The Impact of Changing Agricultural Technology on Land Tenancy in Preindustrial China: Evidence from Confucius's Manors (1759-1901)*

Helen He Yang

hyang6@gmu.edu

Department of Economics,

George Mason University

Abstract

During the Ming and Qing Dynasties, fixed-rent tenancy gradually replaced sharecropping as the dominant form of land tenancy in China. This paper posits that the shift in land tenancy was generated by the technological movement from annual cropping to multiple cropping. To test the hypothesis we exploit a unique dataset gathered from the rent collection archives of Confucius's Lineage in the Qing Dynasty. We estimate the effect of the adoption of wheat-soybean double cropping on the choice of tenancy contract, share contract versus fixed-rent contract. We find that double cropped plots were 30.1% more likely to be managed under fixed-rent contracts than annually cropped plots. The finding is consistent with the factor market imperfections theory. Switching to a double cropping system, farming activities become more complex and the marginal value of tenants' managerial inputs increases. To induce more managerial inputs from tenants, tenancy contract should provide higher self-monitoring incentive.

KEYWORDS: Double cropping, share tenancy, fixed-rent tenancy, factor market imperfection.

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I. Introduction

China's population grew massively in its preindustrial period – increasing from roughly 120 to 150 million in the late Ming (c. 1620) to 350 million in the mid-Qing (c. 1800). During the years that population grew dramatically, China's arable land increased only slightly (Maddison, 2007, Chao 1986). Faced with the extreme low land-man ratio, the Chinese were in pressure to find new methods to raise land productivity. Double cropping, intercropping, crop rotation and other land-saving methods were widely adopted to extract more food per hectare.

While agricultural production became increasingly intensive, there was a secular shift in agricultural tenancy: Fixed-rent tenancy gradually replaced sharecropping as the dominant form of tenancy in the Ming and the Qing Dynasty (Gao 2005,Yang 2009, Li 2007, Chao 1986, Huang 1991).[1] The conventional explanation for the popularity of fixed-rent tenancy was derived from the absentee landlordism hypothesis (Bernhardt 1992, Bell 1993).[2] As landowners moved away from countryside and took up residence in towns, supervising tenants became costly. Absentee landlords would prefer fixed-rent tenancy to sharecropping because fixed-rent system requires minimum supervision of fieldwork. However, this hypothesis cannot explain all the facts. For one thing, many absentee landowners of large manors didn't give up share tenancy under the annual cropping system (Chao, 1986).

This paper posits an alternative hypothesis: The secular shift in land tenancy during the Ming and the Qing Dynasty was caused by technological change - the movement from annual cropping to multiple cropping.[3] The rationale of the hypothesis rests on the factor market imperfections theory that tenancy contracts serve as substitutes for the imperfect market of some important factor inputs besides land and labor (Eswaran and Kotwal, 1985). In traditional Chinese

[1] Li Wenzhi (2007) finds that the archives of the Qing Ministry of Justice provide evidence for the decreased proportion of share tenancy contracts during the Ming and the Qing period. Yang Guozhen (2009) points out that most sample contracts contained in agricultural guidebooks published in the Ming and the Qing Dynasty were in the fixed-rent form.

[2] According to Lynda S. Bell (1993), landlordism in Jiangnan took on a significantly new form during the Qing Period: "a high level of absentee proprietorship, with many of the largest landowning families moving permanently to urban settings; the collection of rent by bailiffs or later by organizations representing collective landlord interests known as 'rent bursaries'; and finally, the shift from sharecropping practices to fixed rents, rent deposits and permanent tenancy rights."

[3] Another alternative hypothesis is the risk-sharing hypothesis (see, for example, Cheung 1969). However, we don't think this hypothesis could explain the long term shift in land tenancy, since there had been no significant change in the risk factor, i.e. natural hazards, in Chinese agriculture during the Ming and the Qing Dynasties.

agriculture, managerial ability was an important factor input for agricultural production. However, the market for such a factor was highly imperfect due to low human capital and slow diffusion of farm managerial knowledge. An effective way of inducing managerial inputs was to offer self-monitoring incentives to the factor owner. In a sharecropping arrangement both landlords and tenants contributed managerial inputs. Landlords provided irrigation management, infrastructure maintenance. Tenants provided managerial inputs in day-to-day farming activities, such as seeding, weeding, pest control, and harvest. Switching from annual cropping to multiple cropping, day-to-day farming activities became more complex and required higher managerial inputs from tenants. The marginal value of tenants' timely managerial decisions increased compared to the marginal value of landlords' administration. To induce more managerial inputs from tenants, tenancy contract should provide higher self-monitoring incentives for tenants. Therefore, agricultural production under the double cropping system should make tenants residual claimants.[4]

Although China historians have found qualitative evidence in support of this hypothesis, there has been no quantitative tests.[5] To test the hypothesis, we exploit a unique dataset to estimate the effect of a newly introduced production technology, wheat-soybean double cropping, on the choice of land tenancy contract in the Qing Dynasty. This original dataset was gathered and digitized from the rent collection archives preserved by Confucius's Manor from 1759 to 1901. One of the important features of the dataset is that it enables us to exclude the hypothesis of absentee landlordism. Throughout this period, the landlords of the Confucius's Lineage, as many other large landlords in the Qing Dynasty, were alienated from administration and supervision of fieldwork. Resident supervisors were hired to supervise the tenants, collect the rents and report to the landlords. Thus the shift in tenancy contractual forms could not have been caused by changes

[4] Theoretically, providing higher incentive could also imply a higher incentive share for tenants in sharecropping. However, this was not common in the history of China. According to Chao (1986), "one notable feature of sharecropping contracts in traditional China was the remarkable stability of the distribution of shares, which remained almost unchanged for more than 2,000 years". The stipulated share was fixed at 50 percent. Variation in contractual mix of share contract and fixed-rent contract was the main instrument used to adjust incentive power.

[5] For instance, Li (2007) discusses that the labor-intensive farming methods and the spread of high yield varieties in the Ming and the Qing Dynasties caused the secular change in land tenancy. Chao (1986) notes that in Southern Song (10^{th}-12^{th} century) "surviving records show that the fixed-rent system for public land was introduced in a given district after the adoption of the rice-wheat double-cropping system."

in the role of the landlords in supervision.[6] We are able to focus on the alternative hypothesis: The introduction of the double cropping system generated the movement from share tenancy towards fixed-rent tenancy.

