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9. ABSTRACT This paper (presented at the Chicago University workshop on Constraints to World Agricultural Production, September 26-28, 1977) focuses on capital investment in the free market and labor surplus economies. Most LDC economies experience a shortage of capital for agricultural and economic development. Domestic savings are usually augmented by foreign borrowings to finance new investments. Introduction of new technology raises the return to capital investment and generates a demand for new forms of capital. Capital investments may also produce new technology and its complementary inputs. For example, technological advances in the fertilizer industry and the lowering of fertilizer prices encouraged the development of fertilizer responsive varieties of cereal grains which in turn stimulated further investment in irrigation. Institutions and policies, as well as physical and human resource endowments, can create incentives or disincentives to further investment at any point. The author holds that capital bias exists in both private and public investment, and it is due not only to market imperfections, but more importantly, to constraints arising from the organizational and institutional structure of these societies.

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BARRIERS TO EFFICIENT CAPITAL INVESTMENT IN ASIAN AGRICULTURE

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Paper presented at the
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BARRIERS TO EFFICIENT CAPITAL INVESTMENT IN ASIAN AGRICULTURE*

Randolph Barker**

Most developing economies are characterized by a shortage of capital for agricultural and economic development. Domestic savings normally are augmented by foreign borrowings to finance new investments. However, Schultz (1964) contends that the low productivity in traditional agriculture is not due to a shortage of capital per se but to a shortage of productive investment opportunities. Introduction of new technology raises the return to capital investment and generates a demand for new forms of capital. New technology and the complementary current inputs are themselves the product of capital investments. The linkages are such that new technology may induce or be induced by new forms of capital. For example, technological advances in the fertilizer industry and the lowering of fertilizer prices encouraged the development of fertilizer responsive varieties of cereal grains which in turn stimulated further investment in irrigation. In this chain of events, responses are molded not only by physical and human resource endowments, but also by institutions and policies which can create incentives or disincentives to further investment at any point.

This paper is concerned with the barriers to efficient capital investment in agriculture. I have chosen to focus this discussion on capital investment in the free market, labor surplus economies. It is my contention that capital bias exists in both private and public investment, and is due not only to market imperfections, but more importantly, to constraints arising from the organizational and institutional structure of these societies.

Capital Requirements for Land and Labor Surplus Economies

Land surplus economies can be distinguished from labor surplus economies by observing the time series relationship between the growth in the net cropped area, A, and the employment in agriculture, L, as follows:

$$A = a L^{\beta}$$

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If B, the ratio of the geometric increase of A with respect to L, is equal to or greater than one, then the country is viewed as land surplus. A "turning point" is often encountered where the opportunities for further expansion of cultivated land are extremely limited and the agricultural labor force continues to grow. It is reflected in the rising value of land relative to labor. Within a country, these turning points vary from region to region and among different crop environments. For example, in Asia, the present opportunities for expanding land area are more limited in lowland rice than in upland crops. A second turning point will be reached when the agricultural labor force begins to decline due to growth in demand for labor and hence wage rates in the non-agricultural sector. In East Asia, the first turning point was reached in the latter part of the 19th and the early part of the 20th centuries. In Taiwan, for example, this occurred in the mid-1920s (Lee, 1971). Taiwan passed through a second turning point in the late 1960s. In a relative sense, according to our definition above, Taiwan once again became a land surplus economy, although no one would regard the countries of East Asia as land surplus in absolute terms.

By contrast with East Asia, South and Southeast Asia could be regarded as land surplus for a decade or more after World War II. For example, the first turning point was reached in the Philippines about 1960 (Crisostomo and Barker, 1972) and is only now being approached in Thailand and Burma. Thus, for many of the labor surplus developing economies, the transition from land surplus has occurred very recently. Institutions, to a large degree, have originated in a land surplus environment.

The different technology requirements for land versus labor surplus economies are illustrated in Hayami and Ruttan's discussion of the Japanese versus the U.S. experience (1971). Land surplus economies must emphasize labor-saving technologies in order to increase agricultural productivity, while the focus in labor surplus economies must be on land-saving or yield-increasing technologies. The implications of this difference for the nature and form of capital investments to augment agricultural productivity is very critical.

Growth in output per worker generally is recognized as a necessary condition for economic development. The labor surplus economy must initially forego rapid increases in labor productivity and increase agricultural productivity through rapid increases in land productivity. Capital is also in short supply. But labor is abundant even to the point where underemployment of labor is a serious social problem in many areas. Thus, there is a need for labor-intensive forms of technology and capital investments which increase the opportunities for productive employment of labor.

Capital in agriculture can be roughly classified into (i) private investments in power and equipment, animals, farm tools, plant propagation materials, buildings, and land and (ii) public investments in irrigation and drainage, land improvements, and farm-to-market roads. Irrigation,

drainage, and land improvements will be referred to as land infrastructure.[1/]

The distinction between private and public forms of investment is, fo course, not clear cut. There can be private investments in irrigations and even in a free economy public investments in power, buildings, land, etc. There are also other forms of capital such as human capital and research investment which will be discussed in other chapters, and working capital expenditures which are to a large extent induced by other capital investments. The above classification, however, draws attention to the critical role of public capital investment.

