The effect of land rental market on misallocation

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Land rental market reduces transaction cost, and thus promote lands reallocated within farmers. This paper examines the effect of land rental market on misallocation using detailed rural household-level panel data in China from 2015 to 2019. We find that land rental market significantly reduces land misallocation by promoting lands reallocated from low ability farmers to high ability farmers. The frictions from land rental market, market failure and searching friction, hinders the efficiency of land rental market. A well-functioning land rental market is crucial for optimizing land allocation. We also point that land rental market helps alleviate ageing threaten on farming. However, we don't find obvious evidence on land rental market effects on capital and labor misallocation.

Keywords: Land rental market, Misallocation, Farmer's managerial ability, Frictions
JEL Classification：O11, O13, Q12, Q15

1. Introduction

A common phenomenon observed in agricultural sector difference across countries is that productivity in poor countries is smaller than in rich countries (Caselli, 2005; Gollin et al., 2007; Restuccia et al., 2008). Farm distortion due to institutions and policies plays an important role on accounting for agricultural productivity difference across counties, and many literatures have provided many powerful insights on it (Adamopoulos and Restuccia, 2014; Le, 2020; Adamopoulos et al., 2022b; Adamopoulos and Restuccia, 2020; Ayerst et al., 2023). Farm distortion, such as the ban on land rental or restriction of land use right, is particularly prevalent in the poor countries before 2000s. Given heterogeneous farmer's managerial ability, the best allocation is the households with highest ability operate the largest scale farm. The ban on land rental thus exert misallocation, which is mostly measured by the dispersion of productivity across farmers (Restuccia and Rogerson, 2017). Recent literatures have quantified aggregate productivity loss from misallocation (Chen et al., 2023; Gollin and Udry, 2021; Aragón et al, 2022; Adamopoulos et al., 2022a, Britos et al., 2022). But to date, many developing countries have established a series of land reforms to construct a liberalized land rental market. While some literatures studied the impact of land reform linked to land rental on productivity and other economic outcomes or explored the relationship between land property and factor reallocation, little focus on the effect of land rental market on misallocation.

In this paper, we provide direct empirical evidence on the effect of land rental market on misallocation by using detailed household-level panel data in China. In 1978, China launched the Household Responsibility System (HRS). The land owned by village-level collective was averagely distributed to all families of collective. No official documents allowed farmers to rental their lands. After the announcement of Rural Land Contracting Law (RLCL) in 2003, more and more farmers have participated in land rental market. By 2020, the ratio of rental land to the total land contracted by household stands at 34 %. With the rapid developing land rental market, China provides us a unique context to study the relationship between land rental market and misallocation. In theory, a well-functioning market should facilitate efficiency-improving factor allocation. Farmers could transfer land with relatively low transaction cost. High ability famers would transfer farms in and thereby increase capital and labor inputs, and low ability farmers would transfer farms out. In practice, however, land rental market or other factor market in poor and developing countries has not matured considerably. There may be lots of frictions that prevent factors from the best allocation. For example, social capital is crucial in land rental market (Deininger and Jin, 2009; Bryan, 2015). It is common that farmers are prefer to transfer their lands to their relatives rather than to other strangers. Some transfer transactions leaded by village-collective perhaps are out of farmers' voluntarily. Additionally, the inefficiency of land rental market may also come from other factor market. If credit market is imperfect, households that have high ability but lack of wealth hardly transfer lands in. If labor market has barriers, farmers who can't find a job won't lease lands out. Consequently, whether land rental market reducing misallocation remains an open question.

We begin our analysis with constructing a framework on misallocation. Hsieh and Klenow (2009) provide a measurement on misallocation by focusing on revenue productivity differing across firms. It's more appropriate for calculating aggregate misallocation within sector. Based on our framework, we take the relationship between input and farmer's managerial ability as misallocation measurement. The deviation of elasticity of actual input with respect to farmers' ability from the best allocation (which equals to 1) represents the extent of misallocation. Combining

with household-level data, we provide the evidence on factor misallocation in rural China. We exploit data on land rental at village-level and estimate the impact of land rental market on land misallocation. We find that land rental market significantly reduce misallocation. It promotes land reallocated, mostly happening within a village, from low ability farmers to high ability farmers. High ability farmers transfer lands in and low ability farmers transfer lands out. The land misallocation in the villages where lands are completely transferred is 15.1 % lower than in the villages without land rental market, which implies an 5% decrease given that aggregate average land rental rate (27.75%).

We perform a range of checks to verify our result is robust. We use another group of agricultural technology parameters and the number of labors instead of labor days to recalculate farmer's ability. We also use indicator or village land rental market as independent variable. In addition, following Hsieh and Klenow (2009), we consider the relationship between ability and marginal product as misallocation measurements. The results are all robust to our basic estimation. We also take land quality, especially double cropping, into consideration for excluding measurement error. Our test shows that land quality would not threaten our basic result after controlling village fixed effect. Although the checks are all robust, our result may still face endogeneity from omit variables. We seek an exogeneous land rental policy, Pilot program on land rental market with standardized management and services, to further identify that the casual relationship between land rental market and land misallocation. We find that misallocation has a 6.1% decline in the cities where has land rental pilot program than the cities where don't have. The estimate remains completely robust.

As we discuss above, a range of frictions from land market or other markets limit the effect of land rental on misallocation. Here, we focus on land market frictions to hope find an efficient path to construct land rental market. The first friction is land tenure security that have been studied by some researchers with policy about land property right (Chen, 2022; Chari et al., 2021). We exploit land titling and certification reform to reproduce the result of land tenure security impact on misallocation. However, the result doesn't show evidence on secure property reducing misallocation in China.

Second, we investigate market failures that may be produced by informal institution, such as social capital. It is common that farmers give farms to relatives for free. Chen et al. (2021) finds that almost 82 percent of farmers lease lands from their relatives and friends in Ethiopia. Although China land rental are mainly market-oriented, there is a percentage of non-market transaction (16%, as shown by our survey data). Some researchers show that informal institution can substitute imperfectly for formal market (Udry, 1994). For instance, farmers tend to give lands to high ability relatives for maintaining farms fertile when farmers with low ability have the willingness of renting out but land rental market is incomplete. From this perspective, the effect of rental market failure is worth examining. Our result presents that market failures have no effect on land misallocation. Only market-oriented rental can promote land reallocate from low ability farmers to high ability farmers. The efficiency of land rental is dominated by formal market with price.

Third, we discuss searching friction in land rental market. Actual rental transaction is complicated. It takes time for farmers searching renters and suitable farms, negotiation, and signing and enforcing contract. The existence of searching friction leads a percentage of farmers don't participate in rental market, which affects the efficiency of land rental market. We next examine the magnitude of searching friction on misallocation by exploiting business registry data on enterprises with rental service. We find that specialized- enterprises provide the most effective rental service

relative to cooperatives. Land misallocation in the villages where only have enterprises specialized rental service or family farms with rental service is almost 11% lower than the villages without land rental market. Searching friction hinders the effect of land rental market on misallocation. That's to say, searching friction has negative effect on the relationship between land rental and misallocation. Reducing searching friction by encouraging specialized rental service is necessary for making a well-functioning land rental market.

Finally, we turn to study some other consequences from land rental market. One important issue, ageing, attracts our interest. Ageing has threatened agricultural output and productivity because of the lack education and skill, which is proved by Ren et al. (2023). Adamopoulos et al. (2022b) demonstrates that most of the farmers engaged in agricultural operations are aged in China. The proportion of aged farmer operators (over 45 years old) have increased from 57.8% in 2004 to 80.5% in 2018. In 2018, 62 % households operate farms all by the olds over 55 shown by our using data. We find that land rental market can lessen ageing threaten by promoting the aged farmers transfer lands out. However, land flowed from old to young farmers can't powerfully explain the process of land reallocation. The effect of land rental market on misallocation is dominated by farmer's managerial ability. We also investigate land rental effects on other inputs misallocation. We don't find the evidence on land rental market improving capital and labor allocation, which is similar for Chari et al (2022). Perhaps, the ineffectiveness of land rental market on capital and labor reallocation is from incomplete machine market and barriers to labor mobility.

This paper relates to the literature on quantifying the impact of factor misallocation across sectors or firms within a sector on productivity (Restuccia et al., 2008; Banerjee and Duflo, 2014; Song et al., 2011; Brandt et al., 2013), particularly that relating to emphasize on farm distortion (Adamopoulos et al., 2022a; Adamopoulos et al., 2022b; Adamopoulos and Restuccia, 2020; Adamopoulos and Restuccia, 2014). While these papers focus on quantifying productivity loss from distortion using a structural model, we aim to assess the impact of land rental market on misallocation with a reduced-form approach, which can clearly display mechanism. Our results contribute to understand the importance of land rental market in accounting for productivity difference across counties.

Our paper is also a part of literatures that investigates the economic influence of land reform that relates to land rental. Bu and Liao (2022) document the effect of land titling reform in China on rural entrepreneurship. Jin and Deininger (2009) study the determinants of farmers participating in land rental market. While these papers are informative about land reform influence, there is no link between them and misallocation. The two mostly related paper to ours are Chari et al. (2021) and Chen et al. (2021). Chari et al. (2021) study the impact of the establishment of Rural Land Contracting Law in China, a reform that gave farmers legal rights to lease their land, on factor reallocation. Unlike them, we more focus on land rental market itself and discuss frictions from land rental market. Our viewpoint is a well-functioning land rental market that have clear price and platform on rental service, not just having secure property right that Chari et al (2021) highlight, would promote factor reallocation. Chen et al. (2021) examined the role of land rental, like us, on factor misallocation in Ethiopia. However, we further contribute to understand the mechanism of land rental affecting factor misallocation. The relationship between farmer's ability and farm size not only reflects the extent of misallocation in agricultural sector but also displays the process of land reallocation through land rental market. Our results demonstrate that land rental market reduces misallocation by lands flowing from low ability farmers towards high ability farmers.