Using land tenure information from the dataset, we find that fixed-rent tenancy constituted over ninety percent of the total tenancy contracts when wheat-soybean double cropping was widely adopted. In a multivariate probit model that estimates contractual choice, double cropping has significantly negative effect on the likelihood of choosing share tenancy contracts. To account for the omitted variable bias due to lack of information on household capital, we use average plot size of a manor as the instrumental variable for the adoption of double cropping. We find that double cropped plots were 30.1% more likely to be arranged under fixed-rent tenancy than annually cropped plots. Larger plots were more likely to have fixed-rent contract. Kin relationship, scattering of holdings and exogenous risk factors didn't have significant effect on contractual choice.

As far as we know, our project was the first attempt at studying agricultural tenancy at plot-level in pre-industrial China. Our paper contributes to the empirical literature on the impacts of agricultural technology on tenancy contract choice. For instance, Kikuchi and Hayami (1980) discuss the emergence of subtenancy after the introduction of double cropped rice and high-yielding rice varieties in rural Philippines. Alston (1981) points out that wage contracts replaced share tenancy in Southern agriculture after 1930 because mechanization reduced supervision costs associated with wage contracts. Basu (1992) argues that tenants might choose risky technologies in the presence of limited liability and the landlord should direct the tenant's choice of projects by offering a share contract. Pandey (2004) tests for the effect of cultivation technology on the incentive structure of share contracts and finds that higher noise in output increases the fixed payment to the tenant and decreases the incentive share that the tenant receives.

The paper is organized as follows. Section II provides a discussion of institutional background of land tenancy in Confucius's lineage and historical background of wheat-soybean double

[6] Moreover, the number of supervisors in a manor was adjusted according to the number of tenants and plots to maintain the intensity of supervision more or less constant over time.

cropping. Section III describes the data and statistics. Section IV outlines the conceptual framework and the hypotheses for test. Section V presents the empirical strategy and regression results. Section VI presents more qualitative evidence. Section VII offers concluding remarks.

II. Historical Background

A) History of Wheat-Soybean Double Cropping

Wheat-soybean double cropping began to spread in northern China during the late Ming through the early Qing period.[7] Double cropping refers to planting soybeans directly into wheat stubble after harvesting winter wheat. According to Chinese agricultural guidebooks, all soybean varieties were seeded in March and April before the Ming Dynasty. This schedule had conflict with the cropping season of winter wheat, which was harvested in May to June. During the late Ming to early Qing period, new soybean varieties were discovered and new cultivation methods were adopted, making soybean seeding after wheat harvest possible.

Some economic historians denied double cropping as a new production technology. For instance, Perkins (1970) argues that even though there was an increase in the proportion of double cropped land in Qing China, most of the rise in yields have resulted from greater capital and labor inputs in conditions of a stagnant technology. Maddison (2007) points out that Perkins' definition of technical change was too narrow, as the long term "improvement in average practice and a successful effort to absorb and adapt knowledge" should also be recognized as technical progress. In line with Angus Maddison's view on technical progress, we also treat wheat-soybean double cropping as a new agricultural technology.[8]

Winter wheat was central to most double cropping systems in northern China, because wheat was one of the few crops that endure the cold winter in northern China and its price was higher than many other coarse grains (see Figure 2). Which crops served as the secondary crops in double cropping systems? After trials and errors, Chinese farmers discovered that late maturity

[7] See Li Lingfu (1995) for a discussion about the history of the invention of wheat-soybean double cropping.
[8] American agricultural experts report that "double cropping soybeans and small grain (primarily wheat) constitutes a relatively new but rather extensively used production technology in the southeastern United States" (Marra and Carlson, 1987, Beuerlein, 2001). If wheat-soybean double cropping was viewed as a new production technology in 20th century America, there is no reason not to recognize it as a new technology in 17th century China.

varieties of summer soybean was an ideal complementary crop for winter wheat. For one thing, soybean, like most legumes, perform nitrogen fixation that can raise the fertility of land.[9] In the days when fertilizers were costly, Chinese farmers in a large part relied on natural nitrogen providers to maintain soil fertility. Secondly, late maturity soybean varieties have shorter cropping season that successfully solve the time conflict with the cropping season of winter wheat. Thirdly, soybean can be seeded into wheat stubble directly. The direct seeding and non-tillage method save time and labor cost of double cropping.

Double cropping requires intensive input of labor.[10] According to the *Handbook of Agriculture and Mulberry* (*Nong Sang Jing*) written in 1705, tenants on double cropped fields need to work almost 10 months annually. Abundant rural labor force was a crucial factor for intensive cultivation.[11] Rural population density had been low until the late Ming period in most northern provinces. Regional adoption rates of double cropping largely depended on population density in the area (Boserup 1993), therefore the adoption of wheat-soybean double cropping in the north didn't prevail until the late Ming to early Qing period.[12] In some northwestern provinces, double cropping appeared much later, due to lower population density as well as unfavorable weather and soil conditions.

The technical know-how and managerial skills associated with wheat-soybean double cropping were more complex than annual cropping. A successful double cropping system begins with proper management of winter wheat. An early-maturity wheat variety can allow for harvest five to seven days before the late variety is ready. An ideal wheat variety in a double cropping system matures early enough to permit timely establishment of soybeans, and consistently produces high yields of high-quality grain. Secondly, every effort must be made to get the wheat harvest and

[9] Li Lingfu (1995) explains why summer millet wasn't the ideal second crop after wheat harvests. The yield of summer millets was much lower than that of summer beans. Millet also depletes land faster.

[10] Chao (1986) points out that "the Chinese methods of fertilization and multi-cropping are so labor consuming that they yield a considerably lower average output per man-hour than other, simpler methods of fertilization and annual cropping".

[11] For instance, Perkins argues that rising population density after the eleventh century made possible widespread double cropping in southern and southeastern China by providing abundant labor force for labor-intensive farming under double cropping. It should be noted that some double cropping systems prevalent in the south, such as wheat-rice double cropping, early maturity rice-late maturity rice double cropping, were adopted much earlier than wheat-soybean double cropping, due to higher population density, favorable weather and irrigation conditions in the south.

[12] China historians (Perkins, Chao, etc.) point out that a necessary condition for double cropping was abundant rural labor force. Low population density was the main bottleneck for adopting double cropping. This argument is consistent with Boserup (1993) that population growth was the driving factor determining the intensification of agricultural cultivation methods.

the soybeans seeded as early as possible, because soybean planting date is crucial in determining the productivity of the system. At the time of wheat harvest, the potential yield of soybeans is decreasing by at least one bushel per acre for each day that planting is delayed. Third, the straw remaining after wheat harvest needs to be rearranged. While excessive amounts of straw can interfere with the soybean planting, some wheat stubble should be left to provide mulch cover for the soybean crop. Fourth, selecting proper soybean varieties is crucial too. Early-maturing varieties do not yield as well as later-maturing varieties. But late-maturing varieties might not avoid the first killing freeze. In addition to those, Pest control and weed control are also critical in determining the yield of the system. To summarize, successful operation of the complex cropping system requires tenants' careful management and timely decisions.

