THE CHINESE METHOD OF TECHNOLOGICAL DEVELOPMENT

—The Case of the Agricultural Machinery and Implement Industry—

SHIGERU ISHIKAWA

I. INTRODUCTION

THIS PAPER aims to study the economic processes leading to remarkable technological development in the People's Republic of China, especially since the middle 1960s, on a basis which makes possible comparison with the experiences of other contemporary developing nations in technological development. The study will be made with regard to the case of the agricultural machinery and implement industry.[1]

The choice of this case is considered relevant for the reason that in China the technological development of this industry has characteristics common to that of most other industries, and some of these characteristics are exhibited in this industry rather emphatically: (1) the products of this industry now range

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[1] This paper presents a new study pursuant to (1) S. Ishikawa, "A Note on the Choice of Technology in China" (1972) [4] and (2) idem, "Chūgoku ni okeru gijutsu hatten no ichi kenkyū" [A study on Chinese technology development] (1975) [5]. The former attempted to assess the development of the Chinese technology policy between 1953–72 by stages, as far as it could be dealt with by reference to the analytical framework of choice of technology from among the existing ones. Thus the focus was on the process by which the Chinese government came to choose so-called intermediate technologies in many fields of industry and agriculture with an accompanying institutional device whereby human initiatives and material resources were mobilized in each locality. Alternative choice formula which seem to correspond to the Chinese policy in the successive stages were studied heuristically. The latter involved an extensive survey of what constitute the characteristics of Chinese technology development in the manufacturing sector for the years 1950–73. The underlying framework was different from the choice of technology in the conventional sense. It dealt with the direction of technology development which resulted from factors on both the demand, and the supply, sides of new technologies. The present study takes up the technology development of the agricultural machinery and implement industry as a case study of the subject discussed in the latter. The aim is to put a sharper focus on the role of the government as well as on the behavior of the supply agents of new technology in the whole mechanism of technology development in contemporary China.

from technologically sophisticated agricultural machines (China is now capable of manufacturing nearly all kinds of previously imported agricultural machines with adaptive redesigning) to improved agricultural implements based upon so-called intermediate technology and the traditional implements of the indigenous technology; (2) side by side with this, a multilayer industrial and social organization of agricultural and implement manufacturing firms has been established as a well-coordinated and cooperating system: (a) on the *top* layer are modern and most often large-scale enterprises run by the central and provincial governments (some of them are organized as a network of main and ancillary firms), (b) on the *middle* layer are newly emerged *hsien*("county")-run enterprises, and (c) on the *bottom* layer are handicraft factories and cooperatives and newly emerged People's Commune factories and Production Brigade workshops; (3) technological development in the agricultural machinery and implement industry has been brought about by dynamic interaction with that on the side of the user industry—interaction which is particularly distinct here since the technological development of the user industry, agriculture, which involves the modernization and mechanization of traditional farm equipment and implements, has been steady and, in certain regions, even rapid, for the past decade.

Another reason for the choice of this case is the observation that in some developing countries in Asia the agricultural machinery industry is one of the few industries which have emerged recently on the basis of successful imitation and adaptation of foreign machinery and equipment. The tendency of agriculture towards technological development involving mechanization has also been distinct since the middle 1960s. Therefore, the aim of doing the study on a basis which makes comparison possible may be well served by choosing this industry as the case.

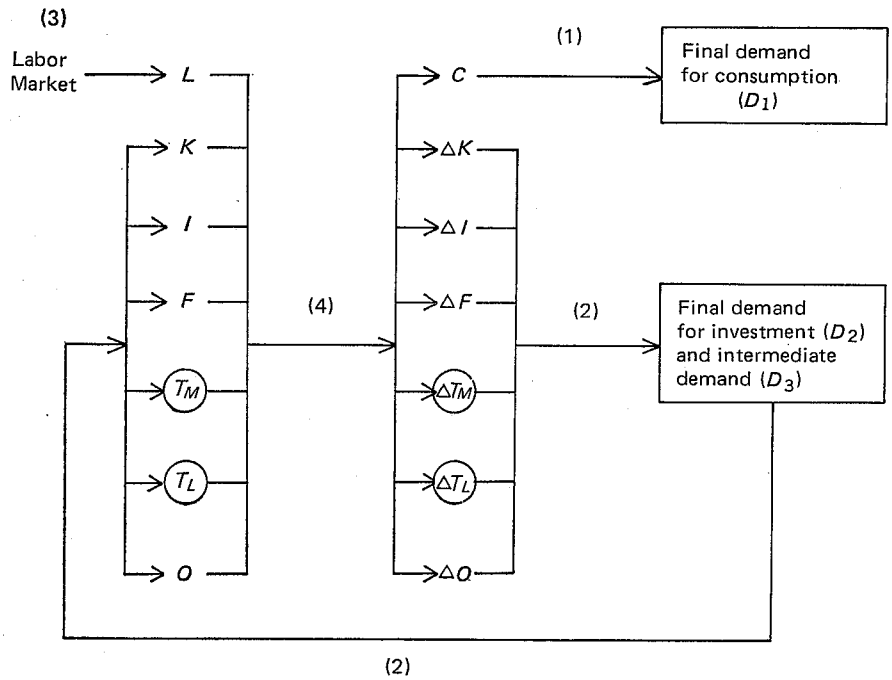
In the following, Section II will present heuristically a general model of the economic processes for technological development that would be applicable to both the planned economy system and the market economy system. Sections III and IV will examine, with this general model kept in mind, certain characteristics of these processes in the Chinese agricultural machinery and implement industry. Section V will try preliminarily to conclude the findings in Sections III and IV by comparing them with some experience in other developing countries of Asia.

II. A GENERAL MODEL FOR COMPARATIVE ASSESSMENT

Figure 1 represents the macroeconomic aspect of a general model of technological development, where all the variables indicate aggregative magnitudes for the economy as a whole,[2] although it can also be taken to represent in aggregative terms the process of technological development in individual industries such as the agricultural machinery and implement industry (hereafter abbreviated as AMI industry, which also is sometimes separated into AM and AI industries). It should be emphasized that in this model the technological development (ΔT, which may be separated into ΔT_M and ΔT_L) is brought about by a process

[2] This model is built by adaptation from R.C.O. Matthews [9].

Fig. 1. Macroeconomic Relations of Technological Change—A General Model



Notes: 1. Notations—L: Labor; K: capital goods; I: intermediate goods; F: foreign currency; T_M: physically embodied technological knowledge; T_L: human-embodied technological knowledge; O: managerial and organizational capability; C: consumer goods output. Δ stands for an addition.

2. Arrows indicate the direction of transformation.
3. For (1)–(4), see the discussion in the text.

constituting part of the entire macroeconomic process of transformation from (1) through (4). This treatment is convenient, because (a) while technological development is an independent product in activities like R&D, importation of foreign technologies, and, in a somewhat indirect sense, education, it is brought about in current production as a byproduct (such as by "on-the-job training" and "learning by doing"); (b) ΔT_M is mostly embodied in ΔK and ΔI and ΔT_L in ΔL; and (c) in many cases ΔO act as a critical factor for realizing the potentiality of ΔT.

The role of ΔO, when it is allocated to the government, should also be noted. It is not only the source of the capability for formualting and implementing an appropriate economic policy of a familiar sense, but also the source of the capability for adequately intervening in the existing institutions and organiza-

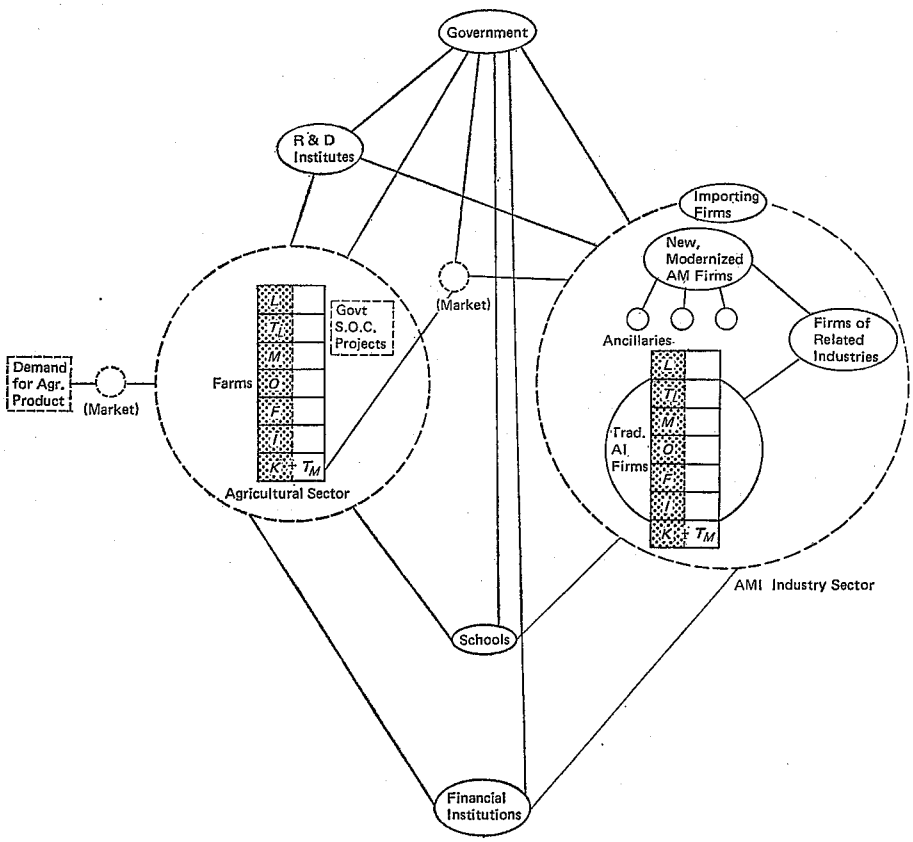
tions of the society, and thereby bringing about realization of the potential of the existing resources to a fuller extent.[3]

The performance of technological development can be assessed in two steps:

(1) In a particular economy, the performance is compared with an ideal one which is attained when the potentials of the existing resources are realized to the maximum extent, and the resource allocation is done optimally.

