

Inhibition of Factor Markets, Institutional Reform
and Induced Technological Choice in Chinese
Agriculture: Theory and Empirical Evidence

by

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Abstract

This paper provides a model of technological choice in an economy where exchanges in primary factor markets, namely land and labor markets, are prohibited, and a method to analyze the impacts of institutional change on technological choice. Empirical data on demand for tractor and chemical fertilizer in China are employed to test several hypotheses derived from the theoretical model. The theory implies that the pattern of technological choice in an economy where primary factor markets are prohibited is similar to that in a market economy. The empirical evidences are found to be consistent with the implication of the model. It is also found and that while the recent change in China's farming institution from the collective system to the household-based system had a positive effect on the incentive for adopting modern inputs, this institutional change also had a negative effect on the demand for modern technology probably due to the disruption in the services of the supply system.

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I. Introduction

The purposes of this paper are twofold: to understand the mechanism of technological choice in an economy where primary factor markets, namely land and labor markets, are prohibited; and to understand the impacts of recent change in China's farming institution from the collective system to the household-based system on technological choice.

Technological change is among the most important factors underlying agricultural productivity growth. This growth can be achieved by two different types of technology, "labor-saving" technology and "land-saving" technology. The former is designed to facilitate the substitution of power and machinery for labor, while the latter is to facilitate the substitution of labor or industrial input for land (Hayami and Ruttan, 1985, Chap. 4). An efficient choice between these two categories of technology is important for the achievement of rapid productivity growth. It is a well-established hypothesis that farmers in a market economy will be induced, by the changes in factor prices, to search for the technological alternatives that substitute for the increasingly scarce factor of production (Hicks, 1932; Hayami and Ruttan, 1985; and Binswanger and Ruttan, 1978). The Hicks-Hayami-Ruttan hypothesis implies that differences in the relative abundance of factor endowments in an economy will result in differences in the efficient path of technological change.

In rural China, as in most developing countries, there are substantial regional differences in both absolute and relative factor endowments (see Table

I). The efficient technological choice in China requires that each region take the differences in its factor endowments into consideration. However, market exchanges in land and labor between different production units were prohibited in the collective system, and severely limited even after the reinstatement of the household-based farming system (Lin, 1989a). Therefore, the relative scarcity of a factor cannot be reflected through this factor's relative prices. It is thus interesting to ask what are the implications of the inhibition in factor market transaction on the path of technological changes, and what are the impacts of farming institutional reforms on the demand for technology.

It will be argued in this paper that, although the inducing mechanism is different, the Hicks-Hayami-Ruttan Hypothesis is also applicable to an economy with no primary factor markets, so long as the markets in secondary factors, namely modern inputs in which technologies are embodied, are competitive. While the relative scarcity of a primary factor is reflected by the relative prices in a market economy, the relative scarcity of a primary factor in a non-market economy is reflected by its relative marginal productivity. Increasing scarcity raises the marginal productivity of a factor. A decision maker in a non-market economy is thus induced to search for the type of technologies that substitutes for the factor that has the increasingly large marginal productivity. Consequently, the efficient path of technological choice in a non-market economy is similar to that in a market economy. This conclusion holds in both the collective system and the household-based farming system. The empirical evidences in China are consistent with the proposition.

While our empirical evidence relates only to China, it is possible that the theoretical analysis may have a more general application to not only other socialist countries where inhibitions in primary factor markets exist but also

other developing countries. Due to the constraints of customs or high transaction costs, malfunction of primary factor markets is an often observed phenomenon in developing countries (Paul Collier 1983, Binswanger and Rosenzweig 1986). The theory suggests that it is rather the secondary factor markets than the primary factor markets that make the pattern of technological choice deviate from an efficient path. Therefore, so long as the secondary factor markets are competitive in a developing country, the imperfection of primary factor markets does not constitute a limitation for efficient technological choice.

This paper also provides evidence for the relative performance of collective farming and household farming as vehicles for technological adoption. Collective farming is often advocated as an institutional design for facilitating the diffusion of modern technologies in a developing country. The empirical evidences in this paper, however, indicate that although in the supply of technology a collective system may have an advantage over the household-based system, the incentives to adopt modern technologies are higher in a household-based farming system than in a collective system. The net impact therefore depends on the relative magnitude of these two effects.

This paper will be organized as follows. Section II briefly reviews the history of technological development and institutional changes in Chinese agriculture. Section III presents a model of technological choice in an economy where transactions in primary factor markets are prohibited but the secondary factor markets are competitive. Several testable hypotheses are derived in this Section. After a short description of data set in Section IV, the method of empirical testing and the results are discussed and presented in Section V. Some concluding remarks are provided in Section VI.