In the labor surplus economies of Asia, where rice is the staple food of most of the population, investment in land infrastructure offers the greatest potential for both increasing land productivity and absorbing labor in productive employment. By contrast, there is much debate over the social benefits of capital investment in various forms of mechanization. Does mechanization increase production or simply displace labor?

The effect of the introduction of modern varieties of rice and wheat which are suited mainly to the areas of good water control was to lower the cost per ton of cereal grain produced under irrigation, and hence, raise the marginal productivity of irrigation investment. Farmers and government officials were quick to respond. Table 1 illustrates that in the decade following the introduction of modern varieties, irrigation investment and increased fertilizer use (which occurred principally on irrigated lands) were the main sources of growth in rice output. Irrigation investment has both an area and a yield effect. (The area irrigated is gross rather than net, and hence, the second crop is counted as an additional hectare). Of the countries where rice production increased at more than 2 percent per annum, Thailand alone achieved this growth through expanded use of traditional inputs--land and labor. There are also countries (not shown in the table), such as Burma and Bangladesh, where rice production increased at less than 2 percent. Many of these areas of low production growth are in major river deltas where the capital requirements to control water are extremely large and where the new rice technology is unsuitable at present. More will be said about this matter subsequently.

Barriers to the Maximization of Social Benefits

Decisions which influence both private and public investment are made by a wide range of people with very divergent views and objectives. Although the private entrepreneur may ultimately decide whether or not to invest in a piece of equipment, government officials' and foreign experts' influence the type of equipment to be made available and the financial terms for purchase. Three measures of efficiency for evaluating decision criteria on investment choices are delineated as follows:

(i) engineering efficiency - measured as the ratio of physical output to physical input

(ii) private efficiency - measured at the rate of return to private investors given market prices.

(iii) social efficiency - measured as the rate of return on investments using shadow prices for factors and products, including the spillovers that are not captured by the investors.

The divergence from (iii) toward (i) or (ii) leads to a misallocation of resources. The conventional economic development view is that the divergence from social benefits is due to market imperfections which cause private efficiency (ii) to diverge from social efficiency (iii). These market imperfections generally take the form of subsidized interest rates on credit, market wages above the opportunity cost for labor, and over-valued exchange rates, all of which tend to bias private investments toward more capital-intensive techniques. Taxes, subsidies, and externalities may also be sources of bias. It is further contended that lack of suitable labor-intensive technology biases the investor's decision. The recent interest in "appropriate technology" reflects this concern. One might speculate, in this connection, as to the substantial change in resource mix and technology development that would occur if international lending agencies were suddenly to declare agencies were suddenly to declare that credit would henceforth be provided at rates in keeping with the domestic opportunity cost for capital.

Timmer (1975) and Thomas (1975) argue convincingly that when government administrators and foreign experts are involved in the choice of technology, the bias of these individuals toward capital-intensive technology may be even more important than the above-mentioned factors. The foreign expert, raised in an environment of high wage rates, is familiar with projects that minimize labor input. Many of the projects are prepared by engineers who think in terms of engineering efficiency. Government officials are generally sympathetic to the views of the foreign technicians since they regard introduction of capital-intensive technology as essential to the modernization of agriculture. Organizations such as the international lending agencies and national government agencies have their own objectives, and these may conflict with or supersede development policy objectives. For example, one objective of the government agency may be to obtain a foreign loan. One condition of the loan agreement may be to utilize equipment of a certain specification (occasionally so specific that only one firm can supply it).

The choice between capital-intensive and labor-intensive technologies is also determined by the organizational and institutional structure of society. For example, consider the impact of farm size and income distribution on demand for capital. When the farm size distribution is highly skewed, as it is in most of the free-market economies of Asia, the bulk of the savings rest in the hands of the large farmers and landlords. The large farmers' preference may be for equipment that displaces labor.

Labor is difficult to organize and manage. For example, as yields increase due to new technology, labor presses to obtain its share of added profits. Where labor is paid a share of harvest, it is difficult to alter the traditional sharing arrangement. The rapidly growing population addes pressure to employ more labor. Land reform legislation is designed to transfer land to the tenants. Large farmers who mechanize to reduce their dependence of hired laborers and tenants frequently manage to avoid many of these problems. The private benefits of mechanization are considerably greater for the large farmers who have access to low-interest credit and hire laborers at the market wage rate than for the small farmers who rely more heavily on family labor.