(2) The performance of a particular economy is also compared with the

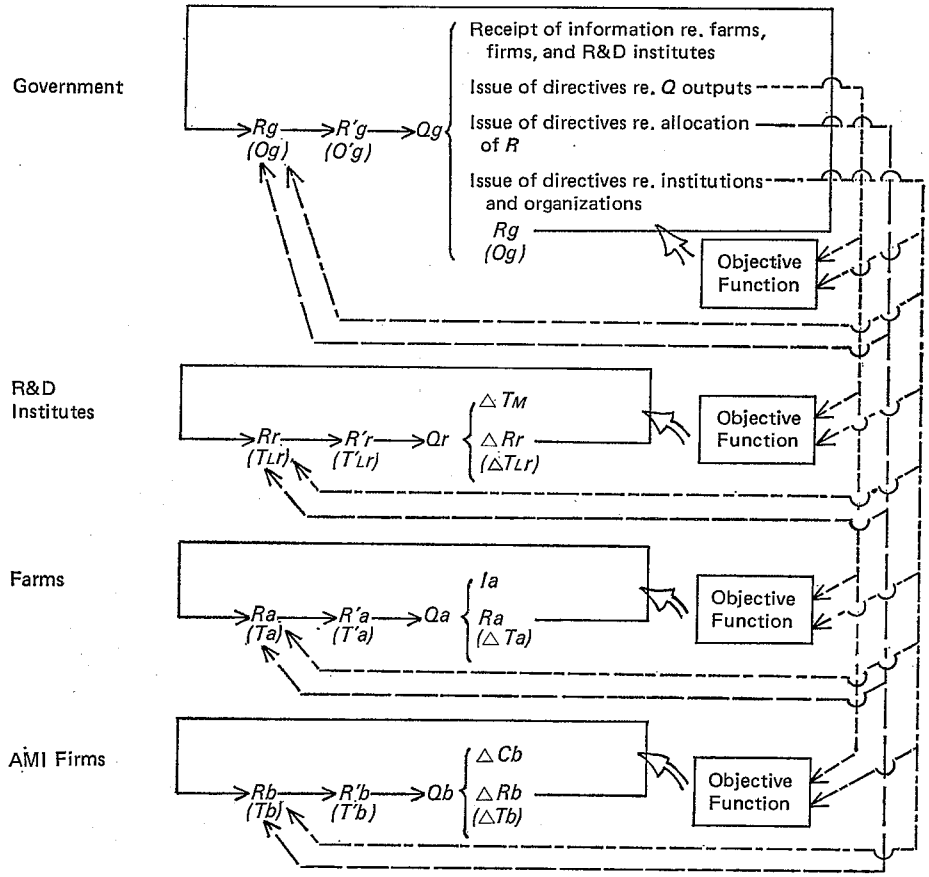
Fig. 2. Agents of Technological Advancement and Their Interrelationships—The Case of the Agricultural Machinery and Implement Industry



Notes: Circles indicate the change agents; rectangles indicate the resources of each category of agents (no significance should be attached to their relative size), with the shaded rectangles standing for its initial endowments and the rectangles without shades for the external resources obtained as the farms or the firms grow; the resources of the other categories of agencies are not indicated; F indicates monetary savings; the lines connecting the agents, or the agents and sectors, indicate the interrelationships, the nature of which is discussed in the text.

[3] "Realization of the potential of the existing resources" is a notion in some sense similar to what Professor Leibenstein called X-efficiency, which is separate from allocative efficiency [8].

Fig. 3. The Role of Government—A General Model



Notes: 1. Suffixes *g*, *r*, *a*, and *b* indicate government, R&D institutes, farms, and AMI firms, respectively.

2. Variables in parentheses illustrate some crucial ones among the resources (R) possessed by the respective change agents.

performance of other economies, allowing for the differences in (i) the patterns of final demand for consumption, (ii) the people's time-horizon, and (iii) the level of productivity development.

Figure 2 indicates what are possibly the main categories of agents of technological development and how they are interrelated, by taking up the case of AMI industry. The farms in the agricultural sector are indicated here as an important category of the change agents, since they are in this case the users of the products of AMI industry. The aggregative R and Q of Figure 1 are here distributed among the change agents, as is shown in Figure 2 in the case of farms and AMI firms. While the specific nature of the interrelationship is not indicated, it consists either in the flow of the existing technological information, the flow of information on the need for technological changes, or government intervention in resource allocation and in institutions and organizations of each category of other change agents.

This figure suggests that from the microeconomic point of view, the economy's performance in technology development is conditioned by the interrelated economic activities of each individual change agent which in turn are conditioned by the specific behavior pattern of the agent, its resource constraints, the institutional constraints, and the nature and activities of the related agents and organizations. The microeconomic process of technological development is, however, shown only in Figure 3 with regard to a special change agent, the government. Here, the major products are various kinds of information, which contribute to technological development only through their effects upon the production process of other change agents. The process of transformation, $R \rightarrow R'$ refers to the realization of the potentials of R in any degree. The exact degree is influenced significantly by the quantity as well as quality of the information issued by the government. It should be noted that this applies not only to the transformation within ordinary change agents but also to the transformation within the government itself.

The above model is presented, not for assessing the performance in technological development of China's AMI industry rigorously in terms of it, but for indicating the framework of reference for identifying those parts or aspects of it which functioned significantly in realizing the above-noted performances. The study is made in the following three parts: (1) the role of government, (2) behavior of the technology supplying agents, and (3) activities of educational institutions.

III. THE ROLE OF GOVERNMENT

The role of government in bringing about technological development in AMI industry has become increasingly comprehensive, active, and even effective since the second half of the 1960s. This can be observed in the government involvement both in technological upgrading of AMI industry itself and in technological development of the agricultural sector relating to the use of AMIs.

A. *Technological Development of Agriculture Relating to AMI*

1. *Discovery by government of needs in relation to technological development*

In the 1950s, there was a search for a perspective on the agricultural mechanization which was to be brought into force by the expansion of state-owned tractor stations equipped with AM imported from Soviet Russia and located in the priority agricultural regions. There was also an interim plan for large-scale dissemination of newly designed, improved AIs such as animal-drawn double-wheeled-double-share plows. Both of these were, however, more or less unsuccessful, mainly because the government was unable to perceive the real needs of both the individual farms and the economy for technological development in relation to AMIs. Perception of the individual's needs is important in the planned economy where they are usually not revealed by the market mechanism and, hence, are liable to be neglected without deliberated efforts. The government perception of the economy's needs refers to activities consisting of two sets of

processes: (1) the choice from the list of alternative sets of available AMIs of a socially desirable set in each individual locality, and (2) the choice of a socially desirable direction of R&D both at the local and national levels for enlarging the spectrum of available AMI sets which constitute the above list. The concept of social desirability suggests that governments should have deep understanding of prospects for agricultural production and the social organization of farms, and also of the technological and economic potentialities of the suppliers (AMI firms) and users (People's Communes reorganized since 1962 in a new structure characterized by "three-level ownership" with the basic ownership units being Production Teams consisting of roughly thirty farm-families). The requirement of perceiving these individual and social needs has, though it was difficult indeed, gradually been satisfied since the middle 1960s. Practical steps for this perception or discovery are our concern. They are described under the following four heads:

(1) "Mass AI Reform Campaigns"

This campaign was first organized on a nationwide scale in 1958 as part of the well-known Great Leap Forward Movement. It was again organized in 1964 and afterwards for implementing a policy of AMI modernization with priority on "semimechanized" AMIs. This was basically an ad hoc measure to encourage and help the working peasants' innovations of improved AIs on the basis of their own perception of the needs and the best technological capability in the locality. It ranged also to the processes of trial of new AIs, their manufacture and dissemination. The specific steps adopted are exemplified below by taking up the case of Ta Li *hsien,* Shensi Province during the first Mass AI Reform Campaign [3, 1958, No. 13, pp. 87–89].

Participants in design and manufacture of improved AIs: (i) woodworking teams, metalworking teams, and "skilled members in AI" from each agricultural cooperative, (ii) cadres of village governments and ACs, (iii) retired soldiers, (iv) graduate students who returned to their home villages, and (v) any other villagers.