II. Technological and Institutional Changes in Chinese Agriculture

The changes in farming institution and the choice of agricultural technology in China have been strongly influenced by the development strategy in the industrial sector. Upon the founding of the People's Republic in 1949, the government inherited a war-torn economy with about 90 percent of population living in rural areas.¹ As an advanced capital-intensive industry is the main characteristic of a developed economy, for the purpose of quickly enhancing national power, China adopted a Stalin-type heavy-industry-oriented development strategy, once the economy recovered from the war destruction.²

The heavy-industry-oriented development strategy resulted in a great demand for agricultural products.³ Consequently, agricultural stagnation and poor harvests would not only affect food supply but also have an almost immediate and direct impact on industrial expansion.⁴ As the government was reluctant to divert the investment resources from industry to agriculture, a new agricultural development strategy which would permit and foster the simultaneous development of agriculture along with the development of industry was adopted. The core of this strategy involved mass mobilization of rural labor to work on labor-intensive investment projects, such as irrigation, flood control, and land reclamation; and to raise unit yields in agriculture through traditional methods and inputs, such as closer planting, more careful weeding, and more organic fertilizer. The collectivization of agriculture was the strategy that the Chinese government believed would perform these functions.⁵

The official approach to collectivization was initially cautious and gradualist. Peasants were encouraged and induced to join various forms of cooperative on a voluntary basis. The movement was surprisingly successful at the initial stage. It encountered no active resistance from the peasantry and

was carried out relatively smoothly. This experience greatly encouraged the leadership within the government and led them to take a bolder approach. The people's commune, with an average size of 5,000 households, was forced upon in 1958.⁶ Payment in the commune at first was made mainly according to subsistence needs and partly according to work performed.

Billions of man-days of labor were mobilized as expected, nevertheless, the communal movement ended up with a profound agricultural crisis between 1959 and 1961. This crisis is estimated to have resulted in 30 million extra deaths during the three disastrous years (Ashton, *et al.* 1984).⁷ Although the communes were not abolished and land was still collectively owned after the crisis, agricultural operation and management were delegated, starting from 1962, to a much smaller unit, called the production team, which consisted of about 20-30 neighboring households. Remuneration, based on the work point earned by each member for his participation in production, was made within the team. This system was not changed until the household-based farming system reform starting in 1979.

After the crisis, more emphases were given to modern inputs.⁸ As shown in Table II, the utilization of chemical fertilizer increased rapidly, at a compound rate of 17.9 percent per year between 1962 and 1978. By the 1980s, China has become the number three consumer and producer of chemical fertilizer in the world (Stone, 1986). Similarly, the pace of mechanization also accelerated after 1962, especially during the 1970s. Measured in total horsepower, the average annual growth rate between 1962 and 1978 was 18.6 percent.⁹ Meanwhile, the government developed a very sophisticated system of agricultural research, breeding, adaptation, seed production, dissemination and extension system. By the early 1970s, almost all the traditional varieties of rice and wheat had been replaced by modern dwarf varieties, which were introduced in the 1960s. Modern varieties of

corn, cotton, and other crops were also introduced and promoted in the 60s and 70s (Zhu Rong, 1988). Hybrid rice started to replace dwarf varieties of rice in 1976. By 1986, 28 percent of rice area was grown to hybrid rice. The innovation and commercialization of hybrid rice in China was considered as the most important achievement in rice breeding in the 1970s (Barker and Herdt, 1985).

Although the research and dissemination of modern technology in the collective system were very impressive, productivity growth was at most moderate.¹⁰ The major drawback of the collective system is its incentive structure. Work points were supposed to be accredited according to the amount of effort contribution by each farmer. However, because of difficulties in monitoring agricultural operations, farmers in general received flat work points for each day's work. Due to lack of incentives, a collective system is found to be less efficient than a household-based farming system (McMillan, Whalley and Zhu, 1989; Lin, 1987).

After the chaos of Cultural Revolution, the government started to reconsider rural development policies. Starting from 1978, a series of major changes, including diversification of rural economy, production specialization, crop selection in accordance with region comparative advantage, expansion of rural fair, and a marked rise in state procurement prices, were implemented. The original intention was to improve the performance of the collective system. However, a small number of production teams first secretly, later with the blessing of local authorities, began to experiment with contracting land, other factors of production to individual households toward the end of 1978. A year later, these teams brought in yields far larger than other teams in the same region. Seeing the remarkable effect, the pragmatic leaders in the central government endorsed this new form of household-based farming system. By the end

of 1983, over 97 percent of production teams in China was converted to the new system, in which land was leased to the individual household's cultivation for 15 years. Farmers, after fulfilling their quota obligations, can keep the rest of their harvests and sell them on the market. In addition to the institutional change in the last decade, the pace of mechanization and the consumption of chemical fertilizer were also accelerated in 1980s.(see Table II).