Although double cropping is potentially profitable[13], the adoption of double cropping means increased risk of production.[14] Both wheat and soybean yields had higher variability under double cropping. The early maturity wheat varieties chosen for double cropping have greater production uncertainties than later maturity varieties. If planted too early, early-heading wheat varieties produce excess fall and winter vegetation, which could increase the risk of plant damage and yield loss from early spring freezes. Double cropped summer soybean varieties also have higher production uncertainties than annually cropped spring soybean, because floods and rainstorms are more frequent in summer. Pest damages are also more severe in summer. Table 3 presents the coefficient of variation of crop yields in volume and value, showing that the double cropping system was riskier than annual cropping systems.[15]

B) Land Tenure on Confucius's Manors

[13] Huang (1985) estimates that double cropping increased productivity by 20-25% compared with annual crops.
[14] It should be noted that wheat-soybean double cropping is still viewed risky to today's American farmers. Marra and Calson (1987) comment that "Double-cropped soybeans are usually planted thirty to fifty days later than full season soybeans and usually have lower yields and more yield variability". A recent American agricultural article says: "Planting double crop soybeans is not recommended in Michigan due to the high risk associated with this practice. However, the high soybean price has increased interest in planting soybeans after wheat harvest this summer. "(Staton, 2011).
[15] A counterargument is that as long as the yields are dependent on the actions of the tenant, such as the timing of farming activities, the main issue is not about exogenous risk, but rather about transactions costs. Although we admit that yield volatility is dependent on the skills and efforts of the tenant, we think that the double cropping system is associated with higher exogenous production risks due to the special wheat varieties, soybean varieties and the postponed soybean seeding dates.

Confucius was born near the city of Qufu in Shandong Province. The direct descendants of Confucius lived in the Kong Mansion (*Kong Fu*) in Qufu. In the Qing Dynasty, the Kong Family was in control of the largest private rural estate (*min tian*) in China. Their properties were located in four provinces (Shandong, Henan, Zhili and Jiangsu). They were also in charge of large amount of public land (*guan tian*). Public lands were managed in manors. In 1705, there were 5,014 tenants working on the public land in the city of Qufu. In 1760, the number of tenants increased to 10,243.[16]

Confucius's manors had two types of tenants- share tenants and fixed-rent tenants. Share tenancy stipulated a 50-50 split of output between the tenants and the landlord. In a sharecropping arrangement, the output of both the primary crop (wheat) and the secondary crop (soybeans) were divided equally between the landlord and the tenants. The holdings under the fixed-rent system were classified into two types- wheat-soybean lands, which were cultivated for double cropping, and the so-called autumn lands (*qiu tian*), which grew annual crops, such as millet, sorghum, and barley. In-kind rent on autumn lands was collected once per year, while rent on wheat-soybean lands was collected twice per year after wheat and soybean harvest, in equal volumes of wheat and soybeans. Rent was determined according to the size of holdings and the quality of soil. The fixed rent was called iron-sheet rent, which means that the landlord did not allow any rent reduction even in case of natural hazards.

Before the adoption of wheat-soybean double cropping, share contract was the dominant form of tenancy contract. Fixed-rent arrangements gained popularity after the new technology was adopted. Adoption of wheat-soybean double cropping was first observed around the turning of the 19th century[17]. Double cropping was widely adopted no later than mid 19th century. [18] Figure 1 presents the distribution of fixed-rent contracts versus share contracts in the pre-adoption, early-adoption and wide-adoption periods respectively.[19]

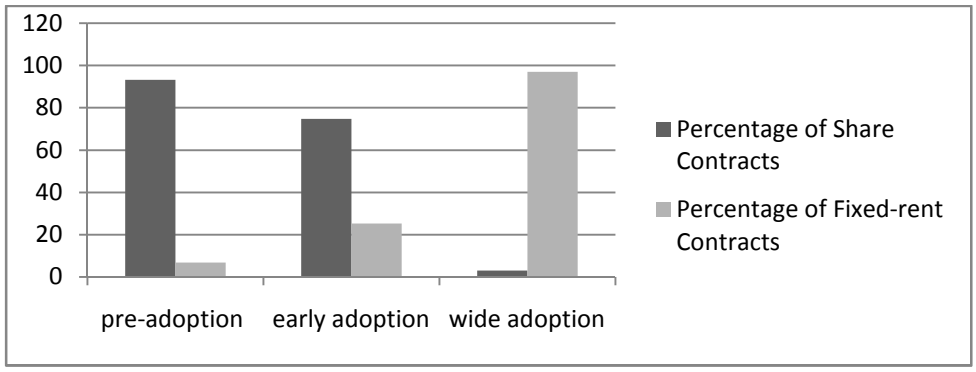
[16] The Shandong Provincial Government, official Info base of Shandong Province. http://www.infobase.gov.cn/bin/mse.exe?seachword=&K=a&A=71&run=12 (accessed on 05/15/2012)

[17] We indentified the first appearance of double cropping by matching the size of soybean plots with wheat plots under the same account of tenants. The year 1803 was the first year observed to have double cropping in our sample. However, due to the data missing in the period from the late 1790's to 1803, it's safer to say that wheat-soybean double cropping was adopted around the turning of the 19th century.

[18] We refer to the wide adoption period as the period in which over half of the plots were double cropped.

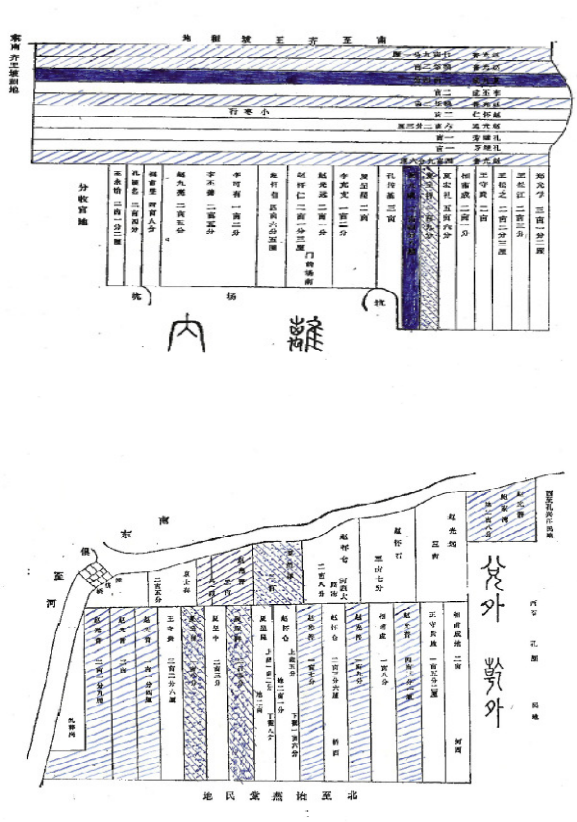
[19] In our sample, the pre-adoption period refers to 1759-1802;the early adoption period refers to 1803-1852; the wide adoption period refers to 1853-1901.

