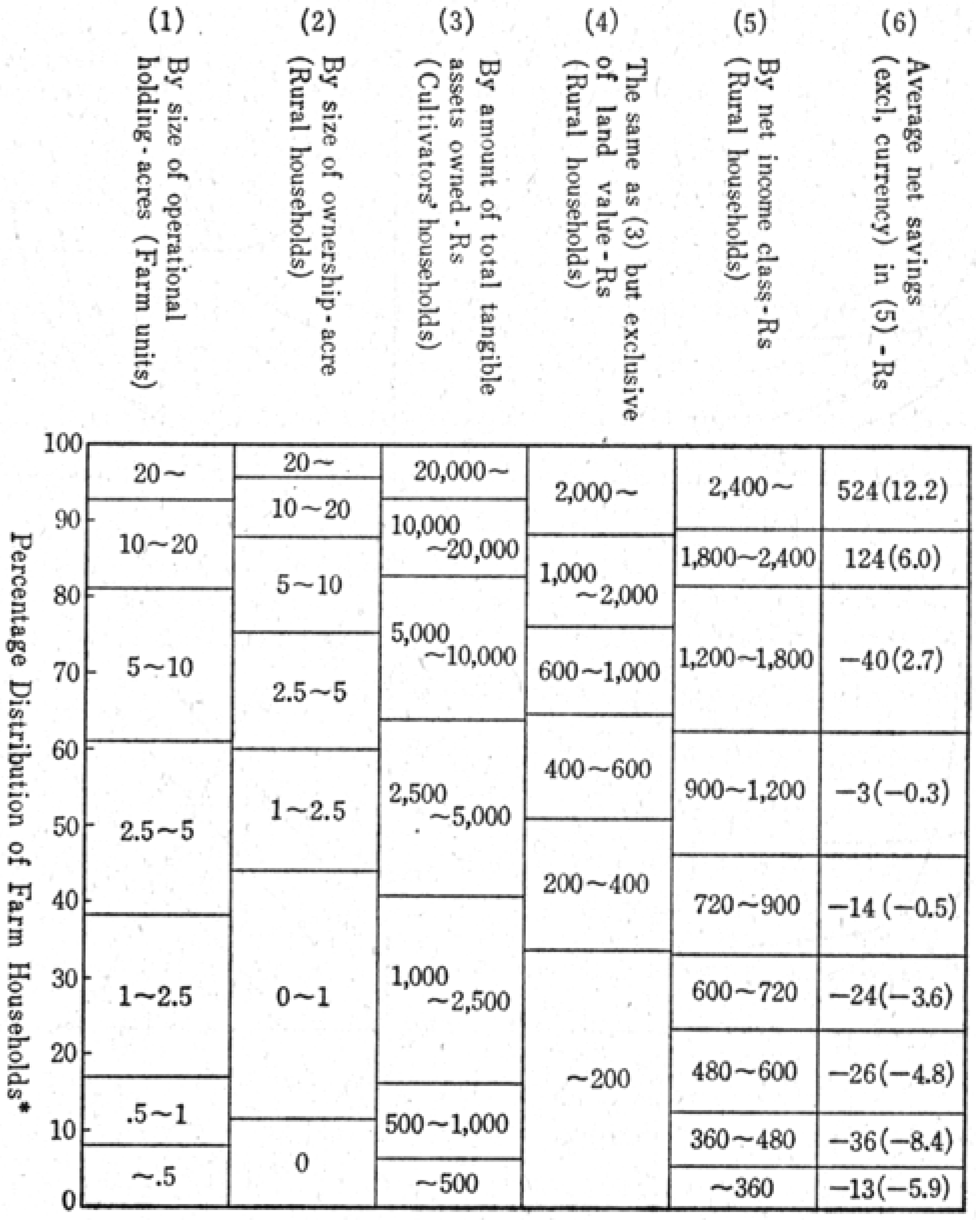
farm households, but removing the assumption of constant prices, the following phases in the disequilibrium process could be differentiated. (For illustration, only the shift from stages I to III is taken up; K is assumed away.)

Phase 1: The appearance of a new production function. This is indicated by the appearance of Q_{III} in addition to Q_I in Fig. 1–*a* and of curves mc_{III0} and ac_{III0} in addition to mc_I and ac_I in Fig. 2–a. At this point of time the price of the product is p_0 (Fig. 2–a and 2–b), the prices of N, p_{N0} (Fig. 2–c) and the price of L such that the relative price of N to L is expressed in relative price line $\hat{p}_0$ (Fig. 1–a).

Phase 2: Initial innovators tend to arise from a random reason. They move from point *a* to point *b* (Fig. 1–a). With p_0, p_{N0} and $\hat{p}_0$ remaining unchanged, they acquire the innovators' profit with the margin indicated by *cd* in Fig. 2–a.

Phase 3: As the number of innovators increases, the price of the product tends to decline ($p_0 \rightarrow p_1 \rightarrow \cdots\cdots$ in Figs. 2–a and 2–b, the demand curve for product being assumed to be unchanged), and the factor prices tend to change depending on the characteristics of a new technology on the demand side of the factors and on those of the factor markets on the supply side.[10] Accordingly, $\hat{p}_0$ (Fig. 1–a) changes

Chart 2 Distribution of Rural Households*by Selected Indicators, All India 1961–1962**



Notes: * This does not hold for all the columns. See remarks in the bracket of each columns. ** For columns (5) and (6), the reference year is 1962 only. The figures in brackets in column [6] indicate the ratio of net savings to net income.
Sources: Columns (1) and (2) from [8]; (3) from [28] and (4), (5) and (6) from [25].

and the margin of innovators' profit declines.