Government intervention: (i) At the stage of villagers' designing and manufacturing of improved AIs, village government extended, through the agricultural cooperatives, required help and facilities to the participants. (ii) Upon emergence of each individual new AI, responsible officials of the *hsien* and village governments paid visits to the innovators to compliment them on their success, and designated technical personnel for making appraisal. (iii) The village and/or *hsien* governments further organized mass discussion meetings, exhibitions, and/or on-the-spot meetings for individual new AIs. Various suggestions for additional improvements or modifications were made at these meetings by the audience, which were taken up seriously by the government in consultation with the technological personnel. This also facilitated the aim of a more rapid dissemination.

The article introducing the above case suggested that the working peasants' potentiality for innovation of AIs would not be realized if the government did not recognize their importance and put them on the agenda of their administrative work. "Three fears" held by the potential innovators among the peasants were

noted: a fear of being accused by other villagers of attempting a novel thing, a fear of putting themselves to shame, in addition to a loss of money, in the case of an unsuccessful attempt, and a fear of no other villagers' being willing to use the innovation result even if it should be successful and, therefore, of losing family assets.

In the Mass AI Reform Campaigns after 1964, certain changes in the procedures were seen, such as that the trials of new AIs before the dissemination were more formalized and made more rigorous by making obligatory the upper-level government's, or the R&D institutes', testing and judgment. However, the essential ingredient of it, namely the discovery of individual and social needs by encouraging the working peasants' innovations, seems to have been unchanged.

(2) Institutionalized Contacts with People's Communes

Since the middle 1960s the above ad hoc method for the discovery of needs seems to have been gradually replaced by institutionalized contacts of the government agencies responsible for the application of AMIs, R&D institutes, and even AMI manufacturing firms with the actual production-points in the agricultural sector. While diverse steps were adopted for this purpose, the followings seem to have been fairly universal: (i) Selection of a particular People's Commune (or its Production Brigade or Production Team) by Agricultural Departments (Bureaus) and AMI Popularization Stations of provincial or *hsien* government as "experimental points" for application and dissemination of new AMI, where the member farmers' opinions and experience were consulted and their suggestions for improvements and modifications were taken up, and where new directions for AMI modernization were perceived.[4] (ii) R&D institutes on AMI (whose nationwide network was established already in the middle 1960s with the top at the Agricultural Mechanization Science Academy in Peking and the bottom at the AI institutes in most of the roughly 2,200 *hsien* all over the country) were to dispatch work teams to particular People's Communes (brigades or teams) for doing research and investigation and for consulting the working peasants' experience and opinions, in connection with particular R&D tasks assigned.[5] (iii) R&D institutes were to compare peasant innovation outcomes of similar kinds, and to generalize the essential technological ingredients contained. Results were sometimes major innovations.[6] (iv) Provincial and especially

[4] E.g., the case in an "experimental point" of the AM Institute of Hunan Provincial Government at Huashan People's Commune in Ch'angsha *hsien* of application and dissemination of semimechanized AMIs such as disk harrows, motorized rice-harvesting machines and dry-land fertilizer application carts [1, 1964, No. 10, pp. 21–22]. As for the provincial "experimental points" for mechanization, Jinhsin Production Brigade in Hsiao Kan *hsien* and Liuchi People's Commune in Hsinchou *hsien*, both in Hupeh Province, are some of those well known [6, Apr. 9, 1966, July 27, 1965, Sept. 6, 1971].

[5] E.g., the case of the AI Institute of Tung An *hsien*, Hunan Province [1, 1965, No. 2, pp. 7–8].

[6] Introduction of electric plow is one example. It is used widely in the muddy rice fields of Yantze River deltaic provinces where it is not possible to plow by use of tractors (see, for example, the report on Chia Hsin *hsien* of Chekiang Province [6, Sept. 1, 1971]). This was an innovation originally made at the Agricultural Mechanization Institute of

district and *hsien* level AMI firms were advised to investigate systematically the local demand for specific models and kinds of AMIs and the operating conditions of the existing AMIs in the localities. They were also asked to dispatch their own AMI repairing teams to as many People's Communes and Production Brigades as possible and to help train technical manpower there.[7] (v) "Skilled peasants in AI" were regularly appraised and promoted to posts in AMI factories and R&D institutes (e.g. [1, 1964, No. 10, pp. 23–24]).

The method of technological progress in AMIs by "three-in-one" combination of R&D institutes, manufacturing firms, and users (or their representatives), which will be described shortly, seems to have become really effective mainly because each of the three agents was thus perceptive of the peasants' own needs and experience.

(3) Choice of Particular Steps for Mechanization

This refers to the case where the local governments (mainly the *hsien* governments since the end of the Cultural Revolution), on occasions of nationwide movements for increasing agricultural production, chose particular steps for semi-mechanization and mechanization commonly suited to the conditions of individual localities. This choice was to be made by consulting the lists of available AMIs already tested within individual localities, and also on the basis of the deep understanding of various constraints in the localities. In the production increase movement accompanied by the semimechanized AMI campaign after 1964, it was directed that the choice of priority AMIs would be either cultivating AMIs, transportation AMIs, or AMIs for agricultural product processing, depending on the locality [6, Oct. 15, 1964, editorial]. To take the case of Honan Province where frequent calamities coming from both flooding and drought resulted in a meager financial position for the majority of the production teams, the resulting choice was first to develop manual- and animal-powered carts with rubber-tired wheels, one of the cheapest means of AMI modernization.[8]

In connection with agricultural mechanization, the first choice of Hsin Chou *hsien* in Hupeh Province, where both drought and water-logging were the main impediments to agricultural expansion, was the introduction of motor-powered machines for irrigation and drainage. In arriving at this choice, the planners (in this case the *hsien* party officials) were given a hint from their past experience that, in an anti-drought campaign in 1956, a cooperative successfully overcame a serious water shortage by borrowing from a nearby factory two diesel engines for irrigation. The choice in the next stage was to introduce threshing and other agricultural product processing machines which could be used with the diesel

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the Chinese Science Academy based upon generalization of the peasants' innovation of a machine-operated cable-towed subsoil plow [3, 1958, No. 17, p. 95].

[7] See, for example, the case of AMI factories in Shenyang City in [6, Feb. 17, 1975], the case of AMI factories in Paochi City (Shensi Province) in [6, Mar. 16, 1975], the case of Fuyang *hsien* AMI Enterprise (Chekiang Province) in [6, Mar. 21, 1969], and the case of Funien *hsien* AMI Enterprise in [6, Mar. 20, 1969].

[8] See [6, Oct. 15, 1964, editorial] and article by Hsiang Nan [6, July 6, 1965].

engines in the period when they were not used for irrigation and drainage. The choice of small-scale and hand tractors came afterwards when the use of the above categories of AMs resulted in an accumulation of funds in many Production Brigades that was sufficient to purchase them [6, Sept. 6, 1971]. This pattern of successive choices for AM (irrigation equipment, processing machines, and tractors) became a model for wide areas not necessarily confined to the southern rice-producing regions. Even when this model was followed, however, the choices of specific AMs by governments in various localities appear to have been geared to the bottlenecks for production increase that were perceived as particular to individual localities.[9]

(4) Role of the Commercial Network

In ordinary market economies, the role of discovery of the users' demand is played mainly by the dealers and other commercial agents. In China the similar role played by the socialized commercial organizations (consisting of the State Trade Companies and the Supply and Procurement Cooperatives) was limited for the following two reasons. (i) The geographical system of commodity markets in rural areas was traditionally, and even in the period of the People's Republic, not well developed. Thus, most of the retail shops and the procurement stations of the socialized commerce organizations were, until the 1960s, located in the traditional market towns and the upper level market centers; those located in the natural villages far from the market towns were relatively few.[10] (ii) All the units of the State Trade Companies and the Supply and Procurement Cooperatives were management units whose activities were subject to centrally determined physical targets similar to those for the state manufacturing enterprises. The most important targets were those indicating the quantities of individual major commodities to be sold or procured and the total amount of sales and procurements. The target for profit was in existence, but its importance was only secondary to the above.[11] Hence, there were few attempts by the rural units of these organizations to discover, on their own initiative, the users' demand for either new, or existing AMIs or to promote the users' purchase of them.

The remarkable performance, as indicated in the above four paragraphs, in the discovery of needs for technological development in AMIs by the government itself and by the change agents may be explained partly in terms of filling the gap thus created by the insufficiency and deficiency of the operation of the market functions. Yet, since the mid-1960s and especially since the Cultural Revolution, the socialized commercial organizations themselves have come to assume the role of a change agent in technological development of AMIs. Three

[9] See examples of Tsun Hua *hsien,* Hopeh Province in [6, Sept. 15, 1971], Chia Hsin *hsien,* Chekiang Province in [6, Sept. 1, 1971], and Pa *hsien,* Hopeh Province in [6, Jan. 17, 1973].

[10] This does not mean that the space system of the market was underdeveloped in the traditional sense. It in fact developed very much—to the extent that, according to a well-known paper by Professor Skinner, the geographical space of the whole of China was filled up with the standard marketing areas of a hexagonal shape [13].