The forms of capital bias mentioned above can be illustrated by the adoption of the tractor. There is increasing evidence to suggest that tractor use does not result, in most cases, in an increase output either through changes in yeild per hectare or through changes in cropping intensity (Duff, 1976).2/ Benefits appear to be associated largely with the reduction in costs incurred by the animals and associated human labor. Tractor investment is also motivated by other less tangible benefits such as conspicuous consumption and preference for leisure or reducing the heavy work load, i.e., many of the same factors that caused U.S. farmers to "overinvest" in mechanization. The relevant question is whether or not greater social benefit can be gained by investing the capital elsewhere. The answer is almost certainly affirmative in those situations where no gain in output is achieved and the investment leads simply to a displacement of labor.

Despite the questionable social benefits of tractorization, the World Bank has loaned over half a billion dollars to Asian countries over the past decade for mechanization. The money has been loaned at well below the interest rate for investment loans from local sources. The bulk of the loans have been used for tractors and power tillers. In the Philippines, for example, two-thirds of the funds dispersed in the first two machinery loans were for 4-wheel tractors (Barker, et.al., 1972), which indicates that the purchasing power rests with the very large farmers. Despite the availability of a wide range of alternatives, including the development of a locally-manufactured small power tiller, and despite the recommendation of an ILO report (1974) that importations of 4-wheel tractors be restricted, the same pattern has prevailed in subsequent bank loans.

In summary, the adoption of tractors and power tillers in Asia has been influenced by capital bias due to (a) market imperfections, (b) preferences of decision-makers, and (c) institutional structure. The development of small power tillers suitable to tropical soil conditions which could be locally manufactured widened the range of available choices and in some instances led to a more labor-intensive choice. However, the forces favoring the larger capital items are preponderant. Institutional changes that affect farm size distribution are likely to occur only gradually.

A more farsighted attitude of international lending agencies and national governments in lending policies could result in a higher level of employment without loss in economic efficiency.

Land Infrastructure Development

The remainder of this paper will be concerned with decisions regarding capital investment in land infrastructure. The major form of capital investment to raise agricultural output in the labor surplus economies is land infrastructure development. This includes the development of irrigation and drainage, as well as the shaping of land to improve the efficiency of water distribution. The bulk of land infrastructure development is accomplished through public capital investment. Thus, similar to the products of agricultural research, land infrastructure has many of the characteristics of a public good, such as indivisibility, externality, and jointness in supply and utilization (Hayami, 1975). The analogy, however, is not complete. Irrigation systems can be developed which permit the benefits to be internalized by the private individual in accordance with his contribution to the costs. This includes not only the private tubewells, but the small community canal irrigation facilities.

The major opportunity for substitution of private for state resources is in the community irrigation systems, where members of the community contribute their off-season labor for the construction of the system. To the degree that institutional and organizational factors prohibit this and necessitate an increase in state investment, social benefits are reduced. The reasons are twofold. The substitution of state resources for community labor comes at a high opportunity cost, and the state-run systems tend to be less efficient. Among the government employees, there is not incentive for efficiency because they share directly in neither the benefits nor the costs. The construction and operation of the systems is to a large extent in the hands of engineers who are not familiar with the needs of agriculture. Ineffective management in irrigation system is coupled with a lack of communication between the managers and the end-users.

The implications, of course, is that the major constraint is not a lack of labor or capital, but rather a lack of management capacity. If we take this constraint as given, the "excessive" investment in capital might be viewed as "management saving", and hence rational in maximizing social benefits at least in the short-run. I will not deal here with the underinvestment in human capital which has created this situation.

The public sector does respond to price incentives and to anticipated changes in price. Since most countries are concerned with maintaining at least some level of self-sufficiency in food grain production, any anticipated widening of the gap in food deficits over a long-term basis would encourage investment in irrigation. Hayami and Kikuchi (1976) show, however, that in the Philippines the magnitude of new investments in irrigation tend to

fluctuate with short-run changes in the benefit-cost ratios due to price fluctuations. Rao (1975) observes that there has been an underinvestment of public funds for irrigation in India. The same can be said for Indonesia, given the acute food deficit situation now facing that country. Even the international lending agencies have not been immune to short-run thinking about long-term investments. Given the short time horizon of policy-makers, we might expect to find a tendency on the part of most countries to underinvest public funds in irrigation.

In what follows, the problems associated with the exploitation of ground water resources, the development of community irrigation systems, and the development of national irrigation systems will be discussed.

Tubewells

There are a wide range of technologies available for lifting water which include mechanical pumps, animal-powered methods such as the Persian wheel, hand methods, and, of course, windmills. However, when water must be lifted more than a few feet, the mechanical pump normally is more efficient in both from the standpoint of engineering and economics. For the installation and operation of the mechanical pump and tubewell, a wide range of technologies are also available. Factors affecting the cost and degree of capital intensity include the (i) drilling technique, (ii) power source and type of engine, (iii) type of pump, (iv) screening material used, and (v) agency installing the well (Thomas, 1975).