Figure 1. Percentage of Share Contracts and Fixed-Rent Contracts



It was common for a household to have multiple holdings in a manor. The following maps show the distribution of holdings in the Qiwang Manor in 1787. The location of a household's holdings features a distinctive pattern-scattering.

Figure 2. Map of the Qiwang Manor, 1787



Source: Selected Historical Archives of Kong Fu, Qufu. Vol.11 .

Note: To best demonstrate scattering, we only marked the plots that were rented to three tenants. The plots shaded by the same strips were rented to the same tenant.

III. Main Empirical Hypotheses

To explain how technological change generated the movement from share tenancy to fixed-rent tenancy, we draw inspirations from the literature on the determinants of agricultural tenancy contract. There is a vast literature on the choice of agricultural contract.[20] The three main types of theories are the factor market imperfections theory, the risk-sharing theory, and the screening theory.[21] We don't think the screening model can explain our story, thus we focus on the other two theories. The screening model proposed by Hallagan (1978) assumes that in the presence of information asymmetry, landlords are ignorant of tenants' initial endowments of entrepreneurial ability. Share and fixed-rent contracts offer a solution to the problem of adverse selection by providing different levels of incentives for tenants. In our context, screening the tenants of different abilities was not the main concern of the landlords because information about entrepreneurial ability in a typical Chinese rural community was easily available due to the immobility of tenants.

We focus on the test of the risk sharing hypothesis and the factor market imperfections hypothesis. The risk sharing hypothesis postulates that optimal contract should balance incentives and insurance in an environment with moral hazard (Stiglitz 1974, Holmstrom 1989).[22] Share contracts display lower incentive power than fixed-rent contracts, since share tenants receive only a fraction of the total output and fully bear the costs of many inputs. However, share contract mitigates the risk borne by the risk-averse tenant in an uncertain environment. The moral hazard problem in a sharecropping arrangement would be compensated by the welfare gain of risk sharing between the landlord and the tenant. If the risk sharing hypothesis can explain the change of land tenancy associated with double cropping, the empirical implication is that as production uncertainty increased under double cropping, risk-averse tenants would be likely to choose share contracts over fixed-rent contracts for double cropped lands.

[20] See Otsuka and Hayami (1988), Dasgupta et. al. (1999) for a survey of the literature.
[21] For a detailed discussion of the three types of theories, see Eswaran and Kotwal (1985).
[22] Another version of the risk-sharing hypothesis emphasizes the trade-off between risk and transactions costs. For instance, Steven Cheung (1968, 1969) argues that sharecropping is an efficient way of saving transactions costs and mitigating production risk between landlords and tenants. He postulates that sharecropping offers the advantage of risk sharing while wage contract and fixed-rent contract involve lower transaction costs.

The factor market imperfections theory envisages incentive contracts as substitute for the imperfect market of some important factor inputs besides land and labor (Reid 1979, Clive and Zusman 1979, Eswaran and Kotwal 1985). According to Reid (1979), the objective of tenure choice was "to best balance owned resources (land, labor, and know-how) with unowned resources, in order to produce most profitably". Following Reid, Eswaran and Kotwal (1985) postulates that the choice of contracts is determined by different methods of combining unmarketed productive inputs, such as managerial ability, technical know-how and labor-supervision ability, given the initial endowment of factor owners and the prevailing production technology.

The empirical implication of the factor market imperfections theory is that tenancy contract should provide higher self-monitoring incentives for tenants on double cropped lands. In the management of a manor, landlords provided infrastructure maintenance and irrigation management. Tenants provided managerial inputs in day-to-day farming activities such as seeding, weeding, pest control, and harvest, etc. Switching from annual cropping to multiple cropping, day-to-day farming activities became more complex and required higher managerial inputs from tenants. The marginal value of tenants' timely managerial decisions increased compared to the marginal value of landlords' administration. Therefore, agricultural production under the double cropping system should provide high-powered incentives for tenants. Double cropped lands were more likely to use fixed-rent tenancy contracts than annually cropped land.

The main determinant of tenancy contract choice that concerns us is double cropping. In a contractual choice estimation equation with the likelihood of choosing share contracts being the dependent variable, the dichotomous variable, *Doublecrop,* indicates the choice between old technology and new technology. It takes on the value 0 when annual crops were cultivated on a given land plot, and 1 when wheat-bean double cropping was adopted. The factor market imperfections hypothesis would predict a negative coefficient of the variable *Doublecrop*, for the reasons mentioned above. But the risk sharing hypothesis would predict a positive coefficient, since double cropping implies higher production uncertainties.

Besides the main regressor, we have several other proxies for managerial ability and risk factors. The variable *scatter* measures the degree of scattering of a tenant's holdings. It is defined as the

number of a tenant's holdings divided by the total size of his holdings. Adjusted for the total size of holdings, the more holdings one had, the greater the degree of scattering was. Managing scattered holdings required higher managerial ability.[23] As the factor market imperfections theory predicts, fixed-rent contract would be more likely to be chosen if higher managerial inputs were required. On the other hand, scattering could also be a mechanism for risk spreading (McCloskey,1989). Due to weather and disease, scattering may serve as the diversification of land portfolios under different locations and crops. Scattering could result from tenants' risk aversion. The more risk averse a tenant was, the more scattered his holdings were. This could mean, if the risk sharing hypothesis is relevant, scattering as a proxy for risk aversion would have positive effect on the likelihood of choosing share tenancy.[24]

The variable *Kong,* characterizing the kin relationship, takes on value 1 if the tenant is a kin tenant, and 0 if the tenant is a non-kin tenant. The factor market imperfections hypothesis implies that the landlord would be more willing to use higher-powered incentive contracts with kin tenants because kin tenants were likely to have better human capital hence higher managerial ability. Confucius's lineage promoted education by organizing lineage schools. Kin tenants had better access to education than non-kin tenants. A literate peasant who was able to read agricultural handbooks would possess better managerial ability than an illiterate peasant, thus more likely to have fixed-rent contracts. In contrast, the risk sharing hypothesis would predict a positive coefficient of the variable *Kong,* since kinship ties guarantee more trust between the landlord and the tenant, and reduces the moral hazard problem in risk-sharing (Sadoulet, et al.1997).