Phase 4: Finally a new equilibrium is reached when all the farm households adopt the new technology ($\hat{p}_e$, p_{Ne}, p_{oe}, mc_{IIIe} and ac_{IIIe}).[11] The margin of innovators' profit reduces to nil; the gains from the technological change are partly transfered to consumers' surplus and partly distributed to the factor incomes.

10) The supply curve of the farmers' own labor is here assumed to be in a form which Professor A. K. Sen discussed in [30].

11) If the assumption of identical farm households is removed, this new equilibrium is reached when the lowest point in *ac* curve of the marginal farm touches the market price line of the product.

III *Initial Agrarian Structure*

In the above discussion of the disequilibrium process arising from the advent of a new technology, we assumed the competitive market conditions of both factors and products and, with it, the agrarian structure consisting of identical farm households. Essentially, our discussions that follow are with regard to the question: How this hypothetical disequilibrium process changes its course when these assumptions are replaced by more realistic ones. Therefore, as the starting point of the discussions, essential characteristics of the agrarian societies must be clarified as an initial condition. While this is in fact a formidable task, particularly in view of considerable differences by country and by locality, we attempt to do this by summarizing into three items these characteristics of the contemporary agrarian societies in South and Southeast Asia. It may be said that as far as these summarized characteristics are concerned, they are also applicable to prewar Japan and Taiwan with the exceptions that will be specifically noted.

1. The agrarian structure is significantly differential in terms of either land-ownership or land-tenurship of the constituent households. A result is a variety of households: non-cultivating and cultivating landowners, semi-owner-cultivators, tenants and agricultural laborers, each constituting a distinct group, though its relative weight varies depending on localities.
2. In terms of the size of cultivator's land holding too, it is significantly differential. The distribution of the holdings indicates that the size of the modal group is the largest in Thailand, being 3–4 hectares; in most others countries it is more or less smaller. To shed some light on the interrelations between this size structure and other indicators of the agrarian structure, Chart 2 is shown with regard to India.[12]
3. In terms of the modes of operations and management of the farms and their assets, the following points should be noted. (1) Not all of the cultivators are independent decision-making units of production. Decision-making powers are the least in sharecroppers. The next weakest is the tenants with fixed rent in kind. (2) Decision rules of land-owners are not uniform. Some of them are simply content with receipt of land rent. Others are, in addition to it, interested in maximizing returns to capital invested in their land under tenancy, especially in the share-cropping form. A group of cultivating landowners are maximizing the mixed income from land, labor and capital; when the land rent rises, they tend to increase the portion of his land rented out, and *vice versa*: [19]. (3) For a majority of small owner and tenant-cultivators, the maintenance of a minimum subsistence level seems to be the greatest concern. Their demand for land to rent in is inelastic to the changes in land rent; the supply curve of own-labor is as shown in Fig. 2–c. This situation might have been somewhat different in prewar Japan: [21].

With regard to the imperfectness of the product and factor markets, our research is not yet in a stage to make possible even a broad stylization. An important part of the causes for this imperfectness, however, comes from the features of the agrarian structure summarized above, and this seems sufficient for proceeding with the discussions that follow.

IV Primary Response of the Existing Agrarian Structure

When a new technology is exogenously given to the agrarian society stylized in the above, the primary response of the society is the appearance of the first group of innovators in differential manners and in differential speed from among the groups constituting it. In some cases, certain groups may respond by changing their mode of operation and management. The aim of this section is to inquire whether there are any uniform tendencies governing this primary response. First, we shall examine actual experience available.

In Japan, the first group of innovators responding to the biological innovation between the 1890's and the 1910's were said to be non-cultivating but enterprising landowners as well as cultivators owning more than 3 hectares of land. Later, they moved to the middle-sized cultivators holding 1 to 2 hectares of land.[13] Detailed investigations are, however, yet to be done. In Taiwan, the innovators of *Pong Rai* innovation seem to have initially been landlords instructing their tenants to adopt it. (This will be dis-

12) In the Philippines, a rural household income and expenditure survey of 1961 indicates that negative-saving classes are those with annual income below 2000 pesos which was equivalent to US $ 860 [18, p. 37]. In India, the same dividing line is *Rs* 1200, equivalent to US $ 240.

13) In prewar Japan, the biological innovation was made in successive stages. The period after 1918 is characterized by varietal improvements based on hybridization. This seems to have accompanied with a new group of the innovators.

cussed in the next section.) The experience in GR is summarized below by classifying it into altogether 5 types:

(1) The innovators are reported to have spread over almost all the strata of the agrarian structure within a few years, such as in a municipality Gapan, Nueva Ecija Province, the Philippines [14, 1969], and selected villages in the Intensive Agricultural District Program blocks on India in Madras and Punjab [10, p. 199][11, p. 132][22]. In Gapan altogether 59% of the farms are planting new seeds. The corresponding figures in Madras (in 1968 Kharif) and in Punjab (in 1968–69 Rabi) are 72% and 98%, respectively. (In terms of area, the figures are much less).

(2) The innovators are limited only to the upper strata of cultivators. In the case of a typical small cultivators in a IADP district in West Bengal, new varieties of rice is planted only at the land which he has rented in from the landlord and when the additional expenses incurred by that is shared by the landlord [31] [26].

(3) The innovators arose by conversion of hitherto non-cultivating landlords to landlords engaging in direct management, such as seen in the Central Luzon [18]. The similar cases were widely seen in India already in the early 1960's, though not directly as a response to GR[14]. This type often involves resumption of the rented-out land from the tenants.