[11] See the discussion on the microeconomic problem of the state enterprises in Section IVB.

events should be noted. (i) Since 1969 a new program has been in progress, designed to expand the frontier of the socialized commercial network in rural areas down to the level of Production Brigades (see [6, Jan. 6, 1973]). The achievement of this program seems to have been facilitated by the extensive movement for constructing rural road networks during and after the Cultural Revolution (e.g., see [6, June 18, 1963 and Jan. 18, 1975]). Side by side with it, the establishment of retail and/or procurement stations at the Production Brigade level has been placed under the double control of the People's Communes concerned and the upper level socialized commercial organizations. This seems to be instrumental in encouraging these retail and procurement stations to take the initiative in orienting their activities towards the needs of the member farmers of the Production Brigades in various ways (e.g., see [6, Jan. 18, 1969 and July 19, 1974]). (ii) The socialized commercial organizations at the *hsien* and district level have been instructed to investigate the needs for AMIs in each locality and even to make arrangements to manufacture and supply the required AMIs within the locality (e.g., see [6, Mar. 21, 1969 and June 17, 1973]). (iii) They have also been instructed to identify the potential local products to be developed for marketing and to advise the Production Brigades and Teams to develop them. The intended result is an increase in purchasing power, making it possible for farmers to obtain a larger quantity of new AMIs (e.g., see [6, Dec. 12, 1971 and Mar. 13, 1972]).

2. *Transmittance of the discovered needs to the supply agents*

The discovered needs for technological development relating to AMIs were transmitted to the supply agents of new technology (AMI firms, R&D institutes, and importing agencies) either by the governments which discovered the needs or by the supply agents themselves which participated in the activities of discovering the needs under the government directions. Therefore, the efficiency of this transmittance depended on the discovery of the needs described above and on the supplies responding to the transmitted needs which will be described in Section IIIB.

3. *Government assistance for upgrading the technical capability of the users*

The significance of this step is implied in the above-discussed concept of social desirability in the choice of technology in AMIs. The main issue here was how to help the People's Communes (and their subunits) overcome the state in which they were incapable of using and managing the newly purchased AMIs appropriately.[12] Three measures may be noted: (i) A "three- (or four-)level network" of AM stations was established already in the early 1970s in many *hsien* under the control of the Bureau of AM Administration of the *hsien* governments. This network extended to the AM administration districts, People's Communes, and even down to Production Brigades. The technical assistance was being given to the People's Communes through this network. (ii) A similar "three-level network" of factories repairing and manufacturing AMs was established, con-

[12] The same source as in note 9.

sisting of *hsien* level government enterprises, People's Commune factories, and Production Brigade shops. In 1973, it was reported that 96 per cent of *hsien* in the country had established the AMI enterprises, and the three-level network downward was gradually in the making. The principal aim of this network was to increase the utilization ratio of AMIs in People's Communes, by enlarging the supplies of machines attached to tractors and engines and also of AM parts and components mainly at the *hsien* level, and by increasing the activities of repair and maintenance of AMIs at each of the three levels. This was resulting in a remarkable increase in the technical capability of People's Communes in use of AMIs. (iii) The central and provincial level enterprises for manufacturing AMs were also advised to help directly the technical capability of the People's Communes to use their product AMs by a variety of measures the discussion of which, however, is omitted here.

B. *Technological Development of AMI Industry*

The discussion of the government intervention in technological development in AMI industry will be made here by assuming that the transmitted needs of AMI modernization had specified within fairly narrow ranges the kinds of technologies to be chosen from among the existing ones and the direction of R&D to be chosen for developing new technologies.[13] The discussion will also be confined to the case of technological development in AMI industry which concerns the development or manufacturing of new products (in contrast to new processes), embodying new technology,[14] for which it is necessary either to build up new factories or to remodel and enlarge existing factories.

1. *Government effort at building up a systematized industrial organization of AMI firms*

In the early 1950s, AMI industry in China consisted simply of handicraftsmen and artisans scattered in small cities and the countryside. They were reorganized gradually into handicraft factories or cooperatives, and technical capability was also gradually raised: the kinds of their products were extended from the traditional small- and medium-sized AIs to the improved AIs. The number of these factories and cooperatives amounted to 25,000 and the number of workers engaged to 810,000 persons in 1966.[15] The central government started in 1955 and 1956 to construct a few large-scale, modern factories manufacturing Soviet-model tractors, which began operation only in 1959 and thereafter. Later on, a number of modern AM factories were established mostly as central and provincial enterprises. Side by side with this, the kinds and amount of AMs and their parts and components produced were increased. However, the major base of production of AMIs was, even in the middle 1960s, still on the handicraft

[13] For a full-fledged discussion of Section B, it is necessary to rearrange the analytical framework of AI in such a way as to be able to bring into focus both the choice of technology in AMI industry from among the existing ones and the choice of the direction of R&D in AMIs; the assumption here should accordingly be removed.

[14] "New" technology is conceived here either from the national, or from local point of view.

[15] Liu Chieh's article in [6, Jan. 4, 1966].

factories and cooperatives. There was a large technological gap between them and the small sector of modern enterprises in terms of both products and production facilities. This gap was coming to be filled up and the technical diffusion channel was gradually built only after the second half of the 1960s, when the *hsien* level enterprises on AMIs and the "three-level" network of repairing and manufacturing AMIs began to be established.

The steps for establishing the *hsien* level enterprises were impressive in that the *hsien* government officials, who discovered the needs of AMI modernization, made all-out efforts in establishing *hsien*-run enterprises on AMIs by reallocating existing human and material resources under their control and also by mobilizing the potentials of these resources, insofar as the required AMIs were expected to be produced in their own *hsien* (see [12] [4]). While there were cases in which the *hsien* enterprises were established as "reconstruction," the original enterprises had been in most cases small workshops in terms of the size and quality of either buildings, equipment, or manpower. New manpower was mainly recruited from the workers previously employed at the handicrafts and "street factories," members of city working class families and, in the case of skilled workers, from the existing *hsien* enterprises in other branches of industry. The equipment required was transferred from the existing *hsien* enterprises or self-manufactured by a traditional labor-intensive method called *tu-fa,* which will be described later.

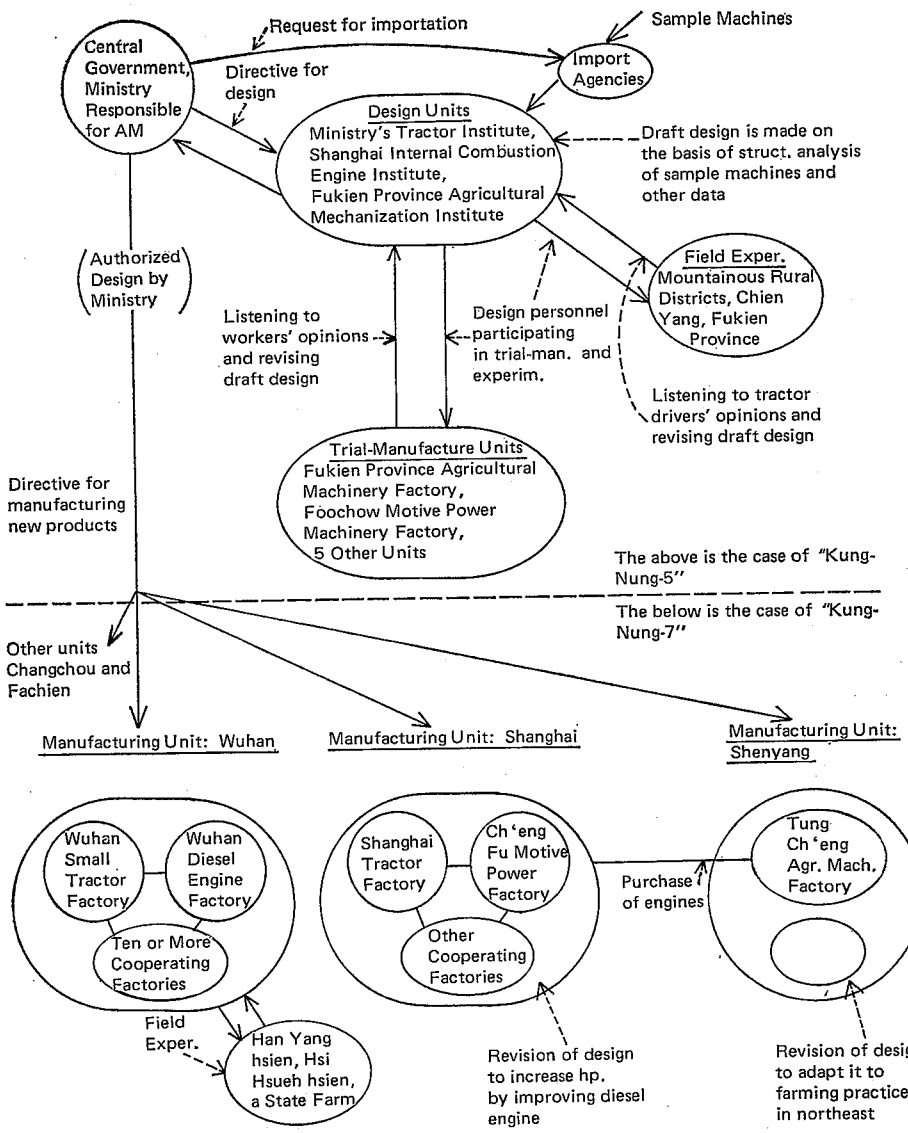
In some *hsien* with rich mineral and power resources, not only were the *hsien* enterprises on AMIs developed considerably, but also backwardly linked industry was established to support the AMI enterprises in terms of the supply of scarce materials and fuels and also in terms of the reduction in costs. A typical example was Tsun Hua *hsien,* Hopeh Province where in 1971 the number of *hsien*-run AMI enterprises was ten and, in addition, there were eight central repair and manufacture stations. The established, backwardly linked industry comprised a small iron and steel enterprise, a small coal mine, a small nonferrous metallurgical enterprise and a small cement enterprise, all run by the *hsien* government [6, Sept. 15, 1971]. There were, however, regional differences. In some *hsien* like Pa *hsien* of the same Hopeh Province where no mineral or power resources were existent and the industrial base was still very weak, the total number of AMI enterprises established by the *hsien* government by 1971 was only one [6, Jan. 15, 1973].