The paper proceeds as follows. Section 2 describes background on China land rental market. In section 3, we construct a framework on misallocation. We present the sources of data and some facts about misallocation in section 4. In section 5, we discuss the empirical method to quantify the effect of land rental on misallocation and provide main results. We discuss frictions from land rental market in section 6. Section 7 presents some potential consequences of land rental market. Section 8 concludes.

2. Background

China land rental market has experienced a remarkable change since 1978. In 1978, a land reform, the Household Responsibility System (HRS), was launched, separating contracts right from ownership right. The land owned by village-level collective was averagely distributed, according to the number of residents, to all families for contracts. There was barely land rental transaction in the 1980s without official documents allowing farmers to transfer their lands. Agriculture Law established in 1993 approved for famers subcontracting to a third party but on the condition of requiring agreement of village-level collective, which reveals the first hint of land rental market emergence. Until 2003, the announcement of Rural Land Contracting Law (RLCL) regulated details of rental contracts, providing official legal right to land rental. A sharp rise in share of land rental since then have begun to appear. China government has been trying to encourage land rental for two decades, such as building platform on rental service. In 2014, China pushed ahead with a reform on land property, additionally separating use right from contract right. In addition to a series of reforms, China government has extended the contract period for ensuring farmers property on lands constantly. The first round of contract period is 15 years. Contract period was extended to another 30 years when the first contract was expired. In 2020, China agreed with extending land contract to another 30 years after the second round of contract period expiration. Land rental market in China has gradually matured with security long-term property right. According to the report of National Bureau of Statistics of China, the proportion of rental land in aggregate arable land have risen from 3.16 percent in 2004 to 27.75 percent in 2020.

Table 1 The ratio of land rental from 1988 to 2019

Year	Transferring-households ratio %	Transferring in ratio %	Transferring out ratio %	Data Source
1988	4.08	3.43	0.78	CHIPS
1995	2.89	2.01	1.01	
2002	10.76	7.33	3.79	
2013	26.77	10.56	17.12	
2015	32.32	13.02	19.8	CRHPS
2017	35.82	11.62	25.22	
2019	35.76	10.23	26.53	

Notes: This table reports the share of households who have transferred their lands. Transferring-households ratio is calculated as the share of number of households who have already transferred lands over the total number of households in the survey. Transferring in and transferring out ratio are calculated as the ratio of number of households who have already transferred in and transferred out lands over the total number of households in the survey. Data on year 1988, 1995, 2002, 2013 are from CHIPS. The household survey is given to a random sample in every rounds. Data on year 2015, 2017, 2019 are from CRHPS, which traced representative households five rounds from 2011-2019. CRHPS has included information about land rental since 2015.

In Table 1, we report the ratio of households that have already rented lands combining two household-level surveys from 1988 to 2019. The first survey is China Household Income Projects Survey (CHIPS), which includes rural household information about the contract land size in HRS and rental land size from 1988 to 2013. The second is China Rural Household Panel Survey (CRHPS), which contains rich data on farm operation of rural households. Column (2) provides the ratio of households who have already transferred lands. Column (3) and (4) separately shows the ratio of households who have transferred in and transferred out. We observe that little households transferred their lands out before 2000s. Since 2002, the share of rental has increased dramatically. There is upward trend on ratio of households transferring out. More and more households choose to transfer their lands out and work in the non-agricultural sector. However, the share of households transferring in turns to decrease after 2015, which is because lands are more likely to flow from households to large-scale farm operators instead of to other small-scale and fragmented households. The share of rental-households is up to 36 percent in 2019. China land rental market was gradually taking form.

We plot geographic distribution on ratio of households with land rental in Fig. 1. The provinces having high land rental rate are located in eastern regions and low-rate provinces are located in central and western regions. More interestingly, land rental across provinces corresponds to agricultural technical efficiency across provinces that is calculated by Gong (2018). The provinces that having the highest ratio of land rental, such as Anhui, Heilongjiang, Jiangsu, have the highest technical efficiency. The provinces that have the lowest ratio of land rental, like Gansu, Hainan, Qinghai, have the lowest technical efficiency. The corresponding relationship between land rental and technical efficiency suggests that land rental has been playing an important role in improving inputs efficiency.

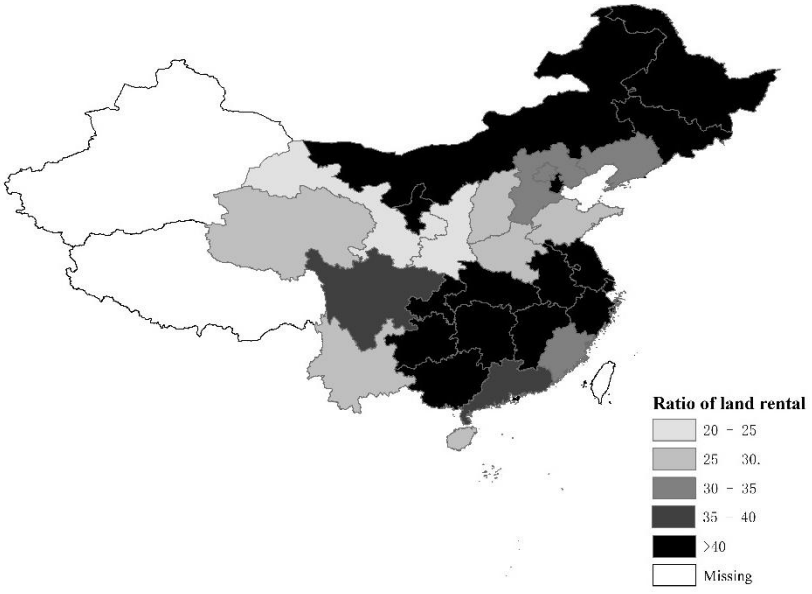

Fig 1: Geographic distribution on ratio of land rental

3.Framework on factor reallocation

We begin our analysis with describing the framework on assessing of factor misallocation.

Consider the economy is consisted of a finite number farm operators with heterogeneous managerial ability s_i in village v. Each village is endowed with amounts of farm land $\overline{L}$, capital $\overline{K}$, labor $\overline{N}$. The production function of farm operator i is:

$$y_i = A_{it} {s_i}^{1-\gamma} ({k_i}^{\alpha} {l_i}^{\beta} {n_i}^{1-\alpha-\beta})^{\gamma} \quad (1)$$

where y_i is agricultural output, k_i, l_i, n_i respectively denote capital, land, and labor inputs. s_i is managerial ability of farm operator i, which can scale up input return. It doesn't vary with time. A_{it} is a common productivity term that captures all stochastic component. γ is returns to scale. α, β, $1-\alpha-\beta$ is the share of capital, land, and labor on total inputs.

Each farmers face idiosyncratic distortions f_i. f_i is closely correlated with farmer's ability s_i, which preforms farm distortion of land market in China that affects marginal products of three factors by the same proportion. The famers with highest ability and lowest ability faced the largest f_i if land is averagely distributed and not allowed to transfer. We also respectively model the distortions that raise marginal product of capital and labor as capital distortion τ_i^k, and labor distortion τ_i^n, which may correlate with farmers' ability and may not. For example, labor distortion may be higher for the low ability famers and lower for the high ability farmers. It also can be identical with all farmers. We assume agricultural price is exogeneous. The profit of farm operator i is:

$$\pi_i = A_{it} (s_i f_i)^{1-\gamma} \left({k_i}^{\alpha} {l_i}^{\beta} {n_i}^{1-\alpha-\beta}\right)^{\gamma} - (1-\tau_i^k) R k_i - z l_i - (1-\tau_i^n) w n_i \quad (2)$$

Profit maximization under resource constraint yields factors allocation across farmers. The details on calculation are shown in Appendix A.

The factor inputs are decided not only by farmer's ability but also by all distortions. While the dispersion on productivity across farmers within a village can represent misallocation, their requirement for sample representative is strict. The measurement by the gap between the best inputs and actual inputs also faces the same question because of the term of $\sum_i s_i$. However, the relationship between land input and farmer's ability provides us a more convenient and efficient method to assess misallocation. We take land misallocation as an example:

$$\log l_i^* = \log(s_i f_i) + \frac{\alpha\gamma}{1-\gamma} \log\left(\frac{1}{1-\tau_i^k}\right) + \frac{(1-\alpha-\beta)\gamma}{1-\gamma} \log\left(\frac{1}{1-\tau_i^n}\right) + c \quad (3)$$

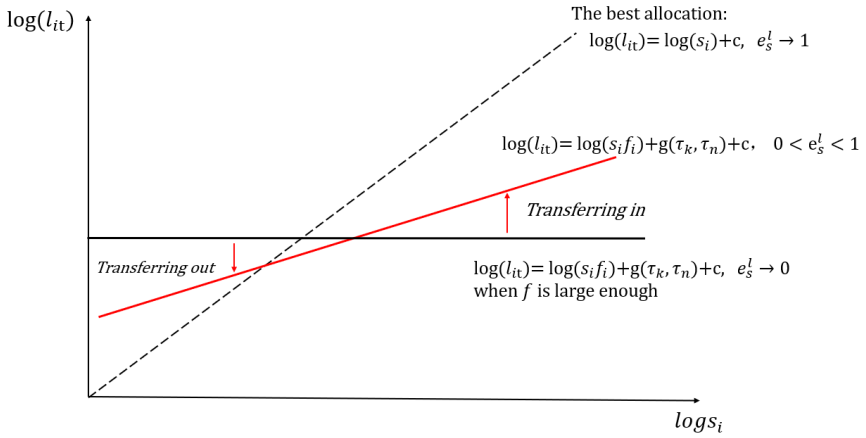

Fig 2 Relationship between farmers' specific ability and land size

If all factor markets face no distortion, the elasticity of land input with respect to farmer's

specific ability e_s^l would equal to 1. Idiosyncratic distortions from land, capital, and labor market (f_i, τ_i^k, τ_i^n) all make e_s^l deviate from 1. We, therefore, take the extent of e_s^l deviating from 1 as misallocation indicator.