(4) The commercialized tenant farmers appear as innovators [36] [27].

(5) The innovators are landlords instructing their tenants to adopt the innovation. This is reported to be seen in the area of West Malaysia where double cropping has spread rapidly [34].

In order to seek a consistent explanation of these diverse cases, one may have at first to refer to the Grilliches-Schultz hypothesis that the difference in the rate of diffusion of new technology is strongly explainable by the difference in the profitability accrued by adopting it [29, pp. 162–168]. This profitability depends largely on the first characteristic of the absolute technology, the rate of shift in the production function, assuming the prices of the factors and product remaining unchanged. It follows that the rapid diffusion of new seeds in the above areas of type (1) may seem to be due in general to an extraordinary high rate of shift in production function under the Green Revolution and that sooner or later, the other areas will follow this type. Two points must be made as reservations, however. One: These areas are among the best areas even within the priority regions of the two countries for the campaign for increasing food grain production, the best areas in terms of irrigation facilities, supplies of modern inputs, the provision of institutional credit and extension services and so forth[15]. Two: As is shown in Chart 3, there is a distinct pattern of response even in these areas: the larger the size class of cultivators the speed of response is higher, and it is higher in tenant-cultivators than in owner-cultivators. These two points combine to require us to explore a more general explanation of the characteristics of the innovators, taking into consideration the vast areas in this region the conditions of which are less favorable.

For this purpose, we consider in the following essential factors that determine the willingness or the capability to innovate of the members of the agrarian society viewed in terms of status or size groups.

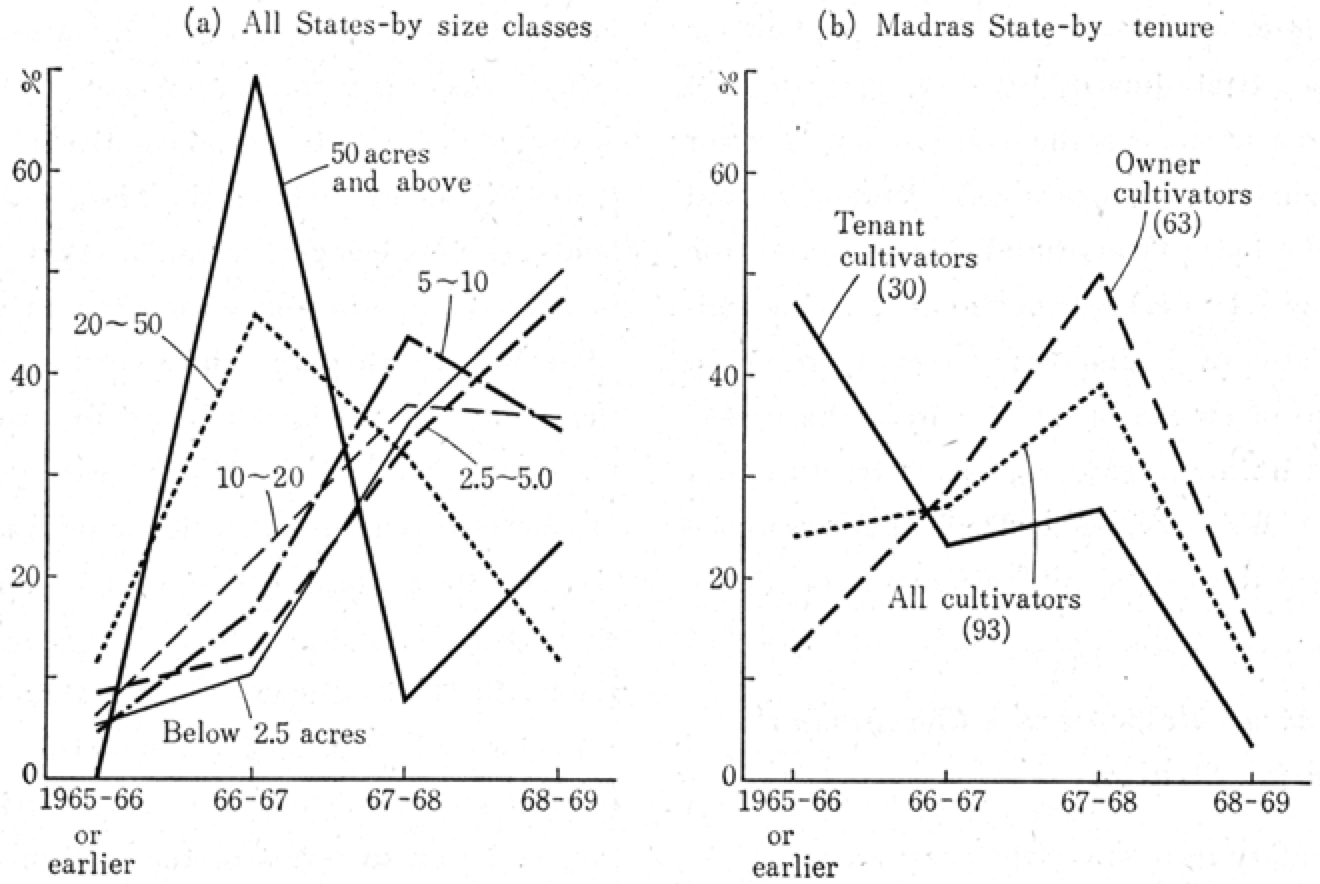
(1) The profitability in the above sense is essential for *potential* innovators. Thus, when it is very high, it can create even the forces that transform absentee landlords into enterprising farmers. Moreover, every member of the agrarian society would be a potential innovator with an equal degree of the willingness, if one could assume a perfectly elastic supply of credit, land to rent in or labor at a common rate of interest, land rent or wages for every member. This, however, is not the case in our stylized agrarian society.