The variable *Shock* is a proxy for exogenous risk, i.e. natural hazards and wars. *Shock* is a year dummy taking on value 1 if natural hazards or wars happened in the year and 0 otherwise. The risk sharing hypothesis would predict a positive coefficient of the variable *Shock*. But the exogenous shock is not relevant to the factor market imperfections hypothesis.

[23] Fenoaltea(1976) argues that scattering was peasant's private "diversification into a balanced mixture of fallow, winter crops, and spring crops and, within each cropping unit, by the heterogeneity of the land itself". His insight applies to our sample. In Confucius's manors, holdings were scattered into autumn lands and wheat-soybean lands to spread the labor needs in different seasons. A tenant who had multiple holdings was able to manage a variety of crops rather than a single crop. (We test this idea and find that a tenant's crop diversification is positively correlated with the degree of scattering.) Thus the more scattered one's holdings were, the higher his managerial ability was.

[24] It might also be possible that as production risks was spread through scattering, risk-sharing between landlords and tenants became less necessary. Strictly speaking, we cannot exclude this possibility in the reasoning.

For clarity, Table 1 summarizes the empirical hypotheses and the expected signs of the variables with the likelihood of choosing share tenancy contract being the dependent variable.

Table 1. Main Hypothesis

Variable	Hypothesis	Expected Sign
Doublecrop	Factor Market Imperfections	Negative
Doublecrop	Risk Sharing	Positive
Scatter	Factor Market Imperfections	Negative
Scatter	Risk Sharing	Positive
Kong	Factor Market Imperfections	Negative
Kong	Risk Sharing	Positive
Shock	Factor Market Imperfections	Irrelevant
Shock	Risk Sharing	Positive

III. Data

A conclusive study of land tenancy is made possible by the publication of the extensive archives of the Mansion of Confucius (*Kong Fu*). The archives include detailed rent collection records and grain crop reports from the farms in eleven manors near the county of Qufu. Rent collection records contain information on the size of plot, type of grain, type of contract[25], number of holdings of each tenant, amount of rent owed and paid to the landlord, etc. [26] Plot-level data is available from 1759 to 1901. The sample was drawn randomly by year and by manor. The dataset are independently pooled cross sections. [27]

[25] Although we know the type of contract of a given plot, we don't know the exact length of the contract. The contracts were usually longer term contracts rather than annual contracts, with the possibility of eviction in case of rent default. However, we have few observations for multiple years, since the records from the same manor were not drawn from consecutive years. Thus, we assume that there is no serial correlation between observations within the same time period.

[26] Since the landlords only maintained the records they were concerned about, the information on peasant tenants was limited. We don't observe the wealth, labor input, and other household characteristics of tenants.

[27] We are not able to track the plots over time, since rent collection records were based on units of tenants rather than plots. We don't have time-series data.

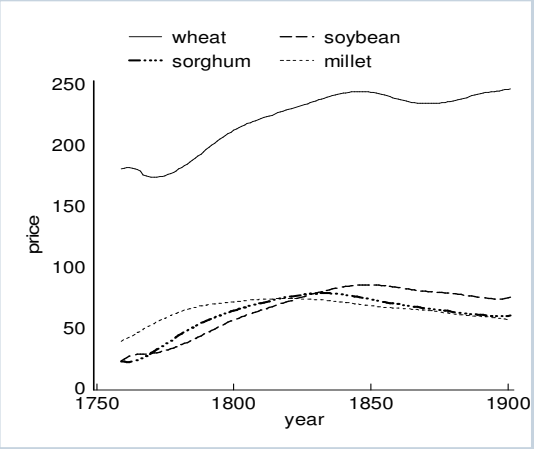
Table 2. Sample Size

	Manor	No. Observations
1759-1788	Junchengchang, Qiwang, Da	207
1789-1818	Qiwang, Da, Xiaoqiwang	277
1819-1848	Nanchi, Shijing, Quantou	121
1849-1878	Nanchi, Zhangyang	158
1879-1901	Anji, Chunting,Qiwang, Hetao, Da, Nanchi,Zhangyang	475
	Total No. of Obs. =	1,238

A) Crop Characteristics

Millet, sorghum, wheat and beans were the main crops in Confucius's manors. Millet had been one of the most popular crops since ancient times because of its stable and high yield. Sorghum was popular in northern China not only because it can survive saline and sodic soils, but also because its stalks can be used as building materials for the maintenance of dikes. Wheat was the most profitable crop in the north. [28] Figure 3 shows the prices of the four major crops from 1759 to 1901.

Figure 3. Grain prices, 1759 - 1901



Sources: Grain Price Database in the Qing Dynasty .

[28] There was an old saying that "One wheat harvest is almost as profitable as three coarse grain harvests". The grain price figure seems to support this saying.

Note: Price information was gathered from Mianzhou, Shandong Province. Price is measured in silver tael per shi. [29]

The following table summarizes the statistics of the four major crops, including number of plots, size of plots, number of share contracts versus fixed-rent contracts. Following Allen and Lueck (1999), we calculate the coefficient of variation of crop yields under different crops to measure the variability of yields. [30] As Table 3 shows, double cropped wheat and soybeans had higher coefficient of variation (calculated both by volume and value) than annually cropped wheat and soybeans. [31] The high coefficient of variation of the double cropping system implies greater volatility of harvest. This could be explained by higher exogenous production risks and greater complexity of farming activities under the double cropping system as explained in Section II.

Table 3. Mean Crop Characteristics

	Millet	Sorghum	Wheat	Soybean	Wheat-Soybean
Size (acre)	0.66	1.00	1.54	2.34	0.85
	(0.68)	(0.79)	(1.43)	(0.19)	(0.95)
Number of Share Contracts	90	127	147	20	102
Number of Fixed-Rent Contracts	199	45	45	0	245
Coefficient of Variation of Yield (volume)	0.50	0.99	0.522	0.35	1.36
Coefficient of Variation of Yield(value)	0.54	1.24	0.48	0.36	1.47
Number of Observations	289	172	287	21	148

B) Changes in the Size of Holdings

Following Boserup (1993) we assume that population pressure was an important driving factor for double cropping. Although we don't have direct measure for population density, the degree of

[29] 1 *shi* = 100 liters. The Grain Price Database contains information of the lowest monthly price and highest monthly price in a given year. We use the average price on a yearly basis from the high-price group.