The relationship between land rental market and misallocation is presented in Fig 2. The black direct line denotes initial distribution where misallocation is the largest, because farm distortion f_i is so large that makes land input weakly correlate with farmers' ability and e_s^l is close to 0. Once a well-functioning land rental market is emerging, it would lessen f_i. High ability farmers would transfer lands in and low ability farmers would transfer lands out, e_s^l would thus increase and misallocation reduces. But there are also many frictions in land rental market. We don't know land rental market would lessen f_i for certain. In addition to frictions from land rental market, distortions from labor and capital market also affects factor reallocation efficiency. Therefore, whether land rental market reduce misallocation still opens a question.

4. Data

4.1 Measuring farmers' ability

The first step of calculating misallocation is estimating farmer's managerial ability. We can measure aggregate TFP from production function:

$$TFP_{ivt} = A_{it}{s_i}^{1-\gamma} = \frac{y_{it}}{({k_{it}}^{\alpha}{l_{it}}^{\beta}{n_{it}}^{1-\alpha-\beta})^{\gamma}} \tag{4}$$

The term of aggregate TFP has two components. The first is random shocks that farmers don't know. The second component is factors that farmers know that contains fixed-time factors and varying-time factors. However, the time-fixed factor not only contains farmer's managerial ability but also includes environmental factors. To get farmer's specific ability, we gradually decompose aggregate TFP.

We first decompose aggregate TFP into time-varying, time-fixed and error term. φ_t captures varying-time factors and e_{ivt} is time varying stochastic component including random shock. We focus on φ_i that is the permanent component of farmer's productivity where ability involves.

$$\log(TFP_{ivt}) = \log(\varphi_t) + \log(\varphi_i) + \log(e_{ivt}) \tag{5}$$

We further exclude village specific shock (φ_v) from φ_i to eliminate fixed environmental factors. One important time-fixed factor should be noticed is land quality that also doesn't vary with time. We also exclude land quality component ql_i from φ_i.

$$\log(\varphi_i) = \log(\varphi_v) + ql_i + \log(\varepsilon_i) \tag{6}$$

The error term, ε_i, is the farmer's managerial ability contribution on output. Farmer's managerial ability can be estimated by:

$$\log(s_i) = \frac{1}{1-\gamma} log\ (\varepsilon_i) \tag{7}$$

With the expression of farmer's ability, the parameters of agricultural technology $\{\alpha, \beta, \gamma\}$ should be determined. Bolhuis et al. (2021) and Chen et al. (2021) set the share of total factor of agricultural production in developing counties at 0.54. Adamopoulos et al. (2022a) estimates the share of total factor in rural China from 1993-2002 to be 0.54, which is consistent with Wang et al. (2020). Wang et al. (2020) find that the total share of land, capital, and labor income in China have decreased from 0.68 in 1995 to 0.48 in 2017. Estimates on factors' share in China agriculture are

similar in literatures. The capital share is in 0.011-0.024, land share is in 0.22-0.5, and labor share is in 0.20-0.25 (Chari et al., 2021; Tian et al., 2020; Wang et al., 2020; Gong, 2018; Cao and Birchenall, 2013; Chow, 1993). Capital and labor share are less controversial, while the share of land return varies a lot. We first use the average value of estimates in literatures to set capital and labor shares, which makes capital share 0.017 and labor share 0.22. Based the fact that agricultural sector has tremendous changes over past decades and thus contribution of factors has decreased from 1990s to 2010s (Gong, 2010), we must make sure the share of total factors is from 0.54 in 1990s (Adamopoulos et al., 2022a) to 0.48 in 2017 (Wang et al., 2020). Tian et al. (2020) estimates the land shares is 0.346 using micro data from 2001 to 2010, which is similar with Cao and Birchenall (2013). Therefore, we take the land share from 0.22 in 2017 (Wang et al., 2020) to 0.346. To guarantee the share of total factors from 0.48 to 0.54 and land share from 0.22 to 0.346, we set total factors and land shares on 0.527 and 0.29, which results in the second parameter values, $\alpha = 0.03$, $\beta = 0.55$, $\gamma = 0.527$.

4.2 Data

The main data that we use is from Chinese Family Database (CFD), which includes three sections cooperatively run by Zhejiang University and Southwestern University of Finance and Economics. The first section is China Rural Household Panel Survey (CRHPS), which allows us to observe data on farm operation at household level. The second section is China Community Governance Survey (CCGS), containing detailed information about rural village and it is collected through direct interviews with the village cadre. The third section is China Household Finance Survey (CHFS), which has data on individual's features and job. This is a nationally representative survey that covers 29 provinces except Xinjiang, Xizang, Taiwan and 346 counties. The survey has been carried out every two years since 2011. The data is in form of unbalanced panel. In each year, we have data on approximately 20000 rural families drawn from 1300 villages. This survey has provided detailed land rental information at household-level and village-level since 2015 and we thus use the 2015, 2017, 2019 waves of survey. We have data on farm operation at household level: output and land holdings by crops, labor, capital, and intermediate product inputs. The richness of data on output and inputs allows us to measure ability and factor misallocation.

Farm operation. (1) Net agricultural output. Farm output by crops is reported in form of market value by interviewees. Wu et al. (2018) has tested the accuracy of output value reported by calculating the output reported in physical quantity multiplying regional common price by crops. Hence, we directly use the survey data on output value. Note that there are intermediate inputs used in agricultural production, including seed, seedling, pesticide, growth agent, herbicide, chemical fertilizer, agricultural film, organic fertilizer. We calculate the net agricultural output by subtracting total intermediate inputs cost from the output value. (2) Land input. Land input refers to gross cultivated land size of food crops and economic crops in four seasons of last year. The crops include rice, corn, wheat, potato, sweet potato, beans, peanuts, rape, cotton, and tobacco. (3) Capital input. Capital input is calculated as the total cost of agricultural machine. It is composed by machine leasing, livestock and machine owning. Machine owning value includes big machine owning per year, per year, and small machine purchased the last year. Machine leasing cost is directly reported in the survey. We choose depreciation rate to be 0.1 to define machine and livestock owning per

year. [1] (4) Labor input. Labor input is the sum of labor days, which includes farmers' family labor days and hired labor days. We have information about labor days in the harvest, the number of family in the harvest and lean season, the number and working months of long-term hired labor, the number and working days of short-term hired labor. However, there is only data on aggregate number of hired labor in 2015. We suppose the hired labor working the same days as family labor. We also use the labor number as robust check.

Land rental Market. We construct village rental rate, computed by rental farm scale dividing aggregate farm size on village level, as our independent variable. The aggregate farm area on village level hardly changes over time but may affected by interviewees. We take aggregate farm size on base period to make sure that land rental rate reflects land rental variation as precise as possible. We also use land rental market indicator as robust check. If there are farmers transferring farms in the village, it shows that the village has land rental market. Data on village rental land rate is reported since 2017 and data on dummy indicator is reported since 2015.

Land quality. In CRHPS of 2015, there are several questions about the largest farm quality. They are all categorical variables, including land type, land quality, whether suitable for large machine working and near to the road of machine working, whether having power, irrigation, and drainage facilities, whether being polluted. Land type has three values: paddy land, irrigated land, and upland. Land quality is evaluated by farmers, having five points. Smaller point means higher quality. The six others are all dummy indicators.

Other related variables. (1) Village-level economic and household-level labor and economic characteristics. We obtain village level variables from CCGS to further control underlying economic conditions that possibly correlates with land rental and land reallocation in empirical analysis. It includes per capita income, number of households and residents registered, ratio of the non-worker, the educated, the old and children left behind. We obtain household labor characteristics from CHFS for examining the effect of land rental on ageing in farm operation and use income factors for studying the mechanism of land rental market. (2) Pilot program on land rental market with standardized management and services. Ministry of Agriculture launched this program started at 2012. The pilots are required to further develop land rental market and establish service market on land rental. The pilot program provides an exogeneous policy shock to solve the problem on endogeneity. (3) Land titling and certification reform. In three waves of CCGS, the question about whether the village has organized land titling and certification reform is reported. We also use data on reform year across provinces from Chinese Ministry of Agricultural and Rural Affairs. We use land titling and certification reform for discussing the role of property insecurity on efficiency of land rental market. (4) The number of enterprises with land rental service. The business registry data contains hundreds of millions of enterprises information from 1978 to 2020. It provides the business's scope, location, type, and start year. We select the enterprises whose scope contain farm rental service and count the number of the enterprises by county and year.

4.3 Summary Statistics

We must exclude the samples who don't have two years farm operation data at least and then exclude the villages where the number of household samples are lower than 2 because the estimation

[1] Our results are all robust if depreciation rate is 0.2.

of famers' managerial ability requires calculate individual fixed effect and village fixed effect. [②] We next combine parameters with data to measure farmer's managerial ability. After excluding the components changing over time, villages, and land quality, we figure out farm ability contribution on output $\log(\varepsilon_i)$. The dispersion of $\log(\varepsilon_i)$ is lower than raw $\log(TFP)$ directly calculated from production function. $\log(\varepsilon_i)$ is a distribution with mean of 0.056 and standard deviations of 0.710. It ranges between -3.023 and 2.161. The distribution of $\log(\varepsilon_i)$ is displayed in Appendix Fig. A.1.