III. A model of Technological Choice in a Non-market Economy

The technological development in China in the last four decades has been very remarkable. However, of questions in this paper are how responsive is the technological development in China reflecting its relative scarcity of factor endowments and how the change in farming institution affects the behavior of technological choice.

In addition to the farming institution, rural institutions in China are different from the other developing countries in many ways. Land is collective owned. Market exchanges in land between different production units in the collective system were outlawed. Leasing out land for rents was also prohibited, because rent was taken as a form of exploitation in Marxian ideology. Labor market exchanges between different production units in the collective system were also prohibited for the same reason. After the household-based farming system reform in the early 1980s, there were some relaxation in the ideological rigidity. A household operated land was allowed to subcontract to other households in case of the original household migrating to other areas or jobs.¹¹ A farm household was allowed to hire workers not exceed certain ceiling. Nevertheless, land and labor markets only exist marginally except in the vicinities of a few major cities. The purpose of this section is to build a

behavior model of technology choice in such an institutional framework.

For the purpose of simplicity, at any given time t , a farm in an area i is assumed to produce only one crop with two endowed factors, land (K) and Labor (L). Since transactions in primary factor markets are prohibited, it is impossible to alter the endowments through market transactions. However, embodied in the manufactured inputs, there exist two types of technology, land-saving technology (k) and labor-saving technology (l), which can augment the service flows of primary factors. The markets in technologies are assumed to be competitive. That is, the price of a technology is given to an individual household and it is readily available at the given price. For simplicity, the prices for both technologies are assumed to be unity. At any given production circle, a farm is assumed, without loss of generality, endowed with a unit of budget to purchase an appropriate combination of these two technologies in order to maximize the output. The maximization problem for a farm in area i at time t can be expressed as follows:

$$\begin{aligned}
 (1) \quad & \text{Max}_{l_{i,t}, k_{i,t}} Y_{i,t}(l_{i,t}, k_{i,t} | L_{i,t}, K_{i,t}, I_{i,t}, C_i, t) \\
 & - Y [L_{i,t} + l_{i,t}, K_{i,t} + k_{i,t} | I_{i,t}, C_i, t], \\
 & \text{subject to } l_{i,t} + k_{i,t} = 1, \quad l_{i,t} \geq 0, \quad k_{i,t} \geq 0.
 \end{aligned}$$

where $Y(\cdot)$ is a well-behaved production function; subscriptions i and t indicate area and time; I indicates the type of farming institution, collective or household farm; C is a vector of region-specific, time-invariant characteristics, such as soil-type, rainfall, etc, which affect the marginal productivity of l and k ; and t is included to indicate the region-invariant time-dependent changes in the demand shifts, which may arise from changes in the prices or technical efficiency of these two technologies, and from changes in the income of the farm.

The technological choice is made by a production team leader in the collective system and by a head of household farm in the household-based farming system. By substitution, Equation (1) can be expressed as:

$$(2) \quad \begin{array}{l} \text{Max} \\ l_{i,t} \end{array} Y_{i,t}(l_{i,t} | L_{i,t}, K_{i,t}, I_{i,t}, C_i, t) \\ = Y [L_{i,t}+l_{i,t}, K_{i,t}+1-l_{i,t} | I_{i,t}, C_i, t].$$

The first order condition for optimality requires that

$$(3) \quad Y_1 - Y_2 = 0,$$

where Y_1 and Y_2 are respectively the partial derivatives of Y with respect to land and labor. Equation (3) implies that, at margin, for the optimality to hold, a decision maker equates the gains from adopting the labor-saving technology with the gains from adopting the land-saving technology.

The efficient path of technological choice in response to the difference in land and labor endowments is implicitly defined in Equation (3). From the implicit function theorem, we can obtain the following relations:

$$(4) \quad dl_{i,t}/dL_{i,t} = - [Y_{11} - Y_{21}]/\text{s.o.c} < 0,$$

$$(5) \quad dl_{i,t}/dK_{i,t} = - [Y_{12} - Y_{22}]/\text{s.o.c} > 0,$$

$$(6) \quad dk_{i,t}/dL_{i,t} = - dl_{i,t}/dL_{i,t} > 0,$$

$$(7) \quad dk_{i,t}/dK_{i,t} = - dl_{i,t}/dT_{i,t} < 0,$$

where s.o.c. stands for the second order condition. According to the assumptions of the production function, s.o.c. < 0 .