The steps for establishing central or provincial level enterprises on AMs were in fact the usual procedures for formulating and implementing the state or provincial economic plan for capital construction, which were very formal and inflexible; hence, they are not very interesting, although the underlying perspectives for building up a modern systematized AM industry are yet to be explored.

2. *Institutionalized steps for developing new products*

The steps for developing new products embodying new technologies will be discussed here only as far as the central and provincial enterprises are concerned. In Figure 4 is shown the government role exhibited in the processes of designing, trial-manufacturing, experimentation, and manufacturing which led to the emergence of a new product (in this case, the process up to the completion of

Fig. 4. The Process of Developing a New Product—The Case of a Hand Tractor



a final design is shown for the case of "Kung-Nung-5" hand tractor[16] and the rest of the process for the case of "Kung-Nung-7" hand tractor).[17] The following characteristic steps are notable, which in turn appear to have already become institutionalized styles: (i) concentrated research on an imported sample machine, (ii) the "three-in-one" combination in the designing, trial-manufactures, and

[16] Drawn from an article written by a Trial-Manufacture Committee of "Kung-Nung-5" Hand Tractors [1, 1966, No. 2].

[17] Drawn from an article by Liang Shuchin [1, 1965, No. 3], an article by K'ung Tiehshan [1, 1965, No. 8], and a news report [6, Jan. 28, 1965].

experimentation stages, (iii) selection of manufacturing enterprises in terms of locality, (iv) revised designing in adaptation to the specific condition of the locality where the manufacturing enterprises were located, and (v) formation of the network combining cooperating enterprises.[18]

The "three-in-one" combination in (ii) refers essentially to the style of work required from the design personnel in all the design organizations in the country, especially, after the campaign for "design revolution" initiated in 1964 [5]. It is a style in which the design activities take place not in the office of the design organization but in the field, listening to and consulting the opinions and experiences of the users of the final products and of the workers and factory managers engaged in manufacturing on the basis of the finalized designs. In the case of the hand tractor design exhibited in Figure 4, this work style was required from the design personnel of the three design institutes indicated. While the initial draft design was to be made on the basis of a detailed analysis of the structure of imported sample tractors and related data (covering perhaps various items of information regarding the task the machine is to perform and the economic effectiveness it should achieve), the design personnel had to participate in field experiment and trial-manufacture and listen to the opinions of the user farmers or the factory workers and managers, and as a result the draft design had to be revised. A similar work style must have been exhibited in redesigning the same tractor before it was to be produced in Shenyang, Shanghai, Wuhan, and other cities, in order to adapt it to the conditions of each locality. The importance of the design process with such a work-style seems to arise from two factors: (i) In the stage of industrial development where R&D capabilities are still limited and, hence, development of new products requires adaptive introduction of foreign technologies, the design process tends to play a critical role in determining the feasibility of manufacturing a specific new product. The production method and the accompanying resource use pattern are also largely determined by it.[19] (ii) Similarly in an economy in which industrial development is still at an early stage, it is not likely that the design organizations and their personnel are capable of producing both effective and economical adaptive designs of new products, by themselves.[20] They may be even unwilling to do so.[21]

[18] This cooperating network is largely the outgrowth of a campaign initiated in 1964 mainly in the machinery and other processing industry in Shanghai, Shenyang, and Tientsin for "specialization and cooperation" among manufacturing enterprises. In the market economy system, this network is often called the network relating "parent company" to the subcontracting companies. See my article [5].

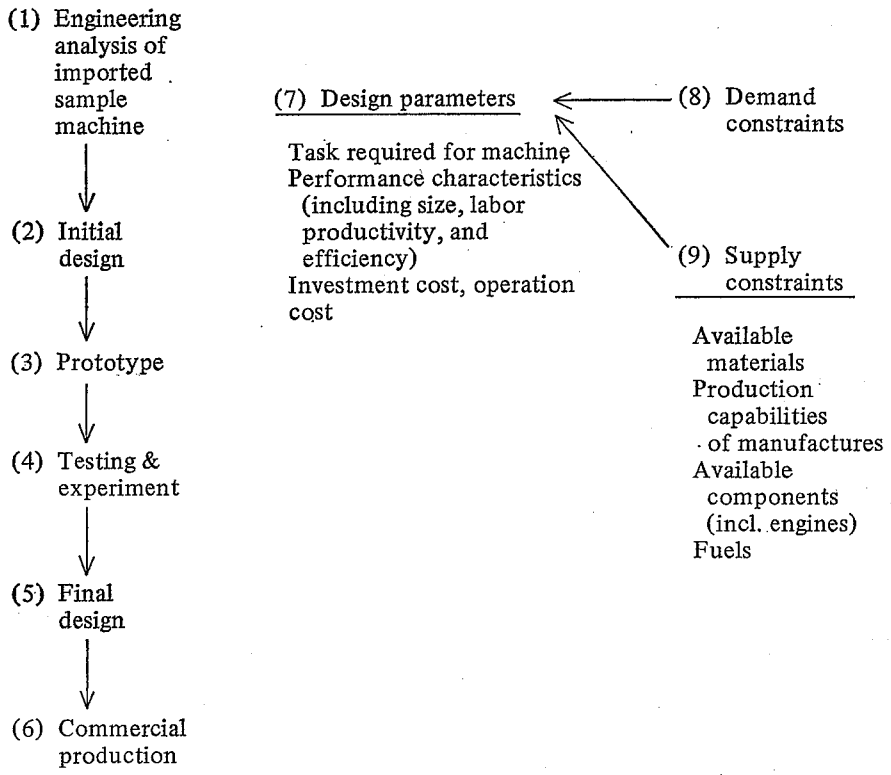
[19] Thus, in the "design revolution" initiated in 1964, the design organizations were instructed to play a leading role in inducing the technology development in each of seven interrelated processes: (i) research, (ii) development, (iii) design, (iv) manufacture, (v) testing, (vi) installation, and (vii) use. See my article [5].

[20] In the typical steps for adaptive introduction of foreign technology, the place of adaptive design is indicated in the following diagram. In this diagram, the combined processes

The work-style of the design personnel exemplified by the "three-in-one" combination is most probably an effective means of bringing about desirable adaptive designs.

from (1) through (6) result in a simple imitation of a foreign machine. In order for this to become an adaptive introduction, it is necessary to add process (7) whereby the design parameters are constructed and issued to the designers in process (2). Construction of the design parameters in turn requires prior surveys on the demand and supply constraints of the final product—processes (8) and (9). This seems to suggest that if the design parameters indicated to the design organizations are rough or incomplete, which is most probably the case in the earlier stage of industrial development, the design organizations will not be able to cover all of the processes (1), (2), (7), (8), and by themselves.

Diagram Showing the Processes of New Product Development



Note: Essential components of this diagram are taken from Amir U. Khan, and Bart Duff, "Agricultural Mechanization Technology Development at the International Rice Research Institute," in *Technology, Employment, and Development*, ed. L. L. White (Manila: CAMS, 1974).

[21] See the discussion in Section IVA.

C. *Motivations of the Government Officials*

As an important supplement to the above discussions in Sections A and B, the role which the motivations and attitudes of the government officials were playing should be noted. The above performance of the government activities since the second half of the 1960s seems to have depended greatly on the fact that the government officials at all administrative levels were highly motivated by the cause of "socialist construction" of the country or, in more general terms, by the spirit of devotion to the public interest. The significance of this dependence is discussed in the following by referring to Figure 3 of the general model.

(i) The good performance of the government activities meant that the receipt of information regarding the People's Communes, the AMI firms, and R&D institutes and the issue of directives of various kinds to the same change agents were made efficiently. The efficiency in the receipt of information was most remarkable in the discovery of the need for AMI modernization in agriculture. The efficiency in the issue of directives was marked in the effort of the *hsien* governments to establish the *hsien* enterprises manufacturing AMIs and to upgrade the technical capability of People's Communes in the use and management of AMIs, and in the institutionalized cooperation among the technology supply agents of individual categories in the designing, trial-manufacturing, experimentation, and manufacturing of new model AMs.