Tubewells and lowlift pumps have been an important source of irrigation in South Asia, but less important in Southeast Asia. Presumably, this is due to differences in the ground water availability, although in many instances ground water resources have not been properly identified and mapped. There is a high degree of variability in ground water supply and in the proximity of the supply to the land surface. Where water can be pumped to the surface from a depth of 20 feet or less, small lowlift pumps, 4 inches in diameter can be used which are roughly equivalent in cost to a power tiller.

Private tubewell development had a major impact on agricultural output in West Pakistan (Mohammad, 1965) and in Northern India. But the expansion of private tubewells down the Gangetic Plain into Eastern India and Bangladesh encountered a number of obstacles. The heavier monsoon rainfall reduces the benefits to irrigation in the wet season. Therefore, the principal benefits have come from irrigating the dry season wheat crop. The small size of farms and fragmentation of holdings in this region further reduce the economic incentives for private tubewell development. Farms and land parcels are too small for one tubewell, and the sharing of wells among farms encounters obstacles in community cooperation and organization discussed in more detail in the following section.

In view of these constraints, one of the most interesting innovations has been the bamboo tubewell developed in Eastern India during the mid-1960s. The "invention" of the bamboo tubewell was not a chance occurrence but part of a process of induced technical and institutional innovation (Clay, 1975). In areas with sandy alluvial soils, private contractors learned that by substituting bamboo casing for steel pipe and by using simple drilling methods, they could reduce installations costs and install wells more rapidly than the government rigs. Farmers found that they could cut costs by installing several wells and using a single mobile diesel pump set. Cost per hectare irrigated was reduced by more than 50%. While the bamboo tubewell has greatly increased private investment, Clay (1975) points out that contrary to popular opinion, the large farmer has been the major beneficiary. The bamboo tubewell can be used only in a fairly limited area of high water table and porous sandy soils. The technology is not transferable, but has been designed locally to complement a very specific environmental and institutional setting.

In other areas, there is no ready substitute for more costly technology. Due to the constraints resulting from fragmentation of holdings mentioned above, there has been an underinvestment in private tubewells, and public tubewells have been a major source of exploitation of ground water resources. The sad performance of the state tubewells is well documented (see for example Moorti, 1971). Common problems include the attempt to irrigate too large a command area and the undependability of the supply due to frequent breakdowns, lack of spare parts, equipment thefts, and diversion fo water by the influential members of the community. Tubewells are also operated by local groups, but as will be discussed in more detail in the next section, local organizations have also encountered major problems. Inability to exploit ground water resources fully with private capital and inefficiency in the use of public investment have reduced substantially the benefits from tubewell irrigation.

The encouragement of private investment in tubewells can result in negative externalities, if excessive exploitation of the ground water resources lowers the water table. Thus public regulatory control over private investment may be desirable in some situations.

Communal Irrigation

The resource endowments of the individual members of the farming community, who range from large farmers to landless laborers, differ widely. Hence, their absolute and relative shares in the benefits of a given project will also differ. Whether or not the project is undertaken depends on the ability of the community leadership to convince a sufficient number of people in the project that it is to their mutual benefit, and to convince the national government that their project is worthy of support. Both are formidable tasks, and the rules of the game -- persuasion, coercion, forging

signatures when necessary -- are not part of the economic literature. Thus, in order for the system to work at all the benefits must be very substantial.

A recent study by Kikuchi, et al. (1976) shows in detail how the development costs and benefits of a small communal irrigation system in the Philippines have been shared. The participation of individual community members depended to a large degree on their relationship with the community leaders who, in this case, were share-tenants. Despite the fact that the landlords received a substantial share of the benefits, they did not contribute to the project. It cannot be expected that landlords would participate in a project initiated by the tenants. One of the consequences of the gradual land reform in some countries of Asia (e.g. India and Philippines) has been to discourage the landlords from investing their savings in agriculture.

The benefit-cost ratio for the project was 3 to 1 (with the communal labor valued at the farm wage rate), and thus, there was a strong incentive to participate. The investment inducement coefficient[3] or the ratio of the government fund allocated to infrastructure development to the total resource investment was 1.50. This means that two-thirds of the total investment came from the national government and one-third came from local sources, primarily in the form of low opportunity cost communal labor supplied during the slack months of agricultural production. In theory, if the landlords had contributed in proportion to the benefits they received, this ratio could have been increased still further.

A major problem is that a leader, who takes on the formidable task of both organizing his community for public works and convincing the government to contribute, will benefit only marginally from the project if he is a small landholder. In this case, unless he is a rare individual dedicated to the good of the community, he will not offer to organize a community project. On the other hand, if he is a large landholder, he will benefit substantially, but other members of the community will see the project as a means of promoting the interests of the leader rather than contributing to the common benefit. In this case, it would be extremely difficult to persuade the community members to contribute their labor.