The implications of Equations (4), (5), (6), and (7) are intuitively correct. Given the level of land endowments, a farm will demand less labor-saving

technology and more land-saving technology, if the labor endowment in that farm increases. Likewise, given the level of labor endowment, a farm will demand less land-saving technology and more labor-saving technology, if the land endowment in that farm increases. The results hold for both time series and cross-sectional comparisons. The demand functions for the land-saving technology and labor-saving technology can thus be expressed as follows:

$$(8) \quad l_{i,t} = l(L_{i,t}, K_{i,t} \mid I_{i,t}, G_i, t).$$

(-) (+)

$$(9) \quad k_{i,t} = k(L_{i,t}, K_{i,t} \mid I_{i,t}, G_i, t).$$

(+) (-)

The sign in the parenthesis indicates the direction of impact when the changes in a respective factor occurs. From Equations (8) and (9) we conclude that, so long as the markets in secondary factors, in which technologies are embodied, are competitive, the patterns of technological choice in an economy where transactions in primary factor markets are prohibited shall be the same as what the Hicks-Hayami-Ruttan hypothesis predicts in a market economy. The reason for this similarity is as follows. The increasing scarcity of a factor will raise the marginal productivity of that factor, therefore, the motive of income-maximization will induce farmers to search for the type of technologies that facilitates the substitution of the increasingly scarce factor of production. Equations (8) and (9) also indicate that the changes in farming institution, from the collective system to the household-based system, will not alter the efficient path of technology choice, although the magnitude in response to the relative scarcity of land and labor endowments may be different in these two systems.

The preceding analysis can be summarized in three testable hypotheses:

Hypothesis I: if the markets in technologies are competitive, the increasing scarcity of land will induce farmers in an economy to search for more land-saving and less labor-saving technology, even transactions in the primary factor markets are prohibited

Hypothesis II. if the markets in technologies are competitive, the increasing scarcity of labor will induce farmers in an economy to search for more labor-saving and less land-saving technology, even though transactions in the primary factor markets are prohibited.

hypothesis III. the pattern of technological choice in a household-based system is similar to that in a collective system. Therefore the change from the collective system to the household-based system will not alter the conclusions of the above two hypotheses.

IV. Data

To test the hypotheses derived in Section III, we need to have data that represent labor-saving technology and land-saving technology, in addition to the information on land endowment, labor endowment, and farming institution. Among the conventionally used agricultural inputs, tractors are typically identified with labor-saving technology and chemical fertilizers are typically identified with land-saving technology. The data used in the empirical testings will thus include time-series data from 1970 to 1987 about land, labor, tractor, chemical fertilizer and farming institution for 28 out of the 29 provinces and municipalities on the Mainland, which are made available to the researcher by

the State Statistical Bureau.¹²

Land refers to total cultivated land. Labor refers to total number of farm workers. Tractor is measured by the total horsepowers of various types of tractor. Chemical fertilizer refers to the gross weight of chemical fertilizer consumed, including N, P, and K. Data on land, labor, tractor and chemical fertilizer are not adjusted for differences in quality. As for the farming institution in each province, we know from Section II that the farming institution was the production team system before 1978 and was the household-based system after 1984. The farming institution was on a transition period between 1979 and 1983. Detailed data on the percentage of production teams in each province that was converted to the household-based farming system between 1981 to 1983 are also available in the data set. The number of production teams which was converted to the household-based farming system at the end of 1979 was 1.02 percent and increased to 14.4 percent by December, 1980. Since detailed information for individual provinces is not available for 1979 and 1980, it will be assumed that the farming institution in each province for these two years was the production team system. A summary information on labor, land, tractor, fertilizer and farming institution at the national aggregate level is reported in Table II.

V. Functional Form and Empirical Results

In order to test the hypotheses, we will employ the approach of estimating a regression model with land and labor as independent variables. The regression equations estimated are the reduced-forms of the above behavior Equations (8) and (9). The equations are assumed to be linear in land and labor. Since our interest is in the overall effect of land and labor endowments on the pattern

of technological choice, the reduced form suffices for this purpose. As the sizes of provinces are different, data on tractor, fertilizer, labor and land will all be normalized by the number of teams in each province in 1980. For the purpose of estimating the impacts of farming institutional change on technological demand, the coefficients of land and labor are allowed to vary in these two different institutions. In addition, to accommodate the potential impacts on the demand due to the changes in factors affecting the supply of technology caused by the institutional change, the interceptions of the demand functions are also allowed to vary in these two institutions.¹³ Equations (8) and (9) suggest that the demand for technologies may depend on certain region-specific time-invariant factors, such as soil-type and average rainfall, and certain region-invariant time-dependent factors, such as the change in income, factor prices or product prices, and the improvement in the technology itself. The demand functions will thus also include 27 regional dummies and 17 year dummies to take care of the above possibilities. To be specific, the functions estimated are as follows:

$$(10) \quad l_{i,t} = a_0 + a_1 I_{i,t} + a_2 L_{i,t} + a_3 I_{i,t} L_{i,t} + a_4 K_{i,t} + a_5 I_{i,t} K_{i,t} \\ + a_6 C_1 + \dots + a_{32} C_{27} + a_{33} Y_{71} + \dots + a_{49} Y_{87} + \mu;$$

$$(11) \quad k_{i,t} = b_0 + b_1 I_{i,t} + b_2 L_{i,t} + b_3 I_{i,t} L_{i,t} + b_4 K_{i,t} + b_5 I_{i,t} K_{i,t} \\ + b_6 C_1 + \dots + b_{32} C_{27} + b_{33} Y_{71} + \dots + b_{49} Y_{87} + v;$$

where $l_{i,t}$ is the total horsepowers of tractors, $k_{i,t}$ is the amount of chemical fertilizer consumed, $I_{i,t}$ is an institutional indicator (percentage of production teams converted to household-based farming system), $L_{i,t}$ and $K_{i,t}$ are respectively labor and land, C_i s represent regional dummies, Y_t s are year dummies, and μ and v are residual terms.¹⁴ It is noteworthy that the number of

workers, $L_{i,t}$ in Equations (11) and (12) is an endogenous variable. How large a population can be sustained on a given unit of land also depends on the soil-type, climate, rainfall, and other region-specific factors, which are included in the list of omitted variables and are represented by the residual terms, μ and v . The number of workers in an area is a function of the size of population in that area. Therefore, $L_{i,t}$ shall be correlated with μ and v in Equations (10) and (11). However, the covariance estimator of the ordinary least-squares model is still a linear unbiased estimator because Equations (10) and (11) are specified in the form of fixed-effects model (Hsiao, 1986, p.72). We will thus use the ordinary least-squares model to estimate Equation (10) and (11). The results are reported as follows.

$$(12) \quad I_{i,t} = 5.88 - 41.24I_{i,t} - .34L_{i,t} + .25I_{i,t}L_{i,t} + .03K_{i,t} + .03I_{i,t}K_{i,t} + a_6C_1 + \dots + a_{49}Y_{87}.$$

(11.56) (9.44) (5.00) (7.15) (23.28)

$\bar{R}^2 = .931;$

$$(13) \quad k_{i,t} = .72 - 3.38I_{i,t} + .026L_{i,t} - .021I_{i,t}L_{i,t} - .010K_{i,t} + .002I_{i,t}K_{i,t} + b_6C_1 + \dots + b_{49}Y_{87}.$$

(1.64) (1.27) (.73) (4.27) (2.22)

$\bar{R}^2 = .890.$

Figures in parentheses are t-statistics. The estimated coefficients for regional dummies and year dummies are suppressed in the expressions. According to Equations (12) and (13), the demand functions for chemical fertilizer and tractors under the collective system and household-based farming system can be written separately as follows (the constant, regional dummies, and year dummies are suppressed).

Demand function for tractor:

$$(14) \quad I_{i,t} = \quad \quad \quad -.34L_{i,t} + .03K_{i,t} \quad (\text{the collective system}).$$

(9.44)*** (7.14)***

$$(15) \quad I_{i,t} = -41.24 \quad -.08L_{i,t} + .06K_{i,t} \quad (\text{the Household-based system}).$$

(11.56)*** (1.61)* (14.2)***

Demand function for chemical fertilizer:

$$(16) \quad k_{i,t} = \begin{matrix} .026L_{i,t} & - & .010K_{i,t} \\ (1.27) & & (4.27)^{***} \end{matrix} \text{ (the collective system).}$$

$$(17) \quad k_{i,t} = \begin{matrix} -3.38 & + & .005L_{i,t} & - & .008K_{i,t} \\ (1.63)^* & & (.15) & & (3.57)^{***} \end{matrix} \text{ (the household-based system).}$$

Note: * and *** respectively indicate significant at 0.1 and 0.001 level.

From the demand equations of (14) to (17), we find that the results are consistent with the implications of Hypotheses I and II. All the estimated coefficients of labor and land have the expected signs and the estimated coefficients are all significantly different from zero except for the coefficients of labor in the chemical fertilizer demand functions. The signs of the coefficients are not altered by the change from the collective system to the household-based system, which is consistent with hypothesis III.