---

14) A number of survey reports made by the Agro-Economics Research Institutes for areas in West Bengal, Orissa, Andra Pradesh and Madras indicate this type [24]. The underlying causes are (1) a rise in prices of agricultural products (2) improvement of infrastructure and (3) measures for land reform.

15) For India, see [9] and for the Philippines, see [18].

Chart 3 Percentage Distribution of Sampled Participants in HYV of Rice Program by the Year of First Adoption-India



Note: For each size or tenure class, the number of total participants in 1968–69 is counted as 100%.
Souces: [10, p. 202] and [22].

(2) The risk-bearing ability which varies among the groups conditions this assumption of an equal degree of the willingness. Hence, in general, the willingness is weaker in the smaller asset groups.

(3) The institutional arrangements for factor pricing and, with it, factor shares are also important. Thus, when a share-cropping agreement covers even innovative activities of a tenant, his eagerness for adopting a new technology will be smaller than otherwise.[16] When the rate of interest for credit varies among the members of different asset groups, the willingness to innovate is smaller in the smaller asset-groups.[17]

(4) The technological characteristics (2), (3) and (4) of a technological change also play a role by combining with the above two factors. Thus, the larger the scale economies factor and the more the factor use is biased toward capital (essentially the capital obtainable through the market), the greater tends to be the reduction in the willingness to innovate of the members of the weaker income and wealth position.

Two comments are in order. One: As is easily conceivable, factors (2), (3) and (4) tend to combine to reduce to nil the willingness of certain strata of the agrarian society for innovation. Two: The government policies with regard to credit, irrigation and other infrastructures, factor and product prices, their distribution and the land tenure and ownership affect the working of the above factors in the way either to accelerate or to decelerate the tendencies described.

16) In the Indian economists' discussion on the relative efficiency of alternative institutional forms or alternative sizes of farm units, which seems to have been made mostly under the static context, this point is discussed specifically in terms of the share-cropper's incentive to absorb fertilizer [2].

17) In actuality, the lack of security in the lower strata of farmers often denies them to be eligible borrowers of loans in the credit market. Landlords tend to act as lenders to their tenants, often together with various instructions regarding crop-raising. It is presumably for this reason that in Chart 3-b the tenants are shown to have responded to HYVP quicker than the owner-cultivators. In the Philippine case, the previous IRRI report does not mention who financed the widespread diffusion in Gapan. Yet, a survey of Lagna Province published in the same report indicates that, of the 30 tenant farms 27 received crop production loans from their landlord [14, 1969].

As a tentative conclusion of this section, the prevailing types of the first group of innovators in GR seem to be those of (2) and (3). This is explainable mainly by the extraordinarily big shift in production function, by the largeness of the scale economies factor and by a significant factor-use bias toward capital (mainly of the extra-farm origin). In the case of the shift from Stages I to III, the contrasting technological characteristics of the innovation seem to result in the first group of innovators arising from the uppermost strata within the *given* agrarian structure and in the *given* mode of operation. Thus, the experience of Japan before the 1910's and Taiwan in the 1930's appeared.

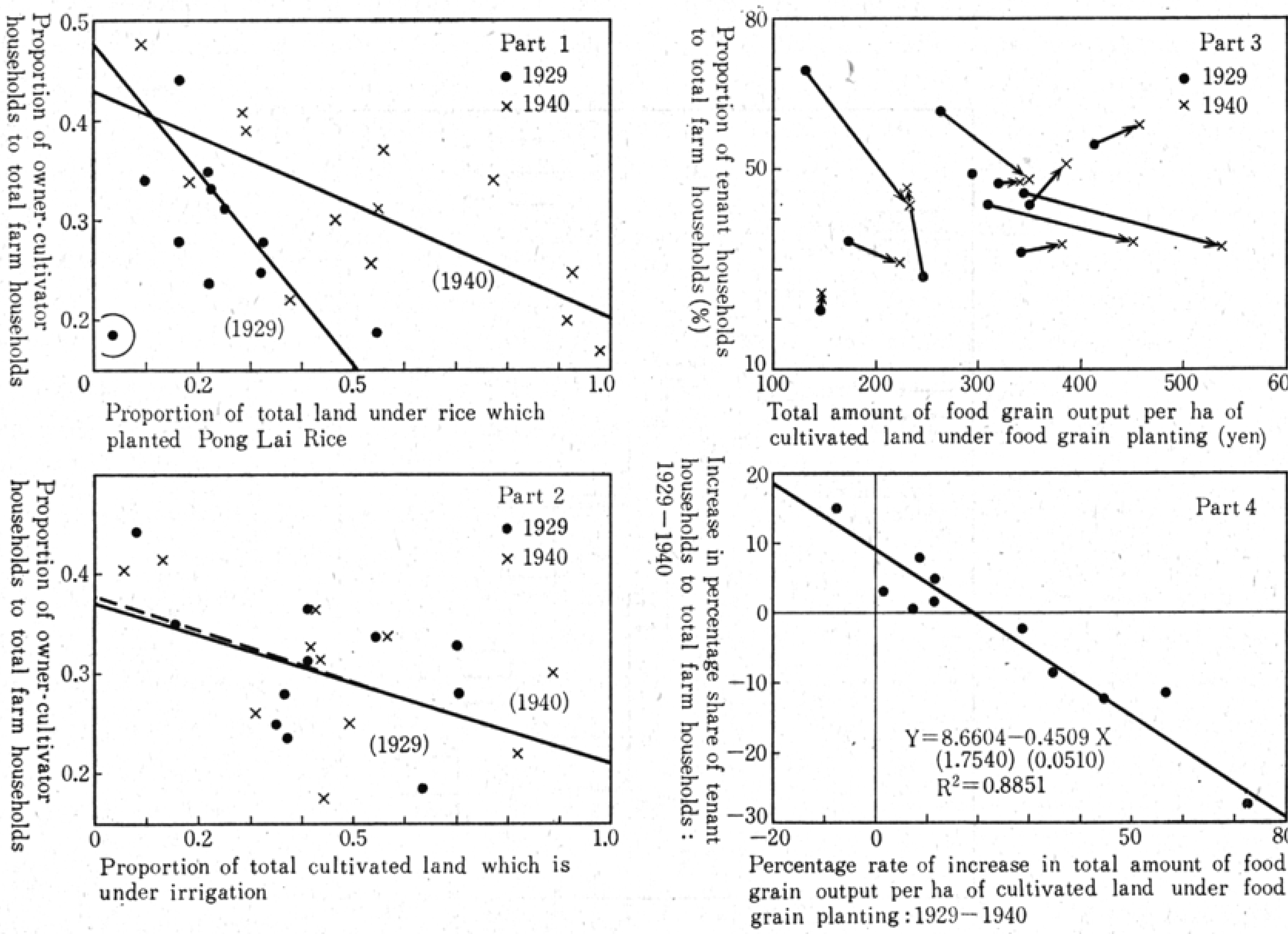
V ***Secondary Response and Changes in the Agrarian Structure***