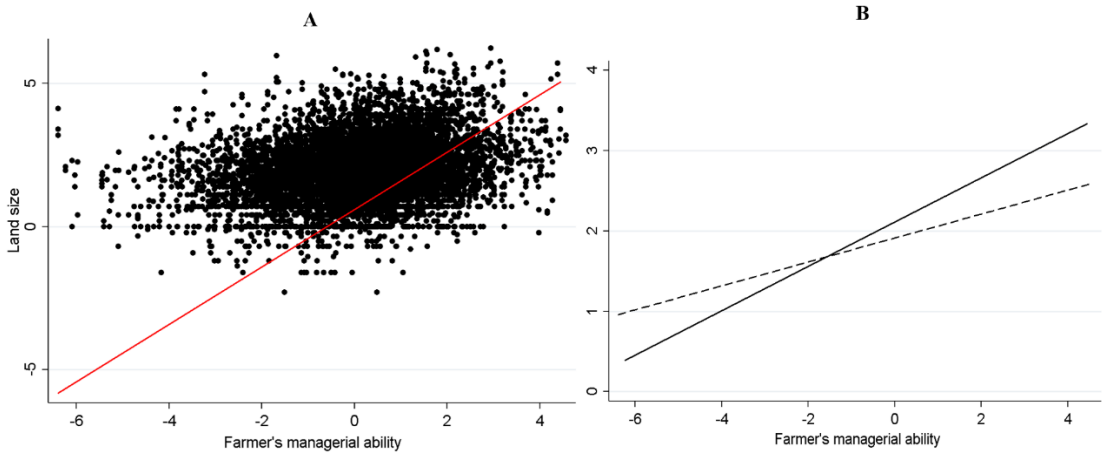

Fig 3 Best inputs and actual inputs by farmer's managerial ability

Note: Panel (a) refers to the best and actual land inputs. Panel (b) reports the capital plot. Panel (c) refers to labor plot. Panel (d) refers to output plot. The red line fits the best inputs that farmers should invest, and the scatter denotes farmers' actual inputs.

We plot the best land allocation and actual input by farmers' managerial ability in Fig.3.A The red line fits the best land that farmers should invest ($e_s^l = 1$), and the scatter denotes farmers' land size. We find that land size is positively correlated with ability. High ability farmers tend to operate larger farm than low ability farmers. However, there remains gap between actual and best land size, representing land misallocation in agricultural sector of China.

We present misallocation by land rental in Fig 3.B. The direct line fits relationship between ability and land size of farmers who have leased land, and the dash line fits the relationship of who don't lease land. We find that e_s^l in the households with land rental is bigger than the households without, which shows that land rental reduces land misallocation.

Summary statistics for variables that we use are presented in Appendix Table A.1. Panel A shows the statistics of variables by farmer-year. The farming-crop are largely food crop. Panel B provides summary statistics on variables at village level. Land rental rate is about 15 percent and 67 percent of villages have land rental market. The average of per capita income in the village is 7400 RMB.

[②] Our results are still robust to excluding the villages where the number of household samples are lower than 5, 8, or 10.

5.Empirical analysis and results

5.1 Empirical Specification

We have roughly presented the correlation between land rental and land reallocation in Figure 3. In this section, we turn to empirical analysis on identifying the effect of land rental market on land misallocation. The deviation of e_s^l from 1 denotes misallocation, and the coefficient shown in empirical model (10) is β_1. The higher coefficient β_1 means misallocation incline and vice versa.

$$\log(land)_{ivt} = \beta_0 + \beta_1 \log s_i + X_{ivt} + \delta_t + \delta_v + \mu_{ivt} \quad (8)$$

To examine the effect of land rental market on misallocation, we introduce land rental market into empirical Equation (10) and we have:

$$\log(land)_{ivt} = \alpha_0 + \alpha_1 rm_{vt} * logs_i + \alpha_2 rm_{vt} + \alpha_3 logs_i + X_{ivt} + \delta_t + \delta_v + \mu_{ivt} \quad (9)$$

where i indexes farmers, v villages and t year. The dependent variables $\log(land)_{ivt}$ is farmer i's aggregate land size, $\log s_i$ is farmer's managerial ability, rm_{vt} denotes village-land rental rate. α_1, our coefficient of interest, captures the effect of land rental market on land misallocation. $\alpha_1 > 0$ means that land rental market reduces land misallocation through high ability farmers increasing land size and low ability farmers decreasing land size.

The vector X_{ivt} denotes a set of control variables. To avoid influence of some factors that correlates with land rental market, we control the share of farmer's farming-crops and village economic and labor conditions. We also control year fixed effect (δ_t) and village fixed effect (δ_v). The village fixed effect is included to capture village-specific factors that are potentially important factors of land rental, such as landform. There is no doubt that land reform is strongly correlated with land rental and farm operation. Village fixed effect also capture some policies difference across villages and therefore, help to separate the effects of policy from land rental market.

5.2 Empirical results: the effect of land rental on land reallocation

We next follow the specification in Equation (9) to examine the effect of land rental market on misallocation in Table 2. We also take land size of transferring in and out as independent variables to make sure that farmers adjust land size by transferring not by abandonment or others. Only focusing the households that constantly operate farm has omitted the samples who exited or entered farm from 2015 to 2019 that may arise selection bias. Therefore, we identify and include those samples and assume their farm crops ratio when they don't operate farms are same as last or next year. The coefficient for the interaction in column (1), α_1, what we are interested about, is positive and significant at 5% level. The land misallocation in the villages where lands are completely transferred is 15.1 % lower than in the villages without land rental market, which implies an 5% decrease given that aggregate average land rental rate (27.75%). Column (2) and (3) proves that land rental market significantly promotes that high ability farmers transfer lands in and low ability farmers transfer lands out.

Table 2 Impact of land rental on misallocation

	log (Land size+0.1)	log (In+0.1)	log (Out+0.1)
	(1)	(2)	(3)
Land rental *Ability	0.151**	0.174*	-0.280***
	(0.070)	(0.092)	(0.066)
Land rental	-0.166	0.186	0.118
	(0.358)	(0.372)	(0.357)
Ability	0.180***	0.160***	-0.005
	(0.016)	(0.025)	(0.014)
Ratio of crops	Yes	Yes	Yes
Village-variables	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes
Village fixed effect	Yes	Yes	Yes
Observations	4,187	4,172	3,854

Note: Crops include rice, corn, wheat, potato, sweet potato, beans, peanuts, rape, cotton, tobacco. Village variables include logarithm of per capita income, number of households and residents registered, ratio of the non-worker, the educated, the old and children left behind. All regressions include year fixed effects, village fixed effect and a constant term. Standard errors clustered at village level are reported in parentheses. *, **, *** denote significance at the 10%, 5% and 1% levels, respectively. Land size plus a minimum before logarithm, because independent variables contain zero. We take land size plus one and the dummy on transferring in and out as independent variable. The results are still robust. We also compare the result of land size plus 0.1 with land size not plus 0.1 after excluding zero value and don't find significant difference.

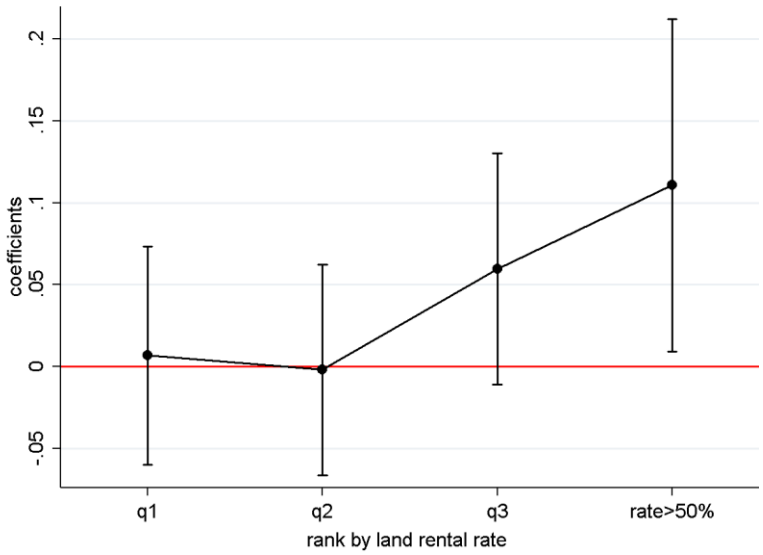

Fig 4 The tendency of land market activeness impact on misallocation

We also plot the tendency of land market activeness impact on misallocation in Fig 4.[③] We divide the villages with land rental market into four groups. We first set a group whose land rental rate is beyond 50%, and then divide other villages, land rental rate lower than 50%, into three groups by quantiles. We find that land misallocation decline is highly correlated with land rental market

[③] The empirical model and results are shown in Appendix Table A.2.

activeness. The effect of land rental market on land reallocation is increasing with its activeness. The misallocation of rank 1 (land rental rate ranges from 0 to 10%) and rank 2 (land rental rate ranges from 10 to 22%) has no significant difference from the villages without land rental market. The highest active land rental market has the largest effect. When land rental rate is more than 50%, land misallocation decline is more than 11%.

5.3 Robust check

We next perform seven robust checks to prove our result robustness.

(1) The first two checks are different measures of farmer's managerial ability. We first take another group of agricultural technology parameters. Our survey period is from 2014 to 2018, which is more closed to Wang et al. (2020). Therefore, we follow Wang et al. (2020) estimations and set total factor share at 0.48, capital share at 0.02, labor shares at 0.24, land share at 0.22. We use the number of labors to re-calculate farmer's ability.

(2) We replace land rental market indicator as independent variable. If there are farmers transferring farms in the village showing that the village have land rental market, which takes value of 1; otherwise, it takes 0.

(3) We adopt another measurement of misallocation, marginal product of lands (MPL), but more concentrate on the relationship between farmer's ability and misallocation instead of variance within a village. MPL should be equal for different ability farmers in the optimal (Hsieh and Klenow, 2009; Chen et al., 2021). High ability farmers should have larger MPL on the background of HRS. The decline of correlation between farmer's ability and MPL indicates smaller misallocation.

(4) There is no need to worry about endogeneity from land quality because we exclude land quality component from farmer's ability. However, double-cropping, not included in land quality variables, may give rise to concern on measurement error. Lands can be successively cultivated two crops in one year, like corn seeded in May and harvested in October and maize seeded after corn being harvested and harvested in May. Our dependent variable, land size, is constructed by gross cultivated size of crops in four seasons. Therefore, the size of land that is double-cropping is double for the same land but that is a year one ripe. In the basic regression, we hypothesis that double-cropping feature of land is identical within a village and village fixed effect can help us eliminate basis that double cropping bring. However, there is a possibility that the feature of double-cropping within a village is various. We keep the sample of cultivating corn, rice, and maize and use data on farm owning size, rental size, gross cultivated farm by crops to accurately identify double cropping or one cropping. We also further control land quality variables.