[30] Note that yields data can only be obtained under sharecropping arrangement, not under fixed-rent arrangement. We use the actual amount of rent collected under sharecropping to infer the quantity of crop yield. It's possible that the selection bias would cause bias in the coefficient of variation. However, they are probably biased to the same extent for different crops.

[31] The calculation of coefficient of variation in volume is straightforward. To obtain coefficient of variation in value, we merged the price data with the rent collection sample and calculated the value of grain products. It should be noted that we only have 20 observations of annually cropped soybean plots and the statistics related to that may not be accurate.

land fragmentation can reflect population density. The size of holdings had been diminishing over time as population density increased. Table 4 below summarizes the statistics of the size of holdings on a 30-year-period basis from 1759 to 1901.[32]

Table 4. Changes in Plot Size over time

Years	Mean (acre)	Std. Dev.	Min.	Max.	No. observations
1759-1788	1.506	1.269	0.311	9.169	207
1789-1818	1.347	1.258	0.075	9.356	277
1819-1848	0.505	0.907	0.013	5.438	121
1849-1878	0.455	0.562	0.012	3.75	158
1879-1901	0.477	0.428	0.004	2.625	475

C) Aggregate Shocks

The rent collection records specify the years with bad harvest due to flood, locusts and frozen rains. Shandong Province was located at the downstream of the Yellow River where flood was a major threat in the summer. The dry spring in Shandong Province also made the crops in this area vulnerable to locusts.

Information about wars and rebellions in the 19th century was also included in the archives. Wars and rebellions were rampant in Shandong throughout the mid and late 19th century. [33] However, most of the wars had limited impact on the farming activities of Confucius's Family in Shandong because the Mansion was under heavy military protection of the Qing Court.[34]

Following Botticini (2000), we summarize the exogenous shocks that might have impacted agricultural activities in Table 5. These "shocks" were recorded in the *Kong Fu* archives and provincial gazettes.

[32] The mean size of holdings from 1819 to 1848 might have been biased down due to the over-representation of paddy fields compared with other periods. Paddy fields were much smaller than plots growing other crops. Nevertheless, the overall declining trend of the size of holdings is clear.
[33] The Opium War, the *Nian* Rebellion, the White Lotus Rebellion, and other rebellions occurred from the 1840s to the end of the 19th century.
[34] The emperors paid close attention to the security of the family and sent troops to protect the temples and the grave of Confucius.

Table 5. Major Aggregate Shocks in Qufu , 1759 - 1901

Year	Event
1759	Locust, Frozen rain
1803	Flood
1821	Flood
1853	The *Nian* Rebellion
1855	Flood, The *Nian* Rebellion
1881	Rebellions against American missionaries
1885	Flood, China-France War
1892	Flood, Frozen rain
1901	Tax Rebellions

Source: a. Selected Historical Archives of Kong Fu, Qufu. Vol. 21.

b. The Shandong Provincial Government, official Infomation base of Shandong Province.

D) Summary Statistics

Table 6. Summary Statistics

Variable	Despriction	Mean	Standard Deviation
Share	=1 if share contract	0.422	0.494
Doublecrop	=1 if land was double cropped	0.280	0.449
Size	Size of a holding (in acres)	0.844	1.012
Kong	=1 if kin tenant	0.117	0.321
Scatter	the number of a tenant's scattered holdings divided by the total size of his holdings	5.155	10.195
Shock	=1 if there was an exogenous shock in that year	0.402	0.491
Meansize	Average plot size in a manor	0.844	0.400

No. observations = 1,238

Note- The minimum and maximum values for all variables except plot size, *Scatter* and *Meansize* of a manor are zero and one, respectively. The minimum value of plot size is 0.004, and the maximum value is 9.355. The minimum value of *Scatter* is 0.107, and the maximum value of *Scatter* is 112.3. The minimum value of *Meansize* is 0.292, and the maximum value of *Meansize* is 1.688.

V. Estimation Results

A) Estimates for Contractual Choice

In this section, we outline a single-equation probit model to estimate the effects of double cropping on contractual selection assuming that the adoption of double cropping is exogenous. The contractual selection problem is described by the latent variable model

$$Share_i^* = X_{1i}'\beta_0 + Doublecrop_i\beta_1 + \varepsilon_i \qquad (1)$$

Where $Share_i^*$ is the propensity of choosing share contracts, and *Doublecrop* indicates the choice between old technology and new technology. X_{1i} is a vector of exogenous variables, including size of a plot *acres*, *acres*^2, degree of scattering, exogenous shocks[35], and kinship variable *Kong*. ε_i is a normally distributed random error with zero mean and unit variance. Results from the multinomial probit specification are presented in Table 7. We cluster standard errors at the manor level. We also report the marginal effects at the mean.

Table 7. Estimated Probit Coefficients for the Regression: Sharecropping versus Fixed-Rent

Independent Variable	Probit Coefficient	Marginal Effect
Doublecrop	-0.823**	-0.185
	(0.382)	
Acres	1.331***	0.354
	(0.324)	
Acres^2	-0.150***	-0.040
	(0.034)	
Kong	-0.496	-0.110
	(0.306)	
Scatter	-0.222**	-0.059
	(0.100)	
Shock	-0.875*	-0.233
	(0.500)	
Constant	0.187	_
	(0.480)	
Number of obs.	1,216	1,216

Note: ***significantly different from zero at 1-percent level;** significant at 5-percent level;*significantly different from zero at 10-percent level. Robust standard errors are in parentheses. Marginal effects are computed at mean.

[35] We lag shock by one period since shocks in t-1 would affect contractual choice in t.