The secondary response of the agrarian society to a *given* new technology is defined here as the changes in the agrarian structure that are brought about by differential growth rates of the constituent groups of the society arising for the two reasons: (1) the innovators appear in differential speed and in differential manners with the result of differential gains from the given innovation and (2) with the diffusion of the new technology, the demand for and the supply of products and factors change and, hence, the income and, with it, wealth position of each group tends to vary.

The actual experience for which this secondary response can be reasonably well traced is limited to that of prewar Taiwan under *Pong Rai* innovation. At first, in terms of land tenurial relations, this experience suggests that the economic position of the tenants improved as a net effect of secondary response, and many of them thereby joined the groups of owner-cultivators. Chart 4 shows some aspects of secondary response by using by-county cross section data of Taipei Province, a main rice-producing region, for 1929 and 1940. 1929 was one of the early years of the *Pong Rai* rice diffusion and 1940 the year in which it already reached a level of saturation. Part 1 of this chart indicates a general tendency in which *Pong Rai* rice was initially introduced mainly in the landlords' lands under tenancy; while it spreaded thereafter widely in other categories of lands, the weight of the landlords' lands continued to be larger than that of other lands in the planting of *Pong Rai* rice. Part 2 indicates that as a technical condition underlying this tendency, the irrigation ratio is larger in the landlords' lands. The tendency observed in Part 1 is examined in Parts 3 and 4 in somewhat different ways, in particular by interchanging the explanatory variable of the change in the land tenureship structure. This is relevant because *Pong Rai* innovation affected the productivity increase in traditional varieties of rice and also the patterns of the second crops. Part 3 indicates that the land productivity is generally higher in the landlords' land under tenancy than in other categories of lands; yet, as the innovation spreaded, this productivity differential reduced. Part 4 examines the same relation in terms of the rate of change of the two variables. The results shows that the increase in land productivity due to *Pong Rai* innovation brought about a decrease in the weight of tenant households in the total farm households. A similar tendency seems to be observable in the data of Taichung and Hsinchu Provinces, other rice-producing areas: but not in Tainan Province which was a major sugar-cane producing area.

Next, census data of the farm households grouped by size of land ownership and operation in three benchmark years 1921 (the year prior to introduction *Pong Rai* rice), 1932 (the year amidst its spread) and 1939 (the year when it already saturated) make it possible to shed some light on other aspects of the changes in the agrarian structure resulting from *Pong Rai* innovation. Chart 5, which takes up also the case of Taipei Province, indicates the following. (1) In terms of land ownership, the size classes smaller than 7 hectares decreased and those larger than 10 hectares increased in the early phase of the spread of *Pong Rai* innovation; but, in the later phase the size classes smaller than 7 hectares increased and those larger than that decreased. (2) In terms of land holdings, the size classes between 2 and 10 hectares increased and all of that other classes decreased in the early phase, while in the later phase the size classes smaller than 3

Chart 4 Interrelationships between Land Tenureship and Adoption of Improved Varieties of Rice——Taiwan, 1920 and 1940 (By County Data of Taipei Province)



Source: [32].

hectares increased and those larger than 5 hectares increased.