Table 3 presents all the robust checks. We find that no matter using another group of parameters (column 1) and using the number of labors (column 2) to recalculate ability, the results are still robust. The estimates of coefficient are essentially identical to the basic result, and they remain significant at the 1% and 5% level. We replace land rental market indicator and find that land rental rate significantly reduces misallocation (column 3). The misallocation is 3.7% less in the villages with land rental market than in the villages where don't have land rental market. The parameter is similar for the estimates given on aggregate average land rental rate. The result of using logarithm of MPL as independent variable (column 4) also obtains similar result. Column (5) and column (6) show that double cropping and land quality won't threaten our result after controlling village fixed.

Table 3 Robust checks

	log (Land size+0.1)			log (MPL)	log (Land size+0.1)	
	(1)	(2)	(3)	(4)	(5)	(6)
Land rental *Ability	0.169***	0.183**	0.037*	-0.122**	0.143*	0.147*
	(0.074)	(0.077)	(0.020)	(0.058)	(0.080)	(0.082)
Land rental	-0.172	-0.172	0.008	0.043	-0.304	-0.314
	(0.357)	(0.374)	(0.042)	(0.224)	(0.217)	(0.215)
Ability	0.203***	0.180***	0.174***	0.322***	0.183***	0.181***
	(0.018)	(0.018)	(0.017)	(0.014)	(0.024)	(0.025)
Double-cropping					0.513***	0.519***
					(0.103)	(0.105)
Land quality	No	No	No	No	No	Yes
Ratio of crops	Yes	Yes	Yes	Yes	Yes	Yes
Village-variables	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Village fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,188	3,851	6,181	4,438	1,302	1,302

Note: Double-cropping is an indicator whether the farmer's is double cropping. Land quality includes land type, land quality, whether suitable for large machine working and near to the road of machine working, whether having power, irrigation, and drainage facilities, whether being polluted. Crops include rice, corn, wheat, potato, sweet potato, beans, peanuts, rape, cotton, tobacco. Village variables include logarithm of per capita income, number of households and residents registered, ratio of the non-worker, the educated, the old and children left behind. All regressions include year fixed effects, village fixed effect and a constant term. Standard errors clustered at village level are reported in parentheses. *, **, *** denote significance at the 10%, 5% and 1% levels, respectively. Ability in column (1) and column (2) are respectively recalculated by another group of parameters and labor days. The dependent variable in column (3) is land rental indicator, and the independent variable in column (4) is log (MPL). Column (5)-(6) further control double-cropping dummy indicator and a range of land quality variables.

5.4 Exogeneous land rental policy

Although the checks are all robust, our result may still face endogeneity from omit variables. We seek an exogeneous land rental policy, Pilot program on land rental market with standardized management and services, to identify that the casual relationship between land rental market and land misallocation. This pilot program was launched by Ministry of Agriculture at 2012. 33 cities (counties), one or two cities every province, were selected to further perfect land rental market by normalizing contract and establishing land rental management and service system, promote lands flowing to large-scale farmers or organizations.

Our result in Table 4 clearly shows the pilot program has significantly perfected land rental rate. Village in the cities where has the pilot, has larger land rental rate than those in the cities without. The critical issue of using this exogeneous land rental policy for testing causality is that the pilots were randomly selected. If the pilots had identical features correlated with land rental market, it would be a doubt that land rental market decreases misallocation. Hence, we control economic, labor structure and characteristics, and government budget factors and use probit model to test whether the pilots were selected randomly. The result is shown in Appendix Table A.2. We don't

find any factors has significant effects on pilots' selection, which exactly proves that this program is exogeneous.

Column (3)-(5) in Table 4 reports the effects of the pilot program on misallocation. Still focusing on the coefficients of interaction, that's the estimates of land rental pilot program effect on misallocation. We find that misallocation has a 6.1% decline in the cities where has land rental pilot program than the cities where don't have. The estimate remains completely robust.

Table 4 The effect of land rental pilot program on misallocation

	Land rental market indicator	Land rental rate	log (Land size+0.1)	log (In+0.1)	log (Out+0.1)
	(1)	(2)	(3)	(4)	(5)
Pilot *Ability			0.061**	0.125***	-0.060**
			(0.027)	(0.042)	(0.025)
Pilot	0.091*	0.054**	0.221***	-0.003	0.085
	(0.049)	(0.027)	(0.083)	(0.116)	(0.067)
Ability			0.181***	0.156***	-0.024***
			(0.012)	(0.019)	(0.009)
Ratio of crops	No	No	Yes	Yes	Yes
Village-variables	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes
Province fixed effect	Yes	Yes	Yes	Yes	Yes
Observations	1,227	7,94	7,059	7,041	6,674

Note: Pilot is an indicator, equals to 1 if the city has land rental pilots; Otherwise, it takes values of 0. Crops include rice, corn, wheat, potato, sweet potato, beans, peanuts, rape, cotton, tobacco. Village variables include logarithm of per capita income, number of households and residents registered, ratio of the non-worker, the educated, the old and children left behind. All regressions include year fixed effects, province fixed effect and a constant term. Standard errors clustered at village level are reported in parentheses. *, **, *** denote significance at the 10%, 5% and 1% levels, respectively. Column (1)-(2) reports the result of land rental pilot program effect on land rental market at village level, and column (3)-(5) reports the result of land rental pilot effect on misallocation.

6. The determinants of land rental market efficiency

Thus far, we have proved that land rental market significantly reduces land misallocation, and also revealed the mechanism that high ability farmers transfer lands in and low ability farmers transfer lands out. In this section, we will discuss the determinants that affects efficiency of land rental market, frictions from land market, which limit the effect of land rental on misallocation. To hope find an efficient path to construct land rental market, it is important to investigate those frictions. In this section, we focus on three frictions from land rental market. The first friction is land tenure security that have been studied by some researchers with policies about land property right (Chen, 2022; Chari et al., 2021). The second is market failures that may be produced by informal institution, such as social capital. The last one we study is searching friction.

6.1 land tenure security

Giles and Mu (2018) point out that village politics in China undermined land security. Perhaps

land rental market is thin because of land tenure insecurity (Brandt et al., 2002). Chari et al. (2021) study the establishment of Rural Land Contracting Law that gave farmers legal rights to lease their land and find that well-defined property right resulted in land retributed to more productive farmers. Chen et al. (2021) also finds that land certification reform in Ethiopia reduces misallocation. We exploit the reform on land titling and certification trying to reproduce the effect of land tenure security on misallocation in China. Land titling and certification begun from 2009 and fully covered in 2019, which clearly regulated each household's land rights, location, and size and presented farmers with certificate. The implementation of land titling and certification reform secures farmers' right on farms, and thus facilitates land rental (Bu and Liao, 2022; Chen et al, 2022).

Table 5 The effect of land certification and titling reform

	log (Land size+0.1)	
	(1)	(2)
Reform*Ability	0.055	-0.036
	(0.041)	(0.059)
Land rental *Ability	0.151**	0.151**
	(0.071)	(0.070)
Reform	-0.207*	-0.005
	(0.116)	(0.267)
Land rental	-0.170	-0.170
	(0.360)	(0.360)
Ability	0.129***	0.215***
	(0.041)	(0.055)
Ratio of crops	Yes	Yes
Village-variables	Yes	Yes
Year fixed effect	Yes	Yes
Village fixed effect	Yes	Yes
Observations	4,185	4,187

Note: The reform variable in column (1) is at village level, reported in CCGS, constructed by the question about whether the village has organized land titling and certification reform. The reform variable in column (2) is constructed according to the timing of land titling and certification reform across provinces. It's an indicator, equals to 1 if the village or the province has launched land titling and certification reform; Otherwise, it takes values of 0. Crops include rice, corn, wheat, potato, sweet potato, beans, peanuts, rape, cotton, tobacco. Village variables include logarithm of per capita income, number of households and residents registered, ratio of the non-worker, the educated, the old and children left behind. All regressions include year fixed effects, village fixed effect and a constant term. Standard errors clustered at village level are reported in parentheses. *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

In Table 5, we examine the effect of land tenure security on misallocation. The results in column (1) are estimated with reform data at village level, and the results in column (2) are estimated with reform year data at province level. We don't find any evidence that land titling and certification reform significantly reduce misallocation from both results, which suggests land tenure insecurity doesn't affect the efficiency of land rental market.

6.2 Market failure

Second, we investigate market failures that may be produced by informal institution, such as social capital. It is common that farmers give farms to relatives for free. Chen et al. (2021) finds that almost 82 percent of farmers lease lands from their relatives and friends in Ethiopia. Although China land rental are mainly market-oriented, there is a percentage of non-market transaction (16%, as shown by our survey data). Market failure undoubtedly threaten the efficiency of market-oriented allocation, while some researchers show that informal institution can substitute imperfectly for formal market (Udry, 1994). For instance, farmers tend to give lands to high ability relatives for maintaining farms fertile when farmers with low ability have the willingness of renting out but land rental market is incomplete. We don't have information about whom farmers lease their lands to or from. Luckily, we respectively know the rent at household and village level. We define village land rental market as market failure by two methods. The first is directly measured by village-rent. When the rent equals to 0 that implies it's a market failure. The second method requires that all of farmers in the village who have participated in rental market have zero rent. The estimated model is specified as:

$$\log(land_{ivt}) = \alpha_0 + \sum_{j=1,2} \alpha_j * rank_{ij} * \log(s_i) + \sum_{j=1,2} rank_j + X_{ivt} + \delta_t + \delta_v + \mu_{ivt} \quad (10)$$

when j=1 indexes the villages that have market failure and j=2 indexes the villages that have formal land rental market. We set the villages that don't have rental market as baseline group, which is omitted in the specification. The coefficient α_j that we are interested about, is the difference between different groups and the baseline group.