The estimated coefficients for labor are not significantly different from zero in the fertilizer demand function. This may arise from the fact that the markets of chemical fertilizer are highly regulated and segmented in China (Lardy 1983). About three quarters of fertilizer currently sold in China are tied directly to the government procurement quotas of grain, cotton, oilseed, and so on. Furthermore, little inter-regional trade of chemical fertilizer exists in China (Stone, 1986). Therefore, the demand in each region is likely constrained by the availability of fertilizer in that region. This explanation is partly supported by the fact that the adjusted R^2 for the fertilizer demand function, Equation (13), is lower than that of the tractor demand function, Equation (12).

The changes in the farming institution from the collective systems to the household-based system, as Hypothesis III postulates and the empirical evidences indicate, will not alter the ways that farmers response to the relative scarcity

of land and labor. As for the impacts of the institutional change on the total demand for tractor and chemical fertilizer, the impacts can be analyzed by how the change affects the incentives to adopt and by the demand shifts related to the changes in factors affecting the supplies of these two factors. The incentives to adopt are measured by the coefficients of land and labor in the demand functions. From the interaction terms in Equation (12) and (13), we find that the estimated coefficients of interaction terms all have positive value and significantly different from zero, except the one for labor in the fertilizer demand function, which is not significantly different from zero. This implies that the incentives to adopt tractor and fertilizer increased after changing from the collective system to the household-based system. Nevertheless, the institutional change also resulted in a negative demand shift which is measured by the coefficients of $I_{i,t}$ in Equations (12) and (13). This negative shift is especially significant for tractors, as the related t-statistic indicates. Several factors may contribute to the negative shift. First, as Perkins and Yusuf (1984, chap. 4), Stone (1988), and others have noted, the distribution, extension and dissemination system of technology under the collective system was very sophisticated and efficient. The collapse of the collective system must have disrupted the network of the original supply system and thus increased the costs of adopting technology. Second, the fragmentation of landholdings make certain technology, such as large- and medium-size tractors, inoperative or inefficient. And third, accompanied the adoption of the household-based system, there is a shift in the crop mix from grain to cash crops.¹⁵ Although it may have a positive effect on the demand for fertilizer, the last factor probably also reduces the demand for tractors because the land tracts grown to cash crops in China are in general smaller than the tracts grown to grain. The total impacts on the demand

for tractor and fertilizer depend on the relative magnitudes of the positive incentive effect and the negative supply effect.¹⁶

V. Concluding Remarks

This paper presents a model of technological choice in an economy in which market exchanges in primary factor, namely labor and land, are prohibited. It is found that, if the markets of modern inputs, in which technologies are embodied, are competitive, the pattern of technological choices in such an economy will be similar to that in a market economy. The reason for such a similarity arises from the fact that the increasing scarcity of a factor raises the marginal productivity of that factor. The income-maximizing motive will thus induce a decision maker in such an economy to search for the kind of technologies that facilitates the substitution of the increasingly scarce factor. The rising marginal productivity of a factor carries the same signal as the rising relative prices of a factor in a market economy. The empirical evidence from China is consistent with the implications of the model.

This paper also provides a way to analyze the impacts of farming institutional change, from the collective system to the household-based system, on technological demand. The impacts are measured in two ways: that related to the changes in the incentive of demand and that related to demand shifts arising from changes in factors affecting the supply of technologies or from changes in income. The empirical evidence shows the recent change from the collective farming system to the household-based farming system in China has a positive incentive effect on demand for tractor and chemical fertilizer. However, this institutional change also resulted in a negative demand shift for tractor and chemical fertilizer.

Since the pattern of technological choice in a non-market economy is similar to that in a market economy, the pattern of technological innovation in a non-market economy will thus be the same as that in a market economy. The empirical evidence from China is also supportive of this statement (Lin, 1989 b).

Notes

1. National statistics shows that 89.4 percent of population living in rural areas and industry consisting of only 12.6 percent of national income in 1949 (see State Statistical Bureau, 1987, p. 89; and 1987 a, p. 11).

2. Wu (1965) argues that the same strategy would have been adopted even if the Communist Party had not been in power. He shows that the symptoms of "take-off" had been exhibited in a number of ways under the National Government's rule in 1930s. T.N. Srinivasan (1984) also argues that the dominate views among the development economists in early 1950s were supportive of an heavy-industry-oriented strategy for developing country.

3. First, the urban population increased dramatically from 57.65 million in 1949, to 71.63 million in 1952, and to 99.49 million in 1957 (State Statistical Bureau, 1986, p. 91). As the heavy-industry-development-strategy would not allow the using of large amount of scarce foreign reserves to import food for urban consumption, the increasing food demand in the urban areas hinged on the growth of domestic grain production. Second, as the bulk of China's exports had been agricultural and sideline products, especially in the 50s, (see Table II), the country's capacity to import capital goods for industrialization depended on agriculture's growth. Third, agriculture was the main source of raw material for many industries, such as textile and food-processing.