Due to the lack of enlightened local leadership, we find only scattered examples of such projects which are successful. Many are failures. On the average, when the benefit-cost ratio is low, the tendency is to invest community resources in irrigation at a level well below their potential social benefit. It appears that governments are becoming increasingly aware of this and are attempting to provide assistance to local communities to help initiate these projects. The simple irrigation schemes in Indonesia, which are financed by domestic and foreign capital, are one example (Booth, 1977). But the problem of local leadership described above probably will impose a major constraint to the success of these projects.

The recent experience of China and the historical development of irrigation in East Asia offers an interesting contrast to contemporary South and Southeast Asia. Growth in food output in China has been sustained

by a major public investment in irrigation. Through the commune organization, it has been possible to mobilize labor and capital for investment in community irrigation works. The commune production team (typically about 30 families working about 10 hectares of land in the high and stable yield areas) is the primary unit where decisions are made about the sharing of profits and the allocation of resources for agricultural production and for investment. Leadership in the commune is provided by the cadre of the Communist Party members who occupy most positions of responsibility down to the production team level. Economic and non-economic incentives encourage production teams to utilize their labor for capital investment during the slack season, particularly the winter months. In the sharing of profits by the production team rather than by the family (as in the free-market economies), labor is paid not on the basis of private opportunity cost, but on the basis of community or social benefit.

A list of farm machinery from a grain-producing commune in the Yangtze River Valley provides an insight into the sequence of capital investments made by the community (Table 2). There was a continuous investment of human labor in land infrastructure development. In 1976 labor was being utilized to straighten canal systems and to lay pipes to bury the entire conveyance network underground. Threshing machines were among the first pieces of capital equipment to be purchased to release more labor for productive investment. Irrigation pumps augmented the land infrastructure investment allowing complete control over irrigation and drainage. This was followed by the introduction of tractors for transport and for land preparation, which, together with an emphasis on breeding short-duration crop varieties, permitted an even more intensive use of labor. Despite the heavy investment in equipment and machinery, the labor input per hectare is comparable to that of Java and yields are about 50 percent higher. Although the list of equipment is impressive, it might not differ greatly from that of a leading community in India.

The pieces of equipment currently felt to be in short supply are indicated by asterisks in Table 2. They include transplanters, seedling pullers, and grain mowers. The return to these investments are not likely to be large. In fact, over time, the return on investment in the form of both labor and capital has declined rapidly. It would appear that the opportunity for more productive investment lies in other poorer communes or in industry. China soon may need to reform its own institutions to strengthen the link between various segments of the economy in order to promote more rapid development.

In the terminology of recent literature, the commune production team is an "induced institutional change." Through the development of this institution, China has been able to lower the cost of the land infrastructure development needed to foster growth in agricultural productivity under a land constraint by fully utilizing available community labor in the off season for capital investment. It is important to emphasize that despite the incentives, institutional changes of this kind do not occur automatically. Witness, for example, the widely acknowledged failure of Russian agriculture to achieve an efficient organizational structure.

Observers are quick to recognize that the commune system in China is not transferable to other Asian countries. But the issue is frequently left at that. The historical development of land and water resources in East Asia depended on a very different set of institutions which nonetheless were based on community leadership and action. For example, Hayami (1975) describes the institutional characteristics of Japanese agriculture in the Tokugawa period and the institutional adjustments during the Meiji Restoration that made it possible to utilize community labor in Japan for irrigation development. Because the growth in population was slower and because the population pressures developed gradually over a longer period of time, institutional adjustments were worked out gradually without social disruptions.

There are also examples in South and Southeast Asia where community resources were mobilized for land infrastructure development over a fairly wide region. But these tend to be regions where strong population pressures were exerted for a long period of time. The subak systems in Bali and the irrigation societies in the Ilocos region of the Philippines are two well-known examples. The 1903 Philippine census shows that farm size in the Ilocos region was less than 1 hectare.

However, these cases are fairly rare. In most regions in Southeast Asia, as previously noted, community structures have been molded according to the traditional land surplus economy before the first turning point. The community institutions have lagged behind the rapidly emerging need for leadership and discipline necessary fo the mobilization of communal labor for construction and maintenance of irrigation systems. Such a lag in the institutional adjustment represents a major factor underlying the underinvestment in land infrastructure at the community level.

National Systems

Government investment in land infrastructure represents, to a large extent, a substitution for community investment. This investment is required when the community lacks the capacity of invest. There are, of course, some components of large-scale irrigation systems that require outside capital. However, a potentially large portion of the national systems can be developed and managed with local resources. Two types of national systems are evident: those which range from a few thousand to 100 thousand hectares and larger ones which occupy the major river deltas in Asia and sometimes cover several hundred thousand hectares. These latter schemes have a special problem which will be discussed subsequently.

In national systems, there is a potential interactive role to be played by the government and the community in both the development and the operation of facilities. In a developed society, there is normally a dialogue between the community and the government when the new irrigation system is proposed. Community interests have a major influence over the location, design and constructions of the system. In the developing economies,

the only dialogue is between the national irrigation authority and the lending agencies. As we observed earlier, both parties tend to have a capital bias in their view of the project.