Table 6 The effect of market failure

	log (Land size+0.1)	
	(1)	(2)
$rank_1$*Ability	0.049	0.006
	(0.049)	(0.039)
$rank_2$*Ability	0.036*	0.044**
	(0.020)	(0.024)
Ability	Yes	Yes
rank	Yes	Yes
Ratio of crops	Yes	Yes
Village-variables	Yes	Yes
Year fixed effect	Yes	Yes
Village fixed effect	Yes	Yes
Observations	4,852	4,842

Note: $rank_1$ implies villages with market failure, and $rank_2$ implies villages with formal rental market. Market failure in column (1) is defined by village-rent, and in column (2) defined by household-rent. Crops include rice, corn, wheat, potato, sweet potato, beans, peanuts, rape, cotton, tobacco. Village variables include logarithm of per capita income, number of households and residents registered, ratio of the non-worker, the educated, the old and children left behind. All regressions include year fixed effects, village fixed effect and a constant term. Standard errors clustered at village level are reported in parentheses. *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

The results are shown in Table 6. The interaction coefficient of $rank_1$*Ability represents the difference of misallocation between the villages that have market failure and the villages without land rental market, and it's not significant. The villages that have formal land rental market have smaller misallocation than the villages without land rental market ($rank_2$*Ability). Our result presents that market failures have no effect on land misallocation. Only formal market with clear price can promote land reallocate from low ability farmers to high ability farmers.

6.3 Searching friction

At last, we focus on searching friction in land rental market. It always takes time for farmers searching for renters and suitable plots, negotiating, and signing and enforcing contract. Transaction cost leads to a percentage of farmers, whose benefits is lower than cost if they transfer lands, don't participate in rental market, which affects land rental market efficiency. As shown by data on reasons farmers transfer not, there are about 10 percent of farmers who are willing to transfer lands but restricted by searching friction. They are facing the problems that can't find renters and appropriate plots, don't know how to lease land, and the rent is too high or too low.

The business on land rental service builds an effective platform on farmer's transaction. The enterprises collect information about the location, size, quality of transfer lands and thus significantly reduces farmer's searching friction. Land rental service has experienced a rapid development since 2010, displayed in Appendix Figure A.2. Not only enterprises that specialize on property service but also collective economic organizations like cooperatives provide land rental service for farmers. We examine the magnitude of searching friction on efficiency of land rental market by exploiting data on land rental service at county level.

The results are shown in Table 7. Column (1) reports the results of land rental market with service business and without. $rank_1$ represents the villages where have land rental market but don't have service business in the county, and $rank_2$ represents the villages where have land rental market and have service business in the county. Surprising, we find that land rental market without service business significantly reduces misallocation (see the coefficient of $rank_1$*Ability), while land rental market with service business has no significant effect on misallocation (see the coefficient of $rank_2$*Ability). We wonder whether different type of service enterprises is the reason of inefficiency. For example, the enterprises specialized rental service promote land rental, but cooperatives that rental service is a very small part of scope and mostly unify purchase of means of production and sales of product for their members. Therefore, we further divide land rental service into two groups. The first group is the cooperatives that has rental service, and the second is the enterprises specialized rental service and family farms with rental service. Column (2) reports the results of land rental market with different type of service business. $rank_1$ still represents the villages without any service business in the county, $rank_2$ is the villages where only cooperatives that has rental service, $rank_3$ is the villages where only have enterprises specialized rental service or family farms with rental service, and $rank_4$ is the villages where have all kinds of service business. We find that specialized firms provide the most effective rental service relative to cooperatives. Land misallocation in the villages where only have enterprises specialized rental service or family farms with rental service is almost 11% lower than the villages without land rental market (see the coefficient of $rank_3$*Ability). The rental service provided by cooperatives has no significant positive effect on misallocation (see the coefficient of $rank_1$*Ability).

Our result shows that searching friction hinders the effect of land rental market on

misallocation. Reducing searching friction by encouraging specialized rental service is necessary for making a well-functioning land rental market.

Table 7 The effect of rental service business

	log (land size+0.1)	
	(1)	(2)
$rank_1$*Ability	0.041*	0.041*
	(0.022)	(0.022)
$rank_2$*Ability	0.032	0.018
	(0.027)	(0.038)
$rank_3$*Ability		0.109**
		(0.050)
$rank_4$*Ability		-0.005
		(0.042)
Ability	Yes	Yes
Ratio of crops	Yes	Yes
Village-variables	Yes	Yes
Year fixed effect	Yes	Yes
Village fixed effect	Yes	Yes
Observations	6,148	6,148

Note: In column (1), $rank_1$ implies the villages where have land rental market but don't have service business in the county, and $rank_2$ is the villages where have land rental market and have service business in the county. In column (2), $rank_1$ still is the villages without any service business in the county, $rank_2$ is the villages where only cooperatives that has rental service, $rank_3$ is the villages where only have enterprises specialized rental service or family farms with rental service, and $rank_4$ is the villages where have all kinds of service business. Crops include rice, corn, wheat, potato, sweet potato, beans, peanuts, rape, cotton, tobacco. Village variables include logarithm of per capita income, number of households and residents registered, ratio of the non-worker, the educated, the old and children left behind. All regressions include year fixed effects, village fixed effect and a constant term. Standard errors clustered at village level are reported in parentheses. *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

7. Other potential Consequences of land rental market

In addition to making lands flow from low ability famers to high ability famers, land rental market may also have some potential consequences. We study those consequences to highlight the importance of a well-functioning land rental market in this section.

One important issue, ageing, attracts our interest. Ageing has threatened agricultural output and productivity because of the lack education and skill, proved by Ren et al. (2023). Combined individual data from CHFS, we plot the ratio of households that operate farm but its operators are all aged by year in Appendix Fig A.3. In 2018, 62 % households operate farms all by the olds over 55, 32 percent all by the olds over 60, 16 percent by the olds over 65. Although ageing in agriculture sector is serious, the olds who don't have energy won't persist engaging in farm operation. The percentage of households that operate farms all by the olds over 70 is only 6 percentage. We suppose that ageing on farm can be alleviated by land rental market. Famers who are too old to engage in farm operation would choose to transfer lands out. We next examine the effect of land rental market

on ageing.

Table 8 The effect of land rental market on ageing

	log (land size+0.1)		log (In+0.1)		log (Out+0.1)	
	(1)	(2)	(3)	(4)	(5)	(6)
Land rental * Share of the olds	-0.480**	-0.427*	-0.466	-0.376	1.071**	0.935**
	(0.219)	(0.222)	(0.444)	(0.435)	(0.478)	(0.467)
Land rental * Ability		0.158***		0.258**		-0.315***
		(0.060)		(0.123)		(0.077)
Share of the olds	-0.160***	-0.170***	-0.214***	-0.230***	0.059	0.081
	(0.052)	(0.052)	(0.082)	(0.081)	(0.084)	(0.084)
Land rental	0.035	0.020	0.265	0.241	-0.235	-0.191
	(0.167)	(0.168)	(0.482)	(0.491)	(0.260)	(0.265)
Ability	0.180***	0.158***	0.183***	0.148***	-0.033***	0.008
	(0.012)	(0.014)	(0.027)	(0.029)	(0.013)	(0.015)
Number of family labors in agriculture	Yes	Yes	Yes	Yes	Yes	Yes
Number of family labors	Yes	Yes	Yes	Yes	Yes	Yes
Ratio of crops	Yes	Yes	Yes	Yes	Yes	Yes
Village-variables	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Village fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,269	3,269	3,254	3,254	3,090	3,090

Note: We use retirement age, 65, in nonagricultural sector as the boundary of farm ageing. The share of olds is family labors in agriculture who are over 65 dividing the number of family labors engaging in agriculture. The number of family labors in agriculture and family labors are controlled. Crops include rice, corn, wheat, potato, sweet potato, beans, peanuts, rape, cotton, tobacco. Village variables include logarithm of per capita income, number of households and residents registered, ratio of the non-worker, the educated, the old and children left behind. All regressions include year fixed effects, village fixed effect and a constant term. Standard errors clustered at village level are reported in parentheses. *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

The result is presented in Table 8. We just control farmer's ability in column (1) and find that land rental significantly reduces the olds engaging farm at the 5% level. When village-lands are completely transferred, the share of farmers who are over 65 would reduce almost 50%. To testify the effect of land rental on ageing is not related with ability, we further control its interaction term with ability in column (2). The coefficient declines slightly and remain significance, which shows that land rental market promotes lands flowing to high ability farmer, at the same time, it also promotes the olds transferring lands out, as shown in column (5)-(6). Land flowed from old to young farmers can't powerfully explain the process of land reallocation. The effect of land rental market on misallocation is dominated by farmer's managerial ability.

Finally, we want to discuss the effect of land rental market on other factor allocation. The difference between farmer's factor inputs is not only decided by technology parameters but also by distortions from factor markets. Distortion from capital and labor market would affect land rental market efficiency. We next examine whether capital and labor allocation get improved through land

rental market.