4. This argument is clearly supported by the fact that the heavy-industry-oriented-development strategy had to temporarily give way to the "agriculture-first-strategy" after the failure in the harvests caused by the collectivization of agriculture in late 50s.

5. Of course, the reasons for the collectivization of agriculture were numerous. The desire of the Party to consolidate its control over the country-

side and the desire to eliminate the disparity in income distribution in rural areas are just two often cited arguments. Among the reasons, it is worth mentioning that collectivization of agriculture in 1958 was also treated as a convenient vehicle for securing the agricultural products for urban industries and residents (Luo, 1985, p.53).

6. The main rationale of collectivization was rooted in the notion that mobilizing rural surplus labor would increase rural capital formation and, hence, increase production. However, if a collective farm of 150 households provided a basis for mobilizing labor for work projects within the collective, the collective farm did not solve the problem of mobilizing labor for large projects, such as digging irrigation canal, building dam, or the like. These kinds of projects would in general require the simultaneous participation of labor from several dozens of collective farms. The obvious solution for the large scale labor mobilization was to pool 20 or 30 collective farms of 150 households into a large collective unit. For this reason, from the end of August to the beginning of November, within only two months, 753,000 collective farms were transformed into 26,000 communes, which consisted of 120 million households, over 99 percent of total rural households in China in 1958. The average size of a commune was about 5,000 households.

7. The commonly accepted explanations for this crisis were bad weather, bad production management, and incentive issue embedded in the commune system. However, Lin (1989 c) argued that the main reason for the sudden hit of production collapse was because the cooperative movement was changed from a voluntary to a compulsory movement. Since close supervision is not possible in agricultural production, the success of an agricultural cooperative depends on a self-enforcing contract in which each member agreed to discipline himself. A

self-enforcing contract is sustainable only in a repeated game. The switch from a voluntary to a compulsory cooperative, from the game-theoretical point of view, changed the movement from a repeated game to a one-time game. Therefore, the cooperative was besieged by the Prisoner's Dilemma. As a consequence, agricultural production collapsed.

8. This argument is best demonstrated by the shift in the emphasis of irrigation method. The irrigated acreage increased 45 percent from 30.5 million hectares in 1962 to 44.4 million hectare in 1987. However, most additional irrigated acreage came from the increasing of powered tube-wells instead of the constructions of labor-intensive canals and dams. The percentage of powered tube-well irrigated acreage in total irrigated acreage increased from 20 percent in 1962 to 56 percent in 1987 (State Statistical Bureau, 1988, p. 233).

9. Mechanization had been used as one of the rationale for the collective campaign in the 1950s. The idea survived the great agricultural crisis. In late 70s, the complete mechanization of farm operation was even pushed forward as the goal of agricultural modernization, which the planners hoped to achieve by 1985.

10. Whether the productivity growth rate in Chinese agriculture before 1978 is positive or negative is debated among China scholars. Based on different methods of estimation, some economists argue that the growth rate is positive, while the others argue just the opposite (see Tang, 1984; Chow, 1985, and Perkins and Yusuf, 1984).

11. In most cases, an out-migration household keeps the entitlement, and gives land to its relatives or friends without obtaining any compensation (Lin, 1989 a).

12. The provincial data for 1980 to 1987 about labor, tractor, chemical

fertilizer can also be obtained on various editions of China Statistical Yearbook. The province not included in the data set is Tibet.

13. An institutional change may affect the demand through the changes in the costs of supply, and through the changes in the incentives of demand. Griliches (1957) suggests that variations in the interception of a demand function can be identified with the demand shift which is associated with the changes in factors affecting supply and variations in slopes with the changes in the incentives of demand. Following the suggestion by Griliches, the institutional indicator is included to estimate the impacts of institutional change related to changes in the supplies of tractors and chemical fertilizer, and the interaction terms of institution indicator with labor and land are included to estimate the impacts on the incentives of demand.

14. The residual terms, μ and ν in Equations (10) and (11), are correlated. However, there is no gain in using Zeller's Seemingly Unrelated Model to estimate these two equations because the regressors are identical in these two equations (Judge, etc., 1985, chap. 12).

15. The acreage of grain area in total sown areas reduced from 80.3 percent in 1979 to 75.8 percent in 1985 while the acreage in cash crops increased from 10 percent to 15.6 percent in the same period (Ministry of Agriculture 1989, pp. 141-43).