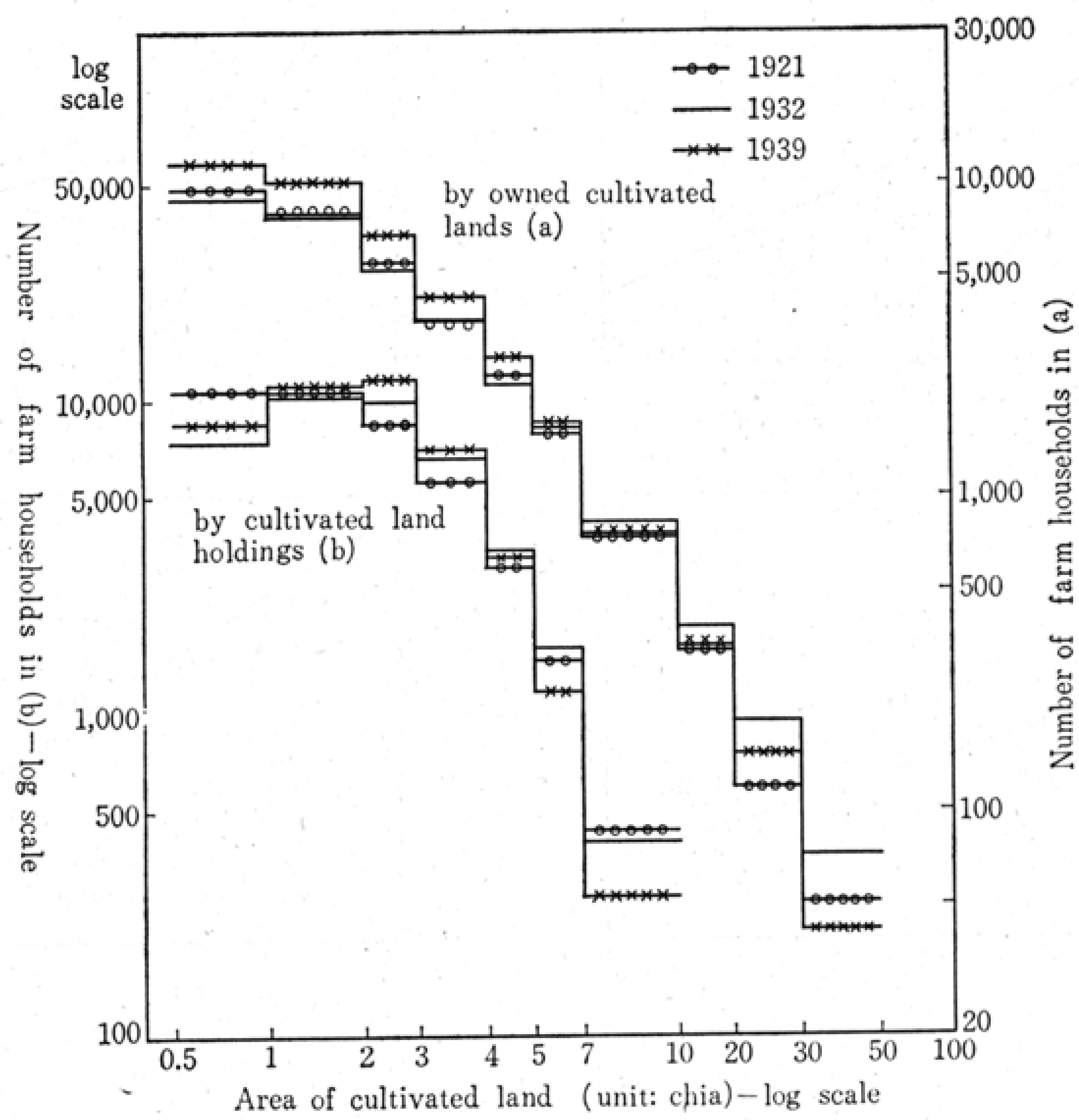
A tentative explanation of these findings is given in the following according to what seem to be the determinants of secondary response.

(1) The growth of the first group of innovators as a result of primary response, and its impact on the agrarian structure. In Taipei Province this determinant worked initially to make the agrarian structure subsided toward the larger size classes in terms of both land ownership and holdings.

(2) The direction of the change in the relative factor shares which arise as a combined result of (i) technological characteristics of a given technological change and (ii) changes in the demand and supply situations in the factor markets. In Taipei's case, (i) seems almost equivalent to the technological characteristics of the technological change from Stages I to III already discussed. As for (ii), while the detailed investigations are yet to be attempted, a cursory check does not indicate any significant change in relative prices among L, N and K. It follows that the relative factor shares would have tended to become favorable to N and K. However, the major part of additional K, new irrigation facilities, was constructed by the colonial government and even the rest of K was largely supplied within the farms. As the result, in the later phase of *Pong Rai* innovation, those strata of farm households who relied on their own labor as the principal means of producion, improved their economic positions.

(3) The limit of the spread of a new technology which is determined by the change in the product price

Chart 5 Distribution of Farm Households by Size of Owned Cultivated Lands (a) and by Size of Cultivated Land Holdings (b)——Taiwan 1921, 1932 and 1939 (Taipei Province)



Source: [33]
Notes: (1) In this chart with both axes measured by log scale, the number of farm household in each size class is expressed by discounting it with the ratio of (the logarithmic value 0.30103) ÷ (the logarithmic value of the range of that size class).
(2) The unit of area a "chia" is approximately equal to a hectare.

together with the situations coming from the above two factors. In Taiwan, the real price of rice remained stable as a trend mainly due to the fact the major source of demand for it came from her then metropolitan country Japan. Hence, *Pong Rai* innovation reached its saturation point when *Pong Rai* rice spreaded all over the rice lands, excepting those catered for producing native rice consumed by the native people.

With regard to Japan's experience, our study is not yet conclusive. Also, mainly because the time elapsed since the advent of GR is yet too short, the information which comes from the countries of South and Southeast Asia with regard to this secondary response is not satisfactory. Yet, there is a set of information which merits particular attention. Namely, in the same report on the IADP Districts in India as we previously referred to as indicating type (1) of primary response, the innovators, spreading in this type to all the strata of the society, are reported to have already accumulated in their hands the amount of surplus funds that was sufficient to finance roughly 80% of the required expenditures for both current inputs and capital investments. While the figures shown there are in some cases almost unbelievably high and, hence, are yet to be examined carefully,[18] the findings may be applicable in general to the areas of this type (1), but only to those.