(ii) The high level of motivation of the government officials meant that transformation $R_g \rightarrow R'_g$ was very efficient and, hence, resulted in a greater government output, Q_g; the greater Q_g again induced a more efficient transformation $R_g \rightarrow R'_g$; and so on.

(iii) What were the factors determining this high level of motivation, however? Obviously, the institutions and organization of the government played an important role. Under the system of centralized, physical planning, the criteria for assessing the performance of a government official tend to be almost exclusively related to clearly defined success-indicators in the clearly demarcated area of his responsibility, e.g., the aggregative amounts of output and profit attained by the industry under his responsibility. Therefore, the interest of the government official tends to be confined to the success-indicators of his responsibility area. In other words, he tends to be indifferent as to whether or not a good performance of these success-indicators entails a bad general performance of his responsibility area, and as to whether or not it exerts an unfavorable impact upon the area under any other official's responsibility.

In China, there were periods before the Cultural Revolution in which the institutions and organizations were strongly oriented towards such a system of centralized, physical planning. In connection with agricultural mechanization, it was reported in 1958 that such an orientation resulted in lack of cooperation among the central Ministry of Agriculture (responsible for production, organization, and technological development in general of agriculture), the provincial agricultural departments (responsible for Machine Tractor Stations), the central Ministry of Water Conservancy (responsible for irrigation and drainage), and

the central authority of Supply and Marketing Cooperatives (responsible for the agricultural subsidiary and processing industry), etc., which in turn brought about many cases of inefficiency; e.g., poor management and utilization of MTS's tractors and prevention from using engines and motors for multiple purposes [2, p. 13]. In connection with the AMI industry, most local enterprises which were unable to make short-run profits were in the early 1960s ordered to close down. Somewhat later, some officials were reported to have suspected that the operations by *hsien* governments and People's Communes of AMI firms ran counter to their "proper" duties [6, Sept. 15, 1971].

In a revised system of economic planning now in operation, the criteria for evaluating the performance of the government officials have been, while partly related to success-indicators similar to the above type, based more importantly upon the general performance of their responsibility areas and even upon their attitude to devoting themselves to the public cause [11]. It seems, however, that the additional components of the new criteria are likely to be hard to quantify objectively. Unless the government officials are sufficiently endowed with the public spirit, they are likely to disfavor these new criteria and, hence, this system may tend to return to the original centralized, physical system. When the Chinese leaders proposed "continuous" Cultural Revolution, they seem to have been conscious of this tendency.

In sum, the spirit of devotion to the public interest seems the most important factor contributing to the high level of motivation of the government officials. The institutions and organization are still important in that even if the motivations are of a high level, the institutions and organizations are likely to prevent these motivations from bringing about a good performance of the government activities, hence the case for appropriate institutions and organizations. However, any amount of good institutions and organization may not bring about on a consistent basis a good performance of the government activities if the officials are not sufficiently motivated by the public spirit.

IV. BEHAVIOR OF THE SUPPLY AGENTS

The activities of the supply agents of the new technology regarding AMI industry have continuously been under the constraints of government intervention which was, as seen in the discussion in the previous section, far wider in scope and far more direct in its means than the government intervention usually seen in the market economy system. If as a result the activities of the supply agents had been fully subordinated to these government directives, the only study required in this section would be to examine the characteristic steps in which these directives were executed by the supply agents.

However, as implied in Figure 3 of the general model, the supply agents were also more or less independent units. This independence comes from the fact that these units are in fact operated by the men in the units and these men, either managerial staff members or workers, must have been motivated by many mutually independent factors in combination: a private interest, a public interest, and unconscious inclinations brought about and formed by their specific social

and educational background, their jobs and the duties assigned to them. The government directives regarding within-unit institutions and organizations (especially the material and nonmaterial incentive system and the system of assigning specific responsibilities to the individuals in specific positions) aim either at utilizing these interests and inclinations as they are, or at changing the relative strengths of these factors, for the maximum possible benefit to the government directives regarding the production activities being implemented. But the experience in many socialist countries seem to indicate that this aim is not easily attainable. The performance of technological development in the Chinese AMI industry since the middle 1960s, however, suggests that the microeconomic issue of the possible divergence between the government aims and the actual behavior of the supply agents has been resolved fairly satisfactorily. Our major concern here is to find out what were the kinds of microeconomic issue that China had faced by that time and how they were resolved.

In the following the discussions are made only with regard to the R&D institutes and the production enterprises.

A. *R&D Institutes*

Main issues that were to be resolved here seem to have been the following two, which were fairly common to those in many other countries.

(i) Choice of the topics of R&D projects regarding AMIs: As was common in all the fields of industrial technology, the R&D people in AMIs strongly preferred to engage in projects on contemporary, frontier issues. Thus, for example, the research topics concerning "semimechanized" AMIs seem to have been disliked and even despised.[22] An often denounced tendency of them for "making a fetish of foreign machinery and holding in contempt native implements" was another expression of the same behavior. On the other hand, there was reported to be a tendency for setting the target task of the research project as conservatively as possible for fear of the failure to attain it.

(ii) Styles of R&D activities: R&D people most often liked to stay at the R&D institutes for doing research and disliked to go out to the production and application points of AMIs, thus prohibiting themselves from discovering the real issues to be resolved by R&D.

These issues seem to have been substantially resolved by the early 1970s. Evidence was already indicated in the discussion in the previous sections, e.g., emergence of a considerable number of "semimechanized" AMIs, the success of imitation and then adaptive improvements of nearly all foreign AMs, and almost institutionalized styles of R&D activities emphasizing the close contacts with the user farmers and the workers in the manufacturing enterprises. One special comment is in order with regard to "semimechanized" or improved AMIs.

[22] In an article written by the Agricultural Machinery Institute, Hunan Province [1, 1964, No. 10, pp. 21–22], it was reported that in 1960 when some districts and *hsien* established agricultural implement institutes, some R&D people at the provincial institute proposed to transfer all the research tasks regarding AIs to these district and *hsien* institutes and to devote all the research efforts of their own to the research tasks regarding AMs.

The essential technological elements that make these AMIs the "semimechanized" or "improved" ones seem to be some of the technological elements constituting imported machines which were found relatively easy to introduce and the economic effectiveness of which was found relatively large. Although these AMIs are sometimes considered to be the products that were developed solely on the basis of the native AIs, this is perhaps a mistaken view. More importantly, the R&D people seem to have very often played a decisive role, either directly or indirectly, in bringing out these AMIs through successful additions of the above new technological elements to the native AIs. They are very often not the products solely of the working peasants' innovation.

The principal method used for resolving the above issues regarding R&D people was perhaps continuous government intervention through the issue of various kinds of directives as indicated in Figure 3. Concerning the directive regarding the institutions and organization, it was extended even to a criticism of the ideology of R&D people which was exhibited in their "individualism" and "a mentality emphasizing fame and honor." This criticism was already manifest in the 1950s when a "1956–1967 Perspective Plan for the Development of Science and Technology" was formulated and the annual plans relating to it began to be discussed. It was especially severe during the days of Cultural Revolution in 1966–69. It is hard to evaluate rigorously how deeply the motivations of R&D people were changed thereby. It seems, however, that to the extent that the government officials issuing these directives were sufficiently endowed with public mindedness, the directives were very likely to be effective in resolving the issues of the R&D people.

B. *Production Enterprises*

Production enterprises refer to the central and provincial level AM enterprises, the *hsien* level AMI enterprises, handicraft factories and cooperatives and the repairing and manufacturing factories and workshops at the People's Commune and Production Brigade level. The last two categories of production enterprises, however, are left aside from consideration. The issue to be resolved here was similar to what was usually referred to as a "microeconomic problem" of the socialist enterprises.[23] The microeconomic problem arises in general when, under the system of centralized, physical planning, similarly to the practice pertaining to the government activities, some partial indicators of the entire enterprise activities (usually the physical output of most important products, total monetary output and/or total profits) are taken out and designated as success-indicators for evaluation of the performance of an enterprise and with it its managerial staff members. The result tends to be the sacrifice of those aspects of the enterprise activities which are not reflected in these success-indicators. The trial-manufacture and production of new products and the quality improvements of the existing products—important activities directly related to technological development at the enterprise level—are among those

[23] Alec Nove, *The Soviet Economy* [10], Chapter 6, especially pp. 167–71 relating to technology development.

which were sacrificed most. In reference to the activities affecting the technological development of other firms and farms relating to AMIs, production of parts and components and rendering of service for repairing and technical upgrading are quite often neglected. Therefore, quite often a good performance of the enterprises in terms of success-indicators does not mean a good general performance of the enterprise activities in themselves, nor a good performance of them in terms of the contribution to the entire economy.

Behind this microeconomic problem is also a specific practice under the centralized planning system of assigning responsibilities to individuals in particular positions. It brings a bureaucratic, "status" structure into the production enterprises. The decision-making power regarding management and technology tends to be held exclusively by the managerial and technological staff members.