Table 9 The effect of land rental market on capital misallocation

	log (Capital)	log (Cap_own)	log (Cap_lease)	log (Labordays)	log (Labor_fam)	log (Labor_emp)
	(1)	(2)	(3)	(4)	(5)	()
Land rental *	0.112	-0.043	-0.041	0.017	0.019	0.040
Ability	(0.137)	(0.237)	(0.164)	(0.105)	(0.106)	(0.063)
Land rental	0.089	-0.332	0.542	0.014	0.145	-0.504**
	(0.644)	(0.662)	(0.842)	(0.456)	(0.448)	(0.257)
Ability	0.205***	0.502***	0.055	-0.006	-0.016	0.076***
	(0.032)	(0.058)	(0.042)	(0.022)	(0.022)	(0.018)
Ratio of crops	Yes	Yes	Yes	Yes	Yes	Yes
Village-variables	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Village fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,098	4,185	4,098	4,166	4,174	4,180

Note: Crops include rice, corn, wheat, potato, sweet potato, beans, peanuts, rape, cotton, tobacco. Village variables include logarithm of per capita income, number of households and residents registered, ratio of the non-worker, the educated, the old and children left behind. All regressions include year fixed effects, village fixed effect and a constant term. Standard errors clustered at village level are reported in parentheses. *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

Table 9 presents the estimation of land rental market on capital and labor misallocation. The dependent variables in column (1)-(4) are aggregate capital, the value of capital owning, and capital leasing, and the dependent variables in column (5)-(7) are aggregate labor days, labor days of family members, and labor days of hired labor. We don't find the evidence on land rental market improving capital and labor allocation, which is similar for Chari et al (2022). We suppose that the ineffectiveness of land rental market on capital reallocation is perhaps from incomplete machine market, and on labor reallocation from barriers to labor mobility.

8. Conclusion

Our paper emphasizes the importance of land rental market for optimizing land reallocation. We calculate misallocation by the deviation of elasticity of actual land input with respect to farmers' ability from the best allocation. With data on farm operation, we find that there is misallocation in China land market. We then identify the effect of land rental market on misallocation and highlight the mechanism. We find that for the villages where have active land rental market, land misallocation is significant lower. The mechanism behind is that lands are reallocated from low ability farmers to high ability market. Land rental market significantly promotes high ability farmers transferring lands in and low ability farmers transferring lands out in. We perform a range of robust checks and confirm our result is robust to all the checks.

Importantly, we investigate the frictions from land rental market. We find that market failure and searching friction hinder the efficiency of land rental market. Making a well-functioning land rental market is crucial for reducing misallocation. Frictions from capital and labor market also have impact on efficiency of land rental market.

We also further examine other potential consequences of land rental market. We find that land rental market can lessen ageing threaten. However, ageing can't completely explain the effect of land rental market on misallocation. The process of land reallocation is dominated by farmer's managerial ability. We don't find evidence on land rental market promoting capital and labor misallocation, which maybe from barriers to capital and labor market. We leave those for further research.

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Appendix

A. The details on farmer's input calculation.

The production function of farm operator i is:

$$y_i = A_{it} s_i^{1-\gamma} (k_i^{\alpha} l_i^{\beta} n_i^{1-\alpha-\beta})^{\gamma} \quad A.1$$

The profit of farmer i is:

$$\pi_i = A_{it}(s_i f_i)^{1-\gamma} \left(k_i^{\alpha} l_i^{\beta} n_i^{1-\alpha-\beta}\right)^{\gamma} - (1-\tau_i^k) R k_i - z l_i - (1-\tau_i^n) w n_i \quad A.2$$

subject to:

$$\sum_i k_i = K; \ \sum_i l_i = L; \ \sum_i n_i = N \quad A.3$$

Farmer $i's$ factor inputs should satisfy profit maximization and we have:

$$\alpha\gamma A_{it}(s_i f_i)^{1-\gamma} k_i^{\alpha\gamma-1} l_i^{\beta\gamma} n_i^{(1-\alpha-\beta)\gamma} = (1-\tau_i^k) R \quad A.4$$

$$\beta\gamma A_{it}(s_i f_i)^{1-\gamma} k_i^{\alpha\gamma} l_i^{\beta\gamma-1} n_i^{(1-\alpha-\beta)\gamma} = z \quad A.5$$

$$(1-\alpha-\beta)\gamma A_{it}(s_i f_i)^{1-\gamma} k_i^{\alpha\gamma} l_i^{\beta\gamma} n_i^{(1-\alpha-\beta)\gamma-1} = (1-\tau_i^n) w \quad A.6$$

Combine Equation $A.3$, $A.4$, $A.5$:

$$\frac{k_i}{l_i} = \frac{\alpha z}{(1-\tau_i^k)\beta R}; \quad \frac{n_i}{l_i} = \frac{(1-\alpha-\beta) z}{(1-\tau_i^n)\beta w} \quad A.7$$

Put Equation $A.7$ into $A.4 - A.6$, we have

$$l_i = s_i f_i (\gamma A_{it})^{\frac{1}{1-\gamma}} \left(\frac{\beta}{z}\right)^{\frac{1-(1-\beta)\gamma}{1-\gamma}} \left(\frac{\alpha}{(1-\tau_i^k)R}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{1-\alpha-\beta}{(1-\tau_i^n)w}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma}} \quad A.8$$

$$k_i = s_i f_i (\gamma A_{it})^{\frac{1}{1-\gamma}} \left(\frac{\beta}{z}\right)^{\frac{\beta\gamma}{1-\gamma}} \left(\frac{\alpha}{(1-\tau_i^k)R}\right)^{\frac{1-(1-\alpha)\gamma}{1-\gamma}} \left(\frac{1-\alpha-\beta}{(1-\tau_i^n)w}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma}} \quad A.9$$

$$n_i = s_i f_i (\gamma A_{it})^{\frac{1}{1-\gamma}} \left(\frac{\beta}{z}\right)^{\frac{\beta\gamma}{1-\gamma}} \left(\frac{\alpha}{(1-\tau_i^k)R}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{1-\alpha-\beta}{(1-\tau_i^n)w}\right)^{\frac{1-(\alpha+\beta)\gamma}{1-\gamma}} \quad A.10$$

The factor allocation subjects to resource constriction $A.3$, and we have:

$$L = (\gamma A_{it})^{\frac{1}{1-\gamma}} \left(\frac{\beta}{z}\right)^{\frac{1-(1-\beta)\gamma}{1-\gamma}} \left(\frac{\alpha}{R}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{1-\alpha-\beta}{w}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma}} C_1 \quad A.11$$

$$K = (\gamma A_{it})^{\frac{1}{1-\gamma}} \left(\frac{\beta}{z}\right)^{\frac{\beta\gamma}{1-\gamma}} \left(\frac{\alpha}{R}\right)^{\frac{1-(1-\alpha)\gamma}{1-\gamma}} \left(\frac{1-\alpha-\beta}{w}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma}} C_2 \quad A.12$$

$$N = (\gamma A_{it})^{\frac{1}{1-\gamma}} \left(\frac{\beta}{z}\right)^{\frac{\beta\gamma}{1-\gamma}} \left(\frac{\alpha}{R}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{1-\alpha-\beta}{w}\right)^{\frac{1-(\alpha+\beta)\gamma}{1-\gamma}} C_3 \quad A.13$$

where

$$C_1 = \sum_I s_i f_i \left(\frac{1}{1-\tau_i^k}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{1}{1-\tau_i^n}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma}}$$

$$C_2 = \sum_I s_i f_i \left(\frac{1}{1-\tau_i^k}\right)^{\frac{1-(1-\alpha)\gamma}{1-\gamma}} \left(\frac{1}{1-\tau_i^n}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma}}$$

$$C_3 = \sum_I s_i f_i \left(\frac{1}{1-\tau_i^k}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{1}{1-\tau_i^n}\right)^{\frac{1-(\alpha+\beta)\gamma}{1-\gamma}}$$

Combine Equation $A.11$, $A.12$, $A.13$:

$$\frac{\alpha}{R} = \frac{\beta}{z}\frac{K}{L}\frac{C_1}{C_2}; \ \frac{1-\alpha-\beta}{w} = \frac{\beta}{z}\frac{N}{L}\frac{C_1}{C_3} \quad A.14$$

Put $A.14$ into $A.11$ and we have:

$$\frac{\beta}{z} = \frac{L^{1-\beta\gamma}}{\gamma A_{it}\left(\frac{C_1}{C_2}\right)^{\alpha\gamma}\left(\frac{C_1}{C_3}\right)^{(1-\alpha-\beta)\gamma} K^{\alpha\gamma} N^{(1-\alpha-\beta)\gamma} {C_1}^{1-\gamma}} \qquad A.15$$

Combine $A.15$ and $A.14$, we get all the factor's equilibrium price. Put it into A.8 and we have farmer's $i's$ factor allocation

$$l_i = s_i f_i \left(\frac{1}{1-\tau_i^k}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{1}{1-\tau_i^n}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma}} \frac{L}{C_1}$$

$$k_i = s_i f_i \left(\frac{1}{1-\tau_i^k}\right)^{\frac{1-(1-\alpha)\gamma}{1-\gamma}} \left(\frac{1}{1-\tau_i^n}\right)^{\frac{(1-\alpha-\beta)\gamma}{1-\gamma}} \frac{L}{C_2}$$

$$n_i = s_i f_i \left(\frac{1}{1-\tau_i^k}\right)^{\frac{\alpha\gamma}{1-\gamma}} \left(\frac{1}{1-\tau_i^n}\right)^{\frac{1-(\alpha+\beta)\gamma}{1-\gamma}} \frac{L}{C_3}$$