According to the estimation results, *Doublecrop* has a significantly negative impact on the likelihood of choosing share contracts, if it is taken as exogenous. *Scatter* has a significantly negative effect too.[36] They both support the factor market imperfections hypothesis rather than the risk sharing hypothesis. The kin relationship variable *Kong*, has a negative effect, but insignificant. The exogenous variable *Shock* exerts a negative impact on the likelihood of choosing share tenancy. This is not consistent with the implication of the risk sharing hypothesis. In summary, the estimation results of the single probit model are consistent with the capital market imperfections hypothesis.[37]

B) Testing for Omitted Variable Bias

In this section we consider the possibility that the adoption of wheat-soybean double cropping is endogenous to contractual choice. On the one hand, household capital could affect technology adoption decisions. For instance, tenants who owned draft animals such as oxen or mules and farming tools would be more likely to double crop their lands than those who had little household capital. On the other hand, household capital could also have direct impact on the choice of tenancy contracts. First, more household capital may be the outcome of stronger managerial ability. Second, tenants with more household capital may need less input sharing with landlords.[38] Thus tenants with more household capital would be more likely to choose fixed-rent contracts, as implied by the factor market imperfection theory. The decision to double crop can be endogenous to contractual choice. Ideally we need to find good proxies for household capital to eliminate the omitted variable bias. However, good proxies for household capital are not available in our sample. More formally, our result could be biased because the double cropping variable in the contract selection equation would be correlated with the error

[36] The variable *scatter* is arguably endogenous. To account for this issue, we used an instrument, the size of a manor, and found that the regression results are not significantly different. Since scatter is not our main concern, we do not report the regression results in the paper.

[37] Note that the variable *size* has a significantly positive effect on the likelihood of choosing share contracts. The interpretation based on factor market imperfections theory is that larger farms need more input sharing (tools, draft animals, etc.) with the landlord. The interpretation based on risk sharing theory is that larger farms need more risk-sharing. Here we cannot sort out the predictions of the two theories.

[38] Wright (1986) argues that tenants without mules and farming tools entered into sharecropping arrangements whereby landlords supplied these assets.

term. Similar problem will arise if the landlord was able to screen tenants on factors such as household capital towards the labor-intensive technology in determining the form of contracts. [39]

In this section, we outline a recursive bivariate probit model that allows for the possibility of endogeneity. Suppose the tenant decides to double crop by comparing costs and benefits using a net benefit function or latent index that is linear in covariates and excluded instruments, with a random component or error term, μ_i. The bivariate probit first stage can be written

$$Doublecrop_i^* = X_{2i}'\gamma_0 + Z_i\gamma_1 + \mu_i \qquad (2)$$

Where Z_i is an instrumental variable that increases the benefits of adopting wheat-soybean double cropping technology. The tenant will double crop the plot if the net benefits of double cropping are positive; i.e. if $Doublecrop_i^* > 0$. Following the latent variable model in equation (1), an outcome of our primary interest is contractual choice. The source of omitted variable bias in the bivariate probit setup is correlation between μ_i and ε_i. In other words, unmeasured determinants of technology adoption are correlated with unmeasured determinants of contractual choice.[40] The model is identified by assuming that Z_i is independent of these components, and that the random components are normally distributed. That is, $E[\mu_i] = E[\varepsilon_i] = 0$, $var[\mu_i] = var[\varepsilon_i] = 1$ and $cov[\mu_i, \varepsilon_i] = \rho$. The exogeneity condition is stated in terms of the correlation coefficient ρ. The null hypothesis is H0 : ρ = 0. If we fail to reject the null hypothesis, then we can conclude that the dummy variable *Doublecrop* is exogenous and the single probit model is the appropriate specification.

This bivariate probit system is identified if the instrument Z_i is correctly chosen. We choose an instrumental variable that proxies for the population density of each manor to solve the endogeneity problem[41]: average plot size of a manor, *Meansize*. If *Meansize* is a valid instrument,

[39] Another potential source of missing variable bias is the unavailability of proxy for soil quality. We do have information on the quality of lands under fixed-rent tenancy, but we don't observe the quality of lands under share tenancy. The amount of fixed rent was based on the quality of soil. There were three types of soils: top-quality soil, medium-quality soil and low-quality soil. It would be natural to assume that high-quality soils were more suitable for double cropping. But we found that many low-quality plots adopted double cropping as well. Therefore, we think that the missing variable on soil quality under share tenancy would not generate serious bias in the results.

[40] For more technical details, see Most Harmless Econometrics , P. 148.

[41] Due to the lack of direct measurement of population density, we have to rely on measurement of land fragmentation as proxy for population density. We assume that the smaller the average plot size in a manor is, the more fragmented the land, and the higher the population density .

then (i) it must be a determinant of the decision to double crop, but (ii) it must not be a determinant of contractual choice, i.e., it must not be correlated with the error term ε_i. Not surprisingly, it's straightforward to show that it meets the first criterion. In a simple probit model that explains the probability of adopting wheat-soybean double cropping technology, the t-statistic on *Meansize* is -4.43. The average plot size of a manor reflects population density. High population density of a manor would result in fragmented plots hence smaller average plot size. According to Boserup(1993), high population density would guarantee abundant labor force and pressure the peasants to adopt more land-saving farming methods. Since higher population density spurs land-saving technology, the mean size of holdings in a manor should have a negative impact on the probability of adopting the double cropping technology.[42]

Thus the credibility of our bivariate probit results turns on our assumption that the number of holdings and the mean size of holdings in a manor didn't directly impact contractual choice. One mechanism through which *Meansize* might impact contractual choice is that the supervision costs in a populated manor with many smaller holdings were higher. However, Confucius's Family hired more supervisors in larger manors so that the tenant-to-supervisor ratio was kept roughly constant across manors. The other mechanism through which *Meansize* might impact contractual choice is that as average plot size fell, the production risks associated with double cropping would decrease, making sharecropping less appealing. The argument has two problems: Firstly, it seems unclear why production risk for an individual plot would drop as average plot size in the manor fell. It's the size of the individual plot rather than average plot that matters. Secondly, even if the production risks of wheat-soybean lands fell, the production risk of annually cropped lands would decrease to the same extent as average plot size fell. Therefore, we should have observed less sharecropping on annual cropped lands as well. Actually we observe that double cropped lands were more likely to have fixed-rent contracts than annually cropped lands even at lower average plot size. Hence, we believe that average plot size (*Meansize*) had no direct impact on contractual choice.

[42] It may be argued that population pressure prompting double cropping is not consistent with profit maximization. Regardless of population tenants and landlords would have an incentive to double crop to increase profits. However, this argument is flawed if we notice that a necessary condition for double cropping (a labor-intensive technology) was abundant labor force. If a family doesn't have abundant male labor, it could hardly adopt double cropping. Ideally we should use the number of males in a family as an instrument. Since such information is not available, we resort to other proxies for population density.