In China, one of the important steps for resolving the above microeconomic problem has been a revision of the criteria for evaluating the performance of enterprises and with it the managerial members, that has been introduced side by side with the revision relating to government officials. The new criteria have placed due importance on the general performance of the enterprises and also on their contribution to the economy as a whole, in addition to the performance in terms of the success-indicators that appear almost similar to the previous ones. Since, however, the additional components of the new criteria have been hard to quantify objectively, it seems that the microeconomic problem still continues to exist at least potentially. The undesirable behavior of the AMI enterprises which is even now reported in the official newspapers does not seem to have been referred to simply as the practices that existed in the past and are now entirely removed. (Examples of this undesirable behavior cited are the tendencies "to put priority on production and to neglect repairing," "to put priority on production of main structure of machines and to neglect that of parts and components," "to put priority on the large-scale AMs and to neglect medium- and small-sized AMIs," and "to consider that the support of agriculture entails a loss and is not our duty.") More fundamental steps seem to be, similarly to the case of the R&D people, continuous government intervention through the issue of various directives. Two particular types of intervention should be mentioned. (i) The system of personal responsibility has been changed, by which the workers are now admitted to participate in the decision-making of the enterprises as regards management and technology. (ii) The regular, part-time participation of the managers and engineers in manual labor in the production processes has been institutionalized. It is likely that these two steps have been effective upon the ideology of the men in the enterprises, especially upon that of the workers.

Only one case will be taken up as to the characteristic events that have occurred as a result of the issues of the enterprises being substantially resolved. This refers to a "three-in-one" combination among workers, managers, and technicians and a *tu-fa* (meaning indigenous methods) solution by experienced workers, such as have become prevalent in the processes of intra-firm technological change from the central level enterprises like Loyang Tung-Fang-Hung Tractor Factory [6, May 28, 1969] down to the *hsien* level AMI enterprises.

Fig. 5. Processes of Intra-firm Technological Change: "Three-in-One" Combination and *Tu-Fa* Solution

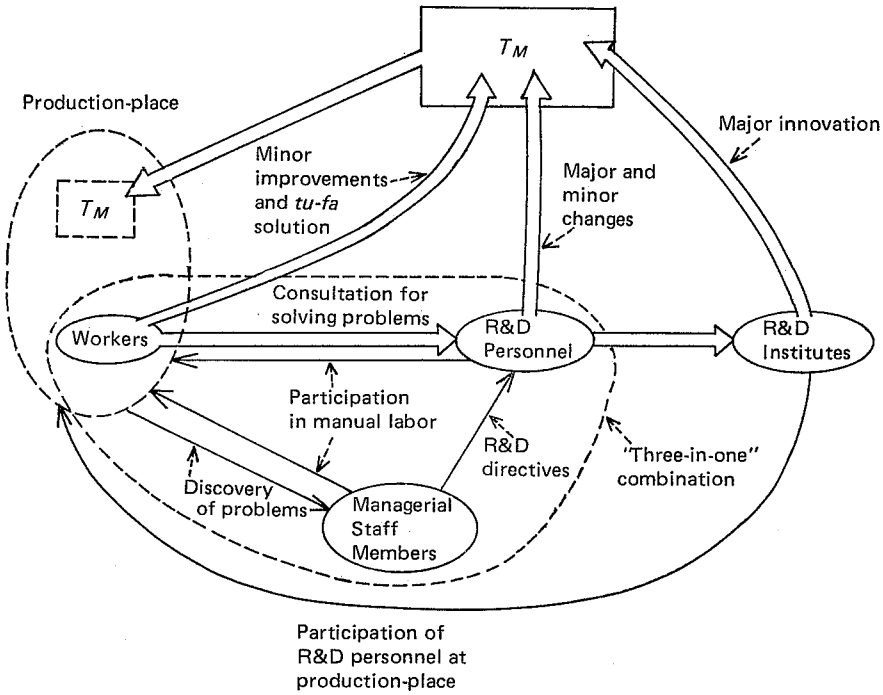


Figure 5 describes it. Essentially, the "three-in-one" combination is an institutionalized method of within-firm technology development in which the workers' experience is usefully combined with the scientific knowledge of the technicians: either the workers bring their innovative ideas to the technicians for materialization as innovations or the technicians consult the workers regarding the technological task they face, and the factory managers must encourage innovations by such a combination.[24] When the workers' innovative ideas are brought to the R&D institute, it is likely that a major innovation results. In contrast, the *tu-fa* solution is a special ad hoc method to overcome certain bottlenecks that are likely to arise from among the series of technological processes required for completing any one project. It is an ad hoc method because these bottlenecks are to be overcome not by routinized technological methods, but by the skills and experience of the old workers once for all. Yet, it has played a decisive role in technological progress, for it enabled the succeeding technological process to be established. A typical example was the building of a 12,000 ton water-pressure pressing machine. Two girders, four large pillars, six large cylinders, and three processing stands were manufactured by *tu-fa* method [6, Jan. 22, 1965]. In AMI enterprises, most frequent application of this method seems to have occurred when attempts were made to self-manufacture the required machine tools and

[24] As for the fuller discussion of this method, see my article [5].

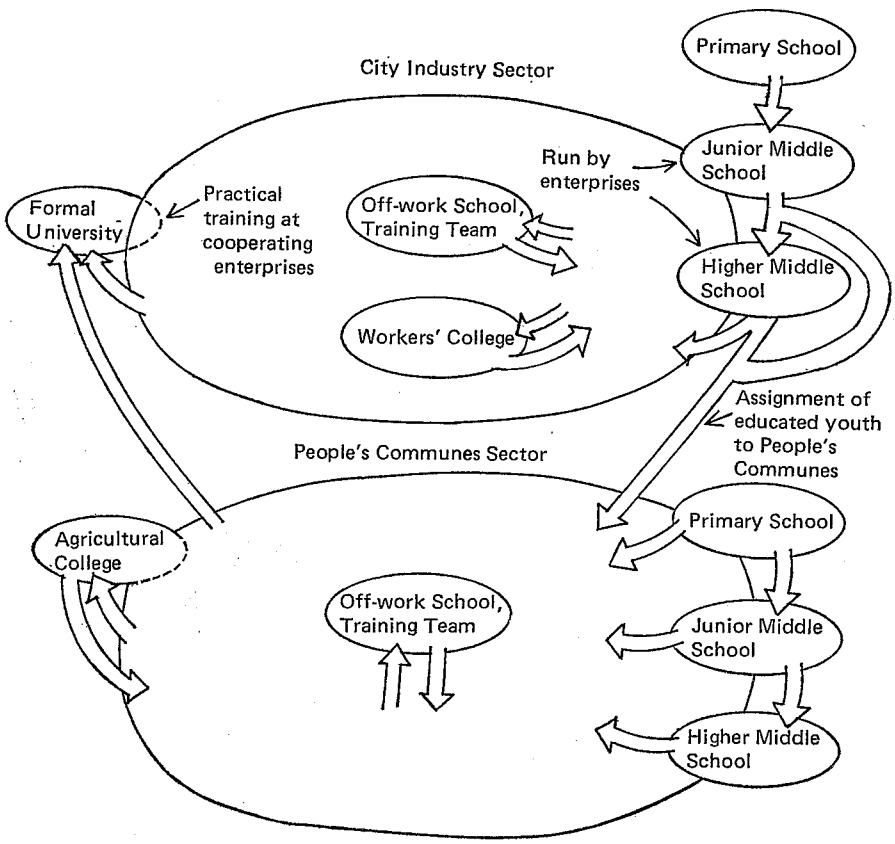
other processing equipment within the enterprises. This method of self-manufacturing was seen at all levels of enterprises, inclusive of the People's Commune factories and even the central level enterprises in their phase of expansion.

V. REFORMS OF THE EDUCATION SYSTEM

In studying the factors contributing to remarkable technological development in China's AMI industry, particular attention should be paid to reforms of the education system carried out during and after the Cultural Revolution. Unfortunately, space does not permit a fuller discussion. Figure 6 is drawn to suggest some of the essential points of these reforms. Only brief comments will be made.

(1) The number of primary schools and junior middle schools in the vast rural area, and with it the school enrollment ratio, have expanded tremendously. (In 1972 the ratio for the primary schools was reported to have reached about 90 per cent for the nation as a whole; the ratio in 1962 was 56 per cent.) This expansion has been made possible by the policy-encouraged initiation and

Fig. 6. Types of Schools and the Courses through which Young People Enter the Schools of Higher Grades or Are Employed



operation of these schools by the Production Brigades with a method that saved substantially the "resources for education": construction and preparation of school buildings and facilities by utilizing local labor and materials; recruitment of teachers even from nonprofessional but experienced and literate members of Production Brigades; and the method of education combining schoolroom teaching with learning by production labor.

(2) The practice began in 1964 seemingly on an ad hoc basis and has since 1968 been institutionalized which send most of the junior and higher middle school graduates in the urban areas to the rural areas for placing them as working members in the Production Teams. The number of graduates who were thus sent down to the rural areas for the five years between December 1968 and December 1973 amounted to 8 million persons—on an average four thousand persons per *hsien*.

(3) A new system has been established in which only those who were engaged in production in factories or People's Communes where they were working were qualified as applicants for entrance into formal universities. The method of education at the formal universities has been changed, similarly to the schools in (1), toward combining classroom teaching with learning by production labor. Education materials also have been revised with great emphasis on increasing knowledge for resolving practical issues. Many informal universities along these lines have also been established.