Commonly, one observes the following progression of events in the development of national systems. The government initially may construct the primary and secondary canals in the system in anticipation that the local community will complete the tertiary canals and farm ditches. Partly for the lack of village organization and leadership as described earlier, the local community takes no action. The farmers may lack the organizational capacity or even the simple ditching and leveling equipment and technical advice needed to complete the job. In many cases due to poor management of water in the major laterals, there may be essentially no benefits to be gained. The farmers blame the irrigation authority who, in turn, blames the farmers. Amidst complaints that the system is not working properly, the national irrigation authority responds in the only way that it can, with more capital investment to undertake land consolidation and lay out the tertiary canals and farm ditches. The construction cost per hectare doubles (Takase and Wickham, 1976).

As with construction, the major weakness in the operation and maintenance of the system seems to be institutional or organizational rather than technical. The water delivered to each farm cannot be metered. Normally, everyone is charged an equal amount per hectare, usually only enough to cover operation and maintenance costs. However, those managing the system take no steps to ration the water and insure its equitable distribution. The farms at the head of the canal waste water; the farms at the end seldom have enough. The system operates with an efficiency well below that projected in the initial feasibility studies.

The choice among system designs at the national level is influenced by the thinking of the engineers who are primarily responsible for both designing and operating the system. The more "modern" the system, the better. For example, it is common to design systems on a standard that will allow water to be rotated within 50-hectare blocks. Such a system is compatible with the level of technical skills in East Asia. But in most of South and Southeast Asia, no advantage can be obtained from this sytem until the water can be properly controlled and distributed in the main laterals.

In short, the design of the system fails to take into account the management constraint. This natural bias toward engineering efficiency and capital intensity is reinforced by personal experience. Those who run the system know that a more labor-intensive solutions does not work because it is difficult to secure active participation of the farmers. Thus, the existing organizational and institutional structure of the irrigation network, and the weak linkage between those delivering the water and the end-users serves as the ultimate constraint to the maximization of social benefits in the design, operation, and maintenance of the system.

The large river delta schemes pose a serious problem for development. The benefits from smaller projects in the system cannot be realized until an extremely large investment is made to achieve a degree of water control which would make the smaller systems feasible. The situation is illustrated in Figure 1. A substantial upward trend in rice yields occurs in Northern India and Pakistan, and in Southern India and Sri Lanka. But yields show no upward trend in Eastern India and Bangladesh, where the crop is grown mainly in the wet season. Water control is a major constraint to increased yields in this region.[4/] Without adequate water control, the new technology has made little progress. The alternative is either to change the environment through land infrastructure investment or to change the plant type to suit the environment through research. Either alternative will require a considerable amount of time and investment before there are benefits substantial enough to encourage either private or community investment.

In closing this section on land infrastructure development, I would to emphasize two points. First, the three forms of irrigation development-tubewells, communal irrigation systems and national systems are by no means complete substitutes for one another. We have to differentiate between situations in determining which form of capital investment is better. The large river deltas, for example, clearly require significant public investment before private or communal investmens could become profitable. In many situations, however, it does appear that substitution of community labor for public investment could reduce the cost of irrigation development and make fuller use of existing labor. The free market economies encounter considerable difficulty in organizing community labor for capital investment. This is a form of "market failure".

Second, the sequence of capital investments is extremely important. Land infrastructure development paves the way not only for the use of modern inputs such as new seed and fertilizer, but also for productive investment in other forms of capital such as tractors. The historical experience of East Asia and Mainland China provides evidence of the importance of the time sequence of investments. Initial investments should raise the productivity of subsequent investments and in the labor surplus economies expand employment opportunities.

The Pressures for Induced Technological and Institutional Change

There have been a number of recent attempts to determine whether future food supplies in Asia will be adequate to meet future demand (IFPRI, 1976; IBRD, 1976; and ADB, 1977). Despite the differences in assumptions and projection techniques, these studies indicate that current trends would lead to a sizable gap between food grain production and demand in Asia by 1985, ranging from 25 million tons (IBRD, 1976) to 40 million tons (IFPRI, 1976). These studies are somewhat academic since on a world basis,

supply (excluding stocks) must equal demand in the target year, but they are useful to indicate the magnitude of the pressure to increase food supplies.

The studies which attempt to estimate the magnitude of the investments required to close this gap are more useful. The Trilateral Commission Report (1977), which devotes most of its attention to irrigation, estimates that food grain production can be doubled at present levels of technology by 1990 (4.8 percent per annum) at an annual irrigation investment cost of $4.5 billion (at 1975 prices) or about 6 times the current investment rate of 700 million. This implies an annual growth in irrigated command area of over 5 percent per annum compared with the current rate of 2 percent. Based on a more modest irrigation growth rate of 3 percent per annum, Herdt, et. al (1977) project a growth in food production of 2.4 percent at current levels of technology. Thus, without further gains from technology in the next decade, this rate of growth in irrigation will be inadequate to meet a 3 to 4 percent frowth in demand.