Table 8. Maximum Likelihood Estimates of Contractual Choice Bivariate Probit Model

	Single-equation Probit		Bivariate Probit	
Independent Variables	Coefficient	Marginal Effect	Coefficient	Marginal Effect
	Contractual choice: *Share*			
Doublecrop	-0.823**	-0.185	-2.009***	-0.301
	(0.382)		(0.279)	
Acres	1.331***	0.354	1.043***	0.296
	(0.324)		(0.214)	
Acres^2	-0.150***	-0.040	-0.119***	-0.034
	(0.034)		(0.022)	
Kong	-0.496	-0.110	-0.355	-0.088
	(0.306)		(0.251)	
Scatter	-0.222**	-0.059	-0.092	-0.020
	(0.100)		(0.071)	
Shock	-0.875*	-0.233	-0.626	-0.185
	(0.500)		(0.439)	
Constant	0.187	_	0.385	_
	(0.480)		(0.482)	
	Technology adoption: *Doublecrop*			
Meansize	-0.527***	--	-1.228***	--
	(0.119)		(0.462)	
Acres	0.068	--	0.269*	--
	(0.090)		(0.157)	
Acres^2	-0.010	--	-0.031	--
	(0.014)		(0.020)	
Kong	-0.078	--	-0.102	--
	(0.123)		(0.099)	
Scatter	-0.031***	--	-0.041***	--
	(0.007)		(0.006)	
Shock	-0.133**	--	-0.141	--
	(0.059)		(0.461)	
Constant	0.050	--	0.555	--
	(0.132)		(0.481)	
	Disturbance Correlation			
Rho	--	--	0.742	_
			(0.177)	
Number of obs.	1,216		1,216	

Likelihood-ratio test of rho=0: chi2(1) = 7.036 Prob > chi2 = 0.008

*** significantly different from zero at 1-percent level;** significantly different from zero at 5-percent level;*significantly different from zero at 10-percent level. Robust standard errors are in parentheses. Marginal effects are computed at mean.

Table 8 summarizes the maximum likelihood estimation of the bivariate probit model that relies on the instruments *Meansize*. Robust standard errors are clustered at the tenant level. We repeat the single-equation probit estimation results from Table 7 for comparison. To obtain MLE of the bivariate probit model, we resorted to the command "biprobit" of STATA 10, which exploits the Newton-Raphson maximization method and allows for Hessian-based estimation of the asymptotic covariance matrix.

The likelihood ratio test suggests that the Null hypothesis is rejected at the 1 percent level of significance. This implies that *Doublecrop* is correlated with ε_i and therefore endogenous. The credibility of the bivariate probit regression shows that *Doublecrop* has a statistically significant negative effect on choosing share contracts after accounting for the endogenous technology adoption problem. Lands that were double cropped were 30.1% more likely to be managed under a fixed-rent contract. The effect was larger than what was predicted by the probit model.

The coefficients of the other factors in the second-stage biprobit estimation have the same signs with those in the single-equation probit model. However, in the biprobit model, the effects of *Scatter*, *Kong* and exogenous shock became less significant. The regression results in the first-stage technology adoption equation suggest that larger plots were more likely to adopt double cropping. Tenants with more scattered holdings were more likely to adopt double cropping. Not surprisingly, *Meansize*, average plot size in a manor, has a significant negative effect on the decision of technology adoption. This can be explained by the hypothesis that population pressure is a driving factor of the adoption of intensive farming technology.

VI. Quantitative Evidence

The sample also provides qualitative evidence in supportive of the factor market imperfections theory: Fixed-rent contract provided higher self-monitoring incentives and induced more managerial inputs from tenants. Switching from annual cropping to double cropping, production uncertainties rose due to higher exogenous risks and complex farming environment. According to the rent collection books, the landlords allowed fixed-rent tenants to substitute "soybean rent"

with “millet rent” at a 1:1 ratio if soybean harvest failed. This was an important managerial decision delegated to the tenants under fixed-rent tenancy. The agreement allowed the tenants to decide crop mix and allocation of lands according to their own profit maximization goals. In contrast, under share tenancy the landlords had more decision right on crop mix. Hence, fixed-rent tenancy was a method to induce tenants' inputs in the management of crop mix and land allocation.

The emergence of sublet under fixed-rent system is also consistent with the factor market imperfection theory. Sublet was not allowed under sharecropping for the convenience of supervision, but was permitted in fixed-rent arrangements.[43] Sublet option meant a further reduction in the administration work of the landlord, since screening and supervising subtenants became the task of the original lease holders. Hence, fixed-rent tenancy induced tenant's managerial inputs in screening and supervising subtenants.

The third type of evidence was the co-plowing option under the fixed-rent system. None of the thirty co-plowing cases occurred under sharecropping arrangement. If a single tenant was unable to finish all the farming work in a busy season, he could join several neighboring tenants to form a cooperative or a farmers team.[44] Fixed-rent contract induced tenants' managerial inputs in coordinating on exchange of labor in the co-plowing arrangement.

VII. Conclusion

What was the impact of changing agricultural technology on land tenancy in preindustrial China? This paper argues that the movement from annual cropping to multiple cropping generated the shift from share tenancy to fixed-rent tenancy during the Ming and the Qing Dynasty. To address this question, we construct a unique dataset from the archives of rent collection books preserved by Confucius’s Lineage in Shandong Province in the Qing Dynasty. The dataset features a quasi-experiment, the adoption of wheat-soybean double cropping, which was then an important new agricultural technology in northern China. We find that fixed-rent contracts were more likely to

[43] Both the original lease holder and the sublease holder were registered in the rent collection book if there was a sublease.
[44] Co-tenants could be related or unrelated, as judged from their last names.

be chosen after the double cropping technology was adopted. Double cropped lands were 30.1% more likely to be managed under fixed-rent tenancy than annually cropped lands.

We derive hypothesis from the factor market imperfections theory to explain why double cropping caused the shift from share tenancy to fixed-rent tenancy. Managerial ability in traditional agriculture was an important factor input, but the market for such factors was highly imperfect due to low levels of education and slow information diffusion. An effective way of obtaining such a factor is to offer a self-monitoring incentive contract to the factor owner. Switching from annual cropping to double cropping, the relative importance of landlords' managerial directions declined while the importance of tenants' managerial decisions increased. Therefore, tenancy contracts for double cropped lands should provide higher self-monitoring incentives for tenants.

This paper is a preliminary attempt to study land tenure system using the vast Chinese historical materials, including land tenancy contracts and rent collection books. Cross-regional comparison needs be done to test the robustness of the findings in the paper. If multiple cropping and other intensive farming methods were factors causing the change in land tenancy, another implication is that fixed-rent tenancy should be the dominant form of tenancy in intensively farmed regions, whereas share tenancy should be the dominant form of tenancy in regions with a high fallow ratio. The rich source of historical land contracts and rent collection books offers opportunities for potential empirical research in the future.

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