With regard to other, more general areas under GR the pattern of secondary response would be inferred as follows. *First,* those strata of the agrarian society which grow fast in connection with determinant (1) of secondary response above would be, as was discussed in Section IV, among the upper asset-groups. *Second,* in connection with determinant (2) it should be recalled that the technological characteristics of GR tends to make the relative factor shares favorable to K, especially that of non-farm origin. The scale economies factor tends to accelerate this. Hence, assuming the constancy of relative factor prices, the first group of innovators would continue to grow faster than other members of the society. *Third,* the directions of changes in the demand and supply situations of L, N and K are not easy to infer. As far as N is concerned, however, the dual effect of GR[19] would work in such a way that, while in the short run the demand for it becomes larger than the supply, in the longer run the demand tends to fall short of the supply.[20] Yet, the wage behavior would further depend on the non-farm demand for farm labor. Similarly, the price of capital, involving both the prices of capital goods and the rate of interest, depends partly on the non-farm development, and the price of land on the rate of growth of farm population. *Fourth,* the price of product in connection with determinant (3) is also inpredictable. The fact that the prices of new varieties of rice already declined in the Philippines and West Pakistan is, though coming partly from their inferior palatability, in need of watching. The long run price prospects, however, depend on the capability of the agrarian society and the economy for crop diversification, export promotion of farm products and industrialization. *Fifth,* despite uncertainties with regard to the third and fourth factors, there is indeed a possibility in which a dualistic structure of the agrarian society consisting of the modern-commercialized and the traditional-subsistent sectors will emerge in both socioeconomic and regional terms.[21] The government policies to which we referred in connection with primary response also affect this possibility.

VI *Tertiary Response and Conclusions*

The tertiary response is defined here as modification or alteration of an initially given new technology on the initiative of those specific strata of the agrarian society who, in the course of primary and secondary responses, are motivated to improve thereby the absolute and relative level of their living conditions. We disregard here the case of the same motivations expressed themselves in social and political violence causing the direct changes in the agrarian structure. This is because we intend here to contain the analysis of tertiary response within the economics framework. Yet, the differentials in the strength of these motivations and, hence, initiatives among countries and localities do not seem to be explained without seeking the aid of sociology and politics. And, here lies the central problem of tertiary response.

18) [22] and [10, 11]. Especially noted is the amount of capital expenditure thus financed in the year 1967–68 of the average participant farm household, ranging from Rs. 1,010 for the size class of holdings less than 2.5 acres to Rs. 17,078 for the size class of holdings larger than 50 acres in the total area of the survey (rice and jowar areas). These figures should be assessed in comparison with those shown in Chart 2. The extraordinary performances shown in this report may be due to the inclusion in the sample of the newly emerged capitalist tenants as indicated in [27]. In any case, the number of sampled farms seems too small, and this may explain the big difference between the above and the statistics shown in [12] for the IADP districts for 1967–68, which seem more reasonable.

19) As was discussed in Sect. II, one part of the effect comes from the element of biological innovation, resulting in the increase in the demand for N; the other comes from the element of mechanical innovation and is labor-replacing.

20) Detailed investigations on these two effects and their net results are made in [3, 4] and [7, 20] in the context of Punjab, India and West Pakistan and hence, in dry region in Asia. See further [9, pp. 31, 114].

21) The possibility of this dualistic structure is discussed in [7, 20], [3] and [18].

Thus, it seems that Japan's medium-sized farmers in early this century had the motivations and initiatives to modify then existing technologies, though by relatively traditional methods such as varietal comparisons and inventions of simple but improved farm machines and implements. With regard to possible tertiary response in the countries of South and South-east Asia, almost no information is yet available. While Professor G. Myrdal [23, pp. 1068, 1378–79] places his hope on "progressive peasant proprietors and priviledged tenants" for transforming traditional agriculture and agrarian society, this group seems to resemble our types (2) and (3) farmers in primary response; hence, they may differ from what we expect here as the agents of tertiary response. If the agrarian society in Asia is such that no tertiary response is in prospect, assuming no social and political violence, the response of the agrarian structure to the new technology will end with secondary response.

To conclude the discussion of this paper, the following points may be noted under the assumptions we have made so far.

(1) The central direction of the changes in the agrarian structure resulting from GR greatly varies depending on the prospects for crop diversification, export promotion and industrialization and also on the degree of tertiary response.

(2) If tertiary response is insignificant and, in addition, diversification and industrialization are not successful, the agrarian society will become stable when the modern-commercialized sector will have emerged side by side with the vast sector of traditional-subsistent agriculture; the technology of GR will become stable in its original form only within the modern-commercialized sector.

(3) If tertiary response is significantly large, a chain of interactions between secondary and tertiary response will continue until some stable agrarian society is finally established, presumably, in a more uniform and equalized pattern than otherwise. In that event, the technology of GR will have been modified to the type that is more labor-using than presently.

(4) There seems to be large room for the government policies to intervene in the above spontaneous courses so as to alter them in various directions.