Change in output per hectare is the product of change in capital intensity (capital per hectare) and change in capital efficiency (output per unit of capital invested). As noted earlier, the introduction of modern seed-fertilizer technology has had the effect of improving the efficiency of capital investment. However, as fertilizer input approaches the optimum level on existing irrigated land, increased capital intensity will have to compensate for the declining contribution of fertilizer to output growth. Furthermore, as irrigated area continues to expand, the cost of developing new lands for irrigation will rise gradually. Kikuchi (1975) shows that the cost-income ratio rose sharply in Taiwan and Korea following the introduction of modern inputs in the 1920s. This ratio currently is rising in the Philippines and probably in most other parts of Asia.

The extraordinary growth in capital requirements for land infrastructure development over the next decade will create a strong incentive to improve capital efficiency. The response to this incentive should take the form of increased activity in the development and introduction of technological, organizational, and institutional innovations. Technological change can be embodied in new forms of capital such as the bamboo tubewell, or in modern rice varieties that perform well under poor water control conditions. There also will be mounting pressure to improve technology for the non-irrigated regions. It can be anticipated that research in the biological sciences and in engineering will bring technological advances in these areas, although there are no major breakthroughs on the horizon at present.

In summary, it has been observed that a number of developing countries in Asia have only recently transcended from land to labor surplus. For these countries, land infrastructure is currently the most critical capital investment needed to increase agricultural production. Such an investment could be achieved most efficiently by full utilization of community labor in the development and operation of irrigation systems. However, the social structure of these economies has been molded under centuries of land surplus

condition (particularly Southeast Asia) and under a highly skewed farm size distribution (particularly South Asia). This social structure erects a formidable barrier to the investment of social overhead capital at the optimum level.

In order to keep pace with food demand, public capital investment needed to maintain the growth in agricultural production should increase sharply over the next decade. There will be strong incentives for institutional reforms and other measures to raise the productivity of these investments. There is a growing recognition that the "software" of land infrastructure development has been neglected, but no clear understanding as to what organizational and institutional changes are needed, and under the existing social structure, what can be accomplished. Social science research that comes to grip with these issues can accelerate the process of change toward a more optimum institutional structure.

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1/ This is the term used by Y. Hayami (1975). As used in this paper, it includes private investment in tubewells as well as public investment in canal irrigation systems, although the latter represents the major portion of investment.

2/ Although the bulk of farm surveys suggests that mechanized farmers have higher yields than non-mechanized farmers, the impact of tractor adoption is invariably confounded with fertilizer input and other management factors. Experiments on rice farm fields in the Philippines using 5 combinations of tractor and animal power under 3 soil conditions showed no gain in yield for mechanization.

Personal correspondence with Binswanger, Hans, Agricultural Development Council, Hyderabad, India (1977) conducting a survey of the literature on mechanization in South Asia supports Duff's (1976) conclusion that output gains have not occurred in most cases.

3/ A concept developed by Ishikawa (1967).

4/ Not everyone would agree with this statement. There are many scientists who argue that the appropriate technology does exist, but there is a "constraint" in moving this technology from the experiment station to the farmer's field. While it is indeed wrong to suggest that all of the problems of Eastern India and Bangladesh can be solved by adequate water control, I doubt that extension of existing technology is currently the dominant constraint in most areas.

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Table 1. Estimated proportion of growth in rice output attributed to components of area and yield for selected Asian countries, mid-1960s to early 1970s.

Country	Period	Annual rate of production growth (%)	Percentage points (%) attributed to Area		Percentage points (%) attributed to Yield	
			Irrigated	Unirrigated	Fertilizer[a]	Residual[b]
Pakistan	1965-73	7.9	1.4	0	1.7	4.8
Malaysia	1965-73	5.7	3.7	0.1	1.4	0.5
Sri Lanka	1965-72	5.6	0.5	0.1	3.5	1.5
Indonesia	1965-72	4.8	2.2	-0.3	1.1	1.8
Philippines	1965-73	3.4	1.2	-0.3	1.5	1.0
India	1965-70	3.2	0.6	0.2	1.5	0.9
Thailand	1965-72	2.1	0.2	1.7	0.3	-0.1

[a]Calculated on the basis of 10 kg of yield for every 1 kg of fertilizer.

[b]Includes the contribution to yield of improved quality of land due to higher proportion of irrigated area.

Source: Robert W. Herdt, Amanda Te, and Randolph Barker (1977).

Table 2. Inventory of agricultural machinery in Chien Chan Commune, Wusih Country, Kiangsa, China.