(4) The reforms in (1)–(3) have combined to bring about to a substantial degree a correspondence between the number and quality of graduates in each level of the school system (i.e., output of education) and society's needs. The correspondence in its present form may be of a transitional nature, because sending down of graduates in the cities to the People's Communes has been currently playing a crucial role for bringing it about. For reaching the steady phase of the correspondence, the substantial expansion of the education system in the rural areas may be necessary.

(5) The particular exhibition of this correspondence in technological development in the AMI industry can be seen largely in the substantial increase in the technological and managerial capabilities of the People's Communes at each of three levels which has been brought about by the graduates sent down from the cities. Sufficient evidence is in existence in the frequent reports in official publications. For example, in Hai Ch'eng *hsien* in the northeast with a population of 1 million, of the number of graduates sent down to the People's Commune amounting to 38,000, about 3,700 persons were now working as heads of Production Teams, accountants, custodians, agricultural technicians, so-called barefoot doctors, and teachers [7]. There were many reports directly related to mechanization, like the one in which an electric generator previously left idle at a People's Commune was said to have been reactivated by graduates sent down to this commune and utilized for urgently needed irrigation; tractors, electric threshers, and other farm processing machines were also introduced by the initiative of these "sent down" graduates [6, Dec. 21, 1974]. A case of curricular reform in favor of technological upgrading in the People's Communes

is seen in the addition of courses on agricultural technology, machinery and electricity, mathematics in common use in rural areas, etc., at a higher middle school in the suburban area of Peking. In the course on machinery and electricity, the principles, structures, simple repair, and operation of tractors were taught [6, Dec. 24, 1974].

Since the workers in the *hsien* level factories were, as mentioned previously, recruited mainly from workers who were previously at the handicraft and "street" factories, members of city working class families and a few skilled workers in the *hsien* enterprises in other branches of industry, the impact of education reform does not seem to have been directly felt here. But the impact in the central and provincial level AM factories has been significant, as in the factories of other branch industries. The chance by the existing workers to enter the informal and even formal universities was increased and, with it, the chance for the factories to have a number of workers who were originally endowed only with sufficient production experience (the capability to discover the problems) and who now obtained a high level of technological knowledge (the capability to resolve the problems).

VI. "CHINESE METHOD"—A PRELIMINARY CONCLUSION

In this final section, the discussions in the previous three sections will be preliminarily concluded by way of comparing the characteristic factors for technological development in AMI industry in China with those in other developing countries in Asia, with the general model of Section II kept in mind.

A. *The State of AMI Industry in Asian Developing Nations*

As one of the preliminaries, the state of technological development in AMI industry in other Asian countries should be described, though only briefly. The products of this industry are mostly traditional types of manual and animal-drawn farm implements. The manufacturers are also indigenous craftsmen and artisans. Since the early 1960s, and especially since the advent of the so-called Green Revolution in the mid-1960s, the demand for tractors, power-tillers, their associated implements, power-driven pumps, and other kinds of AM has emerged and is steadily expanding. This demand is, however, being met either exclusively or largely by imports. In the latter cases, the process of import substitution has been going on, following two different courses. One: the establishment of joint-ventures with the foreign AM manufacturers to produce AMs of the models of these foreign manufacturers mainly on the "knockdown" basis, such as seen in India and Taiwan. The domestic production of parts and components by ancillary firms and the adaptive redesigning of foreign models has proceeded only slowly in most cases. Two: some of the indigenous artisans, small repair shops for imported AMIs, and small-scale metalworking workshops in a few countries (like India, the Philippines, and Thailand) have converted themselves to the manufacture of simple AMs, like power-driven pumps, power-tillers of simplified designs, and associated machines, although the areas in which such a conversion has been taking place are only within some limited parts of these

countries. The above two types of manufacture, however, have not yet been integrated into a well-knit industrial organization of the AMI firms.

B. *Comparability in the Context of Different Economic System*

As the second preliminary, it should be emphasized that we have started the discussion of this paper by assuming that different performances in technological development and their underlying factors can be compared among countries with different economic systems, within a common framework for studying the economic processes leading to technological development.

In the general model suggested in Figures 1 to 3, these differences are made comparable first in terms of the macroeconomic processes and their outcome (Figure 1). They are also made comparable in terms of the interplay among the microeconomic processes of individual change agents of technology (Figures 2 and 3). The differences in these microeconomic terms can be dissolved essentially into the following two aspects:

(1) The internal activity of each individual change agent, i.e., the direction and magnitude of the demand for or the supply of new technology that are created in each change agent of technology.

(2) The interrelationships among the change agents, i.e., the nature and intensity of each of the information flows among these agents. These information flows are separated into the following categories: (a) those transmitting the demand for new technology and the complementary resources, (b) those transmitting the supply of new technology and the associated products, and (c) those transmitting the government decisions intervening in (a) and (b) and also in institutions and organizations affecting (1).

A study on these lines seems effective for avoiding a hasty reduction of otherwise useful issue of the differences in technological development among countries with different economic systems to an a priori discussion on the relative merit and demerit of particular economic systems.

Thus, for instance, the efficiency of technological development in AMI industry in developing economies under the market economy system may be due to the low levels both of internal activities of each individual change agent and of the interrelationships among the individual change agents, both in the private sector. These low levels are likely to be an outcome of either the underdevelopment of the market economy, the familiar limits of the effectiveness of the market mechanism or the mal-operation of the market mechanism as far as it is in operation. However, there seems to be no clearcut limit on government intervention to cover the lack of market mechanism due to its underdevelopment and to correct particular defects of it. For the purpose of finding out specific points and measures for the government intervention, a comparison with the Chinese experience may be useful.

On the other hand, the planned economy system in the context of economic development may be considered as a system aiming at not only correcting the above defects of the market mechanism by replacing it but also covering the lack of market mechanism due to its underdevelopment. The interrelationship among the change agents must be more intensive, and so is the internal activity

of each change agent. However, if the government intervention is simply concerned with substituting for the market mechanism, or with correcting the "microeconomic problems" that are likely to arise in the socialist enterprises, it is not interesting for our comparison. The government intervention of this kind is only interesting insofar as it goes beyond these substitutions and corrections to intensify the internal activities and the interrelationships that are really effective for technological development.

C. *"Chinese Method"*

Keeping this methodology and purpose of comparison in mind, we may itemize the characteristic factors that led to the generally superior performance of technological development in China's AMI industry since the middle 1960s as follows. They seem to constitute some of the essential points of a "Chinese method" for technological development.

1. *Interrelationships among the nongovernment change agents effectively promoted by government intervention*

(a) The interrelationship between the agricultural sector, as the user of AMIs, and the AMI industry arose, on the one hand, from a systematic program for improving AMIs in use (on the basis of comprehensive investigation of the existing AMIs and the needs for new AMIs in each locality) and, on the other hand, from a systematic program for technological development in AMI industry to the extent that the entire range of necessary AMIs would be met domestically. Both of these programs aimed at gradual processes of shifting the weight from traditional AIs to improved AMIs and then to modern AM, reflecting the practical conditions of each sector.

(b) In terms of industrial and social organizations of farms and firms, the above interrelationship arose, on the one hand, from the new structure of the People's Communes in which nearly all the member farmers were participating in the demand for the new set of AMIs and, on the other hand, from the integral network of AMI manufacturers which was constituted or being constituted by the traditional handicrafts cooperatives, the central and provincial level modern enterprises which were expanding, and, to fill the gap between the two, the newly emerging *hsien* level enterprises and the repairing and manufacturing workshops of the People's Communes and Production Brigades.

(c) The participation in the above interrelationship of R&D institutes, government agencies administering AMs and educational institutions (recently reformed) was very comprehensive and intimate. These agents in turn were forming their own extensive network. This was another dimension of the comprehensive interrelationships under question.

(d) Regarding the technology import which was still playing an essential role in technology development in AMI industry, concentrated import of sample machines and their concentrated testing, imitation, and adaptation constitute a particular aspect of these interrelationships.

(e) As a macroeconomic framework permitting the above interrelationships, a characteristic government policy for protecting the domestic AMI industry

from foreign AMI should be noted also as part of the Chinese method. This protectionist policy was implemented by completely separating the domestic price system from the foreign price systems through the apparatus of nationalized foreign trade. A similar protectionist policy was implemented even for the *hsien* level enterprises in some branches of industry by the means of *hsien* government subsidies.

2. *Internal activity of individual change agents as the basis of the above interrelationships*

(a) The spirit of the government officials at all levels in devotion to the public interest was emphasized as the most essential criterion for assessing their individual performance, and this spirit was evidenced fairly widely in the activities of the government officials, especially at the *hsien* level.

(b) The role of the workers in technological development was significant, through the bringing into fuller play of their capability to discover problems (learning by experience) and sometime through their contribution to solution of technological bottlenecks by the *tu-fa* method. This was made possible partly by the new system of transferring part of the decision-making power regarding management and technology to the workers.

(c) The role of the graduates sent down from the cities to the People's Commune was significant in upgrading the technological capability of the People's Commune regarding the use of AMIs.

(d) The activity of the R&D people was toward selecting the research projects which were best suited to practical needs and toward respecting the capability of the workers and peasants in discovering the problems.

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