References

1. Asian Development Bank, *Asian Agricultural Survey*, University of Tokyo Press, 1968.
2. Jagdish N. Bhagwati and Sukhamoy Chakravarty, "Contributions to Indian Economic Analysis: A Survey," *Amer. Econ. Rev.*, Sept. 1969, Part 2.
3. Martin H. Billings and Arjan Singh, "Mechanization and Rural Employment with Some Implications for Rural Income Distribution," *Economic & Political Weekly*, June 27, 1970.
4. Martin H. Billings and Arjan Singh, "Labour and the Green Revolution——the Experience in Punjab," *Econ. Pol. Weekly*, Dec. 27, 1969.
5. Murray Brown, *On the Theory and Measurement of Technological Change*, Cambridge University Press, 1968.
6. Lester R. Brown, *Seeds of Change: The Green Revolution and Development in the 1970's*, Praeger Publishers, N. Y., 1970.
7. John Cownie, Bruce F. Johnston and Bart Duff, "The Quantitative Impact of the Seed-Fertilizer Revolution in West Pakistan: An Exploratory Study," *Food Research Institute Studies in Agricultural Economics, Trade and Development*, IX-1, 1970.
8. Government of India, Cabinet Secretariat, *The National Sample Survey No. 144, Tables with Notes on Some Aspects of Landholdings in Rural Areas, Seventeenth Round, Sept. 1961-July 1962*, Delhi, 1968.
9. Government of India, Ministry of Food, Agriculture, Community Development and Cooperation, Expert Committee on Assessment and Evaluation, *Modernising Indian Agriculture: Report on the Intensive Agricultural District Programme, (1960–68)*, Vol. 1, 1969.
10. Government of India, Planning Commission, Program Evaluation Organization, *Report on Evaluation of the High Yielding Varieties Programme, Kharif-1968*, June 1969.
11. Government of India, PC, PEO, *Evaluation Study of the High Yielding Varieties Programme, Report for the Rabi 1968–69——Wheat, Paddy and Jowar*, November 1969.
12. Yujiro Hayami and V. W. Ruttan, "Factor Prices and Technical Change in Agricultural Development: The United States and Japan, 1880–1960," *Jour. Pol. Econ.*, Sept./Oct. 1970.
13. Yujiro Hayami and Saburo Yamada. "Agricultural Productivity at the Beginning of Industrialization," in K. Ohkawa, B. F. Johnston and H. Kaneda

(ed.), *Agriculture and Economic Growth: Japan's Experience,* Univ. of Tokyo Press, 1969.

14. International Rice Research Institute, *Annual Report for 1962, 1963, 1964, 1967, 1968, 1969,* Manila.
15. Ichiro Inukai, "Farm Mechanization, Output and Labor Input: a Case Study in Thailand," *International Labour Review,* May 1970.
16. Shigeru Ishikawa, *Economic Development in Asian Perspective,* Kinokuniya, 1967.
17. Shigeru Ishikawa, "Direction of Technological Change in Agricultural Production in ECAFE Region during the 1970's," a paper presented at the U. N. Fifth Inter-regional Seminar on Development Planning, Bangkok, 15–20, Sept. 1969 (ISDP. 5/A/R. 7).
18. Shigeru Ishikawa, *Agricultural Development Strategies in Asia–Case Studies of the Philippines and Thailand,* Asian Development Bank, Manila, 1970.
19. K. O. Janlekha, *A Study of the Economy of a Rice Village in Central Thailand,* Ministry of Agriculture, Bangkok, 1955.
20. Bruce F. Johnston and John Cownie, "The Seed-Fertilizer Revolution and Labor Force Absorbtion," *Amer. Econ. Rev.,* Sept. 1969.
21. Ryoshin Minami, "Population Migration Away from Agriculture in Japan," *Econ. Dev. Cul. Ch.,* Jan. 1967.
22. P. K. Mukherjee, "The HYV Programme, Variables that Matter," *Econ. Pol. Weekly,* March 28, 1970.
23. Gunner Myrdal, *Asian Drama,* Pantheon, N. Y., 1968.
24. Dharm Narain and P. C. Joshi, "Magnitude of Agricultural Tenancy," *Econ. Pol. Weekly,* Sept. 27, 1969.
25. National Council of Applied Economic Research, *All India Rural Household Survey, Vol. II, Saving, Income and Investment,* New Delhi, 1965.
26. Gyaneshwar Ojha, "Small Farmers and HYV Programme," *Econ. Pol. Weekly,* April 4, 1970.
27. G. Parthasarathy and D. Haranatha Babuy, "HYV Programme: Variables that Matter," *Econ. Pol. Weekly,* June 20, 1970.
28. Reserve Bank of India, "All India Rural Debt and Investment Survey, 1961–62," *Reserve Bank of India Bulletin,* June, 1965.
29. Theodore W. Schultz, *Transforming Traditional Agriculture,* Yale Univ. Press, 1964.
30. A. K. Sen, "Peasants and Dualism with or without Surplus labor," *Jour. Pol. Econ.,* Nov. 1966.
31. S. Sengupta and M. G. Ghosh, "HYVP for Rice: Performance in a Bengal District," *Econ. Pol. Weekly,* Oct. 26, 1968.
32. Taiwan Government-General, *Taihoku-Tokeisho* (Statistical Yearbook of Taipei Province) *1920, 1940,* Taipei.
33. Taiwan Government-General, *Kochi-bunpai oyobi* (or *narabini*) *Keiyei* (*jokyo*) *Chosa* (Survey on Distribution of Cultivated Lands and Management), *1921, 1932* and *1939,* Taipei.
34. UN, *Economic Survey of Asia and the Far East 1969,* Bangkok 1970, 1–76.
35. Mataji Umemura *et al, Agriculture and Forestry,* Toyo Keizai Shinposha, 1966.
36. V. S. Vyas, "Tenancy in a Dynamic Setting," *Econ. Pol. Weekly,* June 27, 1970.

(Shigeru Ishikawa——Hitotsubashi University)