	1966	1976
*Diesel engine (12 hp)	-	243
Diesel engine (25 hp)	-	11
Diesel engine (4 hp for transplanter)	-	37
Gasoline engine (4 hp for transplanter)	-	30
Hand tractor (12 hp)	2	171
Large 4-wheel tractor	-	1
*Seedling puller	-	4
*Transplanter	-	25
*Mower for grain	-	18
Electric motor	288	1112
Thresher (electric)	231	368
Thresher/cleaner (electric)	-	54
Power sprayer	-	54
Hand sprayer	312	802
Duster	3	177
Boat engine	-	65
Grain cleaner	-	285
Pump with motor	61	224
Crusher for water plants	-	5
Flour grinder	12	40
Rice miller, 5 FPH	24	38
1-ton trailer	-	14
Rice huller	2	2
Huller-crusher for wheat	1	2
Hand cast for 2-wheel tractor	-	124

*Indicates the machines in short supply.

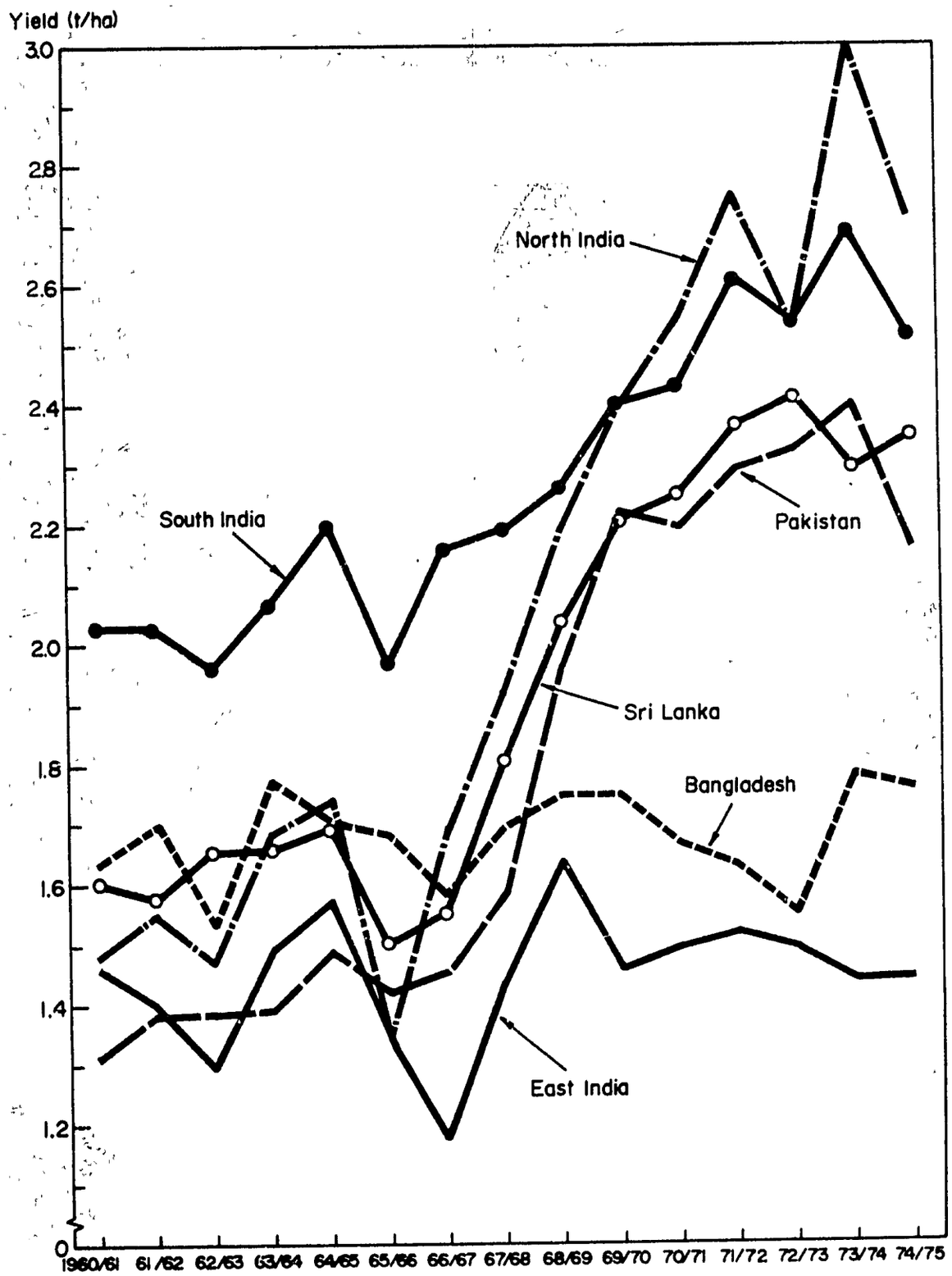

Fig. 1. Rice yield trends in 3 regions of India, Bangladesh, Pakistan, and Sri Lanka, 1960/61 to 1974/75.