16. The total number of farm workers was 390 million and total cultivated acreage was 1,438 million mu (95.8 million hectare) in 1987 (State Statistical Bureau, 1988 p. 212 and p.224). The total number of production teams in 1980 was 5.66 million (State Statistical Bureau, 1981, p. 131). Therefore, the average size of a team was 69 workers and 254 mu (16.9 hectare). Based on the average size and estimated coefficients of institutional indicators and the interaction

terms of labor and land in Equations (12) and (13), the net impacts of the institutional changes on the demand for tractors and fertilizers in 1987 were negative. However, the total demands for fertilizer and tractors increased in 1987 as indicated in the Table II. This is because there were some positive changes associated with the demand factors which were captured by the year dummies. The estimated 1987 year dummies were 47.6 in tractor demand function and 17.3 in fertilizer demand function.

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Table 1
Land and Labor Endowments in Each Province

Province	(1) Labor	(2) Cult. Land	(3) Land- Labor Ratio	(4) % of Area Irrigated	(5) Multiple Cropping Index	(6) Effective Land-Labor Ratio
Guizhou	10,087	28,480	2.8	24	153	3.8
Sichuan	38,712	98,109	2.5	47	181	3.9
Zhejiang	14,030	27,249	1.9	84	252	4.0
Yunnan	12,808	42,488	3.3	34	140	4.3
Guangdong	19,061	47,130	2.5	65	200	4.4
Guangxi	13,963	39,301	2.8	54	177	4.4
Fujian	7,083	19,240	2.7	64	189	4.5
Tibet	825	3,437	4.2	53	93	4.6
Hunan	20,239	50,998	2.5	82	218	4.8
Henan	25,370	106,508	4.2	45	160	4.9
Shanghai	2,071	5,249	2.5	98	218	4.9
Anhui	17,478	66,518	3.8	50	177	5.9
Jiangsu	20,068	69,451	3.5	75	184	5.9
Shandong	24,988	107,728	4.3	63	146	6.1
Hubei	14,572	55,481	3.8	63	200	6.6
Tianjin	1,391	6,879	4.9	67	133	6.7
Beijing	1,372	6,343	4.6	81	151	6.9
Hebei	17,481	98,551	5.6	54	131	7.3
Jiangxi	9,305	35,753	3.8	74	229	7.4
Shaanxi	9,124	56,377	6.2	33	127	7.6
Qinghai	1,104	8,640	7.8	27	87	7.7
Liaoning	6,488	54,814	8.4	19	102	8.9
Gansu	5,841	53,425	9.1	24	98	9.5
Shanxi	6,647	58,076	8.7	28	107	9.6
Ningxia	1,061	12,605	11.9	28	101	12.8
I. Mongolia	4,657	75,974	16.3	20	91	16.3
Jilin	3,845	60,895	15.6	18	100	16.3
Xinjiang	2,570	47,422	18.5	83	92	21.4
Heilongjiang	4,110	131,273	31.9	7	98	32.1

Source: China Agriculture Yearbook 1984.

Note: (1) Agricultural labor force excluding workers in village-run industry, unit = 1,000 workers;

(2) cultivated land unit = 1,000 mu; (3) col.2/col.1;

(4) % of cultivated land irrigated; (5) unit= %;

(6) effective land-labor ratio is the land-labor ratio adjusted for irrigation and multiple cropping; its formula is: effective land-labor ratio = Land-labor ratio x (1 + % of area irrigated/4) x (1 + (Multiple cropping index- 100)/2). See A. M. Tang, An Analytical and Empirical Investigation of Agriculture in Mainland China 1952-1980 (Seattle: University of Washington Press, 1984) for the rationale of these adjustments.

Table II

Indices Labor, Land, Tractor, Fertilizer, and Institution

Year	labor (1952=100)	Land (1952=100)	Tractor (1957=100)	Chemical Fertilizer (1965=100)	Household Farm* (%)
(1)	(2)	(3)	(4)	(5)	(6)
1952	100	100	3	9	67
1957	111	104	31	57	0
1962	120	95	100	100	0
1965	130	96	75	286	0
1970	154	94	187	509	0
1971	155	93	503	583	0
1972	157	92	721	671	0
1973	160	93	962	820	0
1974	162	92	1203	771	0
1975	165	92	1484	851	0
1976	165	92	1789	926	0
1977	164	92	2183	1023	0
1978	164	92	2638	1400	0
1979	168	92	2725	1686	1
1980	172	92	3588	1880	14
1981	177	91	3858	1982	45
1982	180	91	4145	2185	80
1983	183	91	4594	2369	98
1984	183	91	4691	2403	99
1985	175	90	5470	2346	99
1986	176	89	6048	2566	99
1987	178	89	6854	2691	99

Source: State Statistical Bureau.

* Percentage of households in the household-based farming institution.