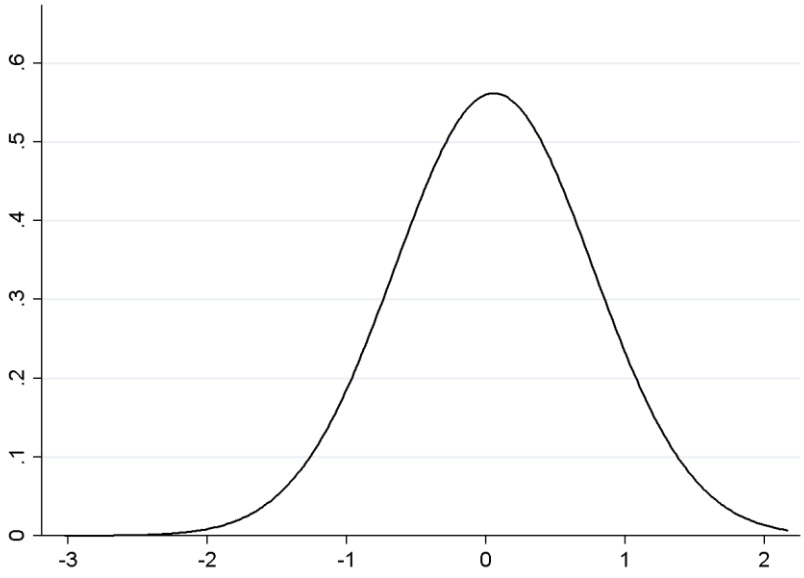

Fig A.1 The distribution on $\log(\varepsilon_i)$

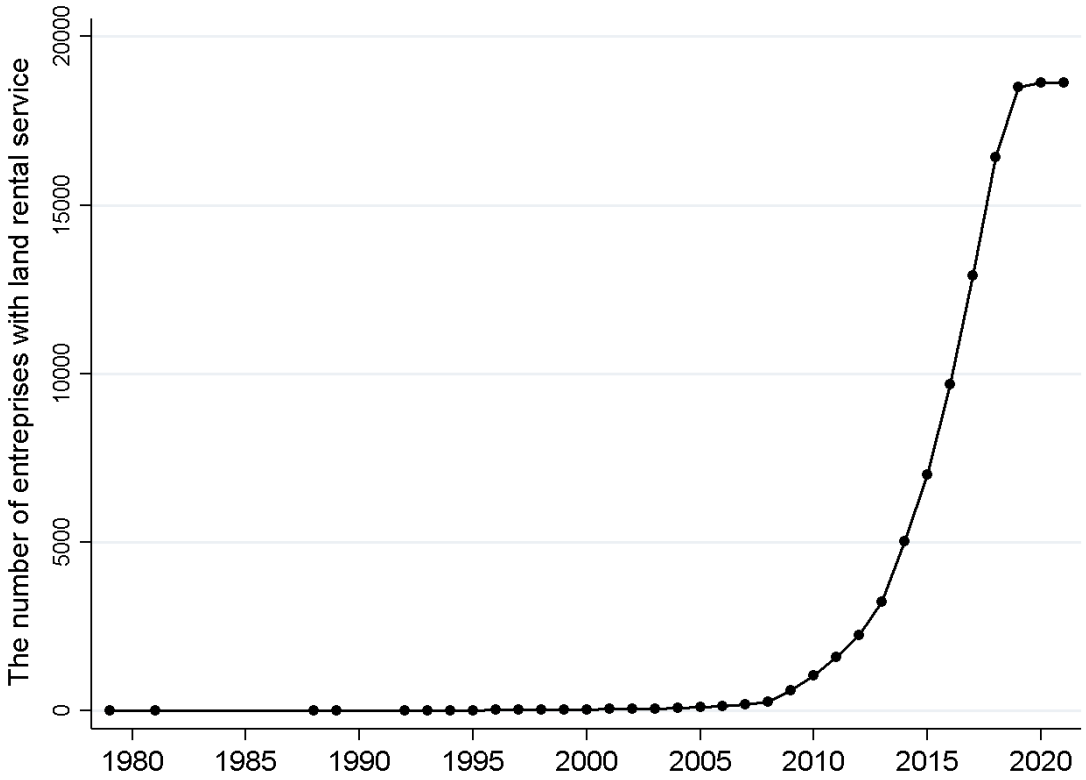

Fig A.2 The number of enterprises with rental service from 1978 to 2021

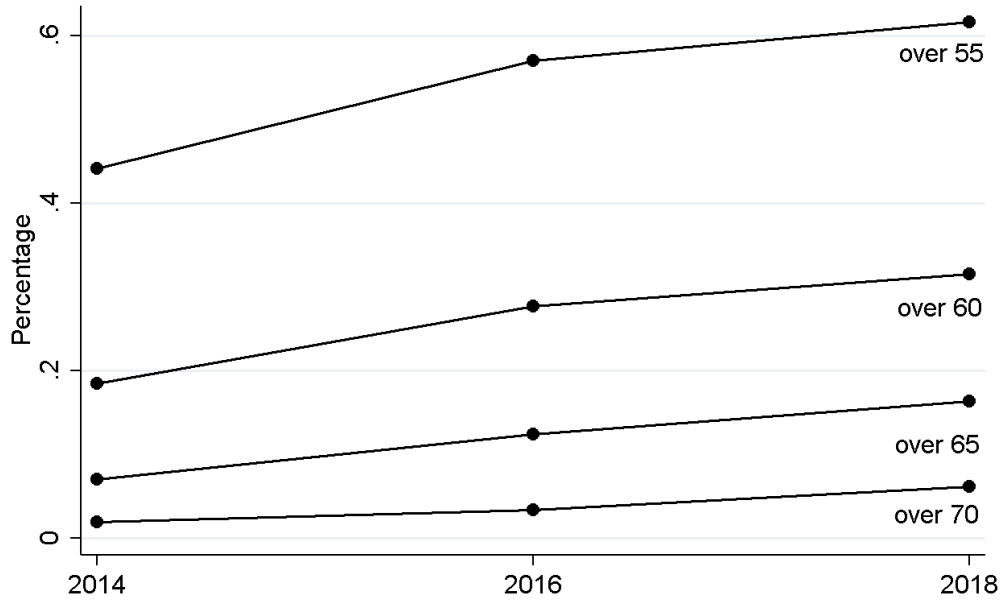

Fig A.3 The ratio of households that operate farms all by the olds

Table A.1 Summary Statistics

		Observations	Mean	SD	Min	Max
Panel A: Variables by Farmer-Year						
Farm operation	(log) Output	8680	8.358	1.374	1.099	16.700
	(log) (Land+0.1)	9249	1.855	1.280	-2.303	6.215
	(log) (Capital+1)	9529	5.753	2.582	0	13.816
	(log) Labor	9593	6.045	1.003	0	12.258
	(log) Ability	9992	0.118	1.500	-6.392	4.568
Land quality	Land type	9992	2.176	0.877	1	3
	Land quality	9992	2.663	0.972	1	5
	Suitable for large machine working	9992	0.615	0.487	1	2
	Near to machine working road	9992	0.597	0.490	0	1
	Power facilities	9992	0.241	0.428	0	1
	Irrigation facilities	9992	0.394	0.489	0	1
	Drainage facilities	9992	0.347	0.476	0	1
	Being polluted	9992	0.067	0.251	0	1
Ratio of crops	Corn	9249	0.466	0.370	0	1
	Wheat	9249	0.160	0.253	0	1
	Rice	9249	0.246	0.365	0	1
	Potato	9249	0.024	0.095	0	1
	Sweet potato	9249	0.019	0.087	0	1
	Beans	9249	0.026	0.098	0	1
	Peanuts	9249	0.024	0.101	0	1
	Rape	9249	0.024	0.093	0	1
	Cotton	9249	0.002	0.028	0	1
	Tobacco	9249	0.009	0.074	0	1
Panel B: Variables by Village-Year						
	Land rental rate	5513	0.149	0.199	0	0.952
	Land rental dummy	8493	0.672	0.470	0	1
	(log) Per capita income	9688	8.682	0.697	5.298	11.513
	(log) Number of residents registered	9159	7.399	0.739	4.060	9.903
	(log) Number of households	9155	6.101	0.699	1.946	7.958
	Ratio of the educated	8558	0.050	0.062	0	0.785
	Ratio of the left-behind children and old	8878	0.086	0.112	0	0.935
	Ratio of the non-worker	8150	0.402	0.145	0.048	0.980

Note: This table reports summary statistics for the main data we used. The sample period is from 2015 to 2019. Panel A presents variables on household level. Panel B shows information collected at the village level.

Table A.2 The effect of land rental market activeness on misallocation

	log (Land size+0.1)
Rank1* Ability	0.007
	(0.034)
Rank2* Ability	-0.002
	(0.033)
Rank3* Ability	0.060*
	(0.036)
Rank4* Ability	0.111**
	(0.052)
Ability	Yes
Rank	Yes
Ratio of crops	Yes
Village-variables	Yes
Year fixed effect	Yes
Village fixed effect	Yes
Observations	4,187

Note: The empirical model is: $\log(land_{ivt}) = \alpha_0 + \sum_{j=1,2,3,4} \alpha_j * rank_j * \log(s_i) + \sum_{j=1,2} rank_j + X_{ivt} + \delta_t + \delta_v + \mu_{ivt}$. Rank0 is omitted, which is the villages whose don't have land rental market. Land rental rate of rank1 ranges from 0.01 to 10%, with a mean of 4.8% and standard deviation of 0.030; rank2 from 10 to 22% with a mean of 14.7% and standard deviation of 0.036; rank3 from 22 to 50% with a mean of 33.5% and standard deviation of 0.084; rank4 from 50 to 95% with a mean of 66% and standard deviation of 0.13. Crops include rice, corn, wheat, potato, sweet potato, beans, peanuts, rape, cotton, tobacco. Village variables include logarithm of per capita income, number of households and residents registered, ratio of the non-worker, the educated, the old and children left behind. The regression includes year fixed effects, village fixed effect and a constant term. Standard errors clustered at village level are reported in parentheses. *, **, *** denote significance at the 10%, 5% and 1% levels, respectively.

Table A.3 Determinants of pilot selection

	Pilot indicator
(log) Pgdp	0.182
	(0.988)
Share_gdp_fir	0.014
	(0.030)
Share_gdp_sec	-0.021
	(0.018)
(log) population	0.487
	(0.649)
Share_pop_nonagri	0.992
	(1.302)
(log) Worker	0.976
	(0.632)
Share_worker_fir	-0.048
	(0.039)
Share_worker_sec	-0.018
	(0.015)
(log) Gov_revenue	-0.262
	(0.596)
(log) Gov_expenditure	-0.507
	(0.583)
Observations	109

Note: Each observation is a city. The dependent variable equals to 1 if the city has land rental pilot. Because land rental pilot program was launched at 2012, all the determinants are in 2011. The regression includes a constant term. Robust Standard errors are reported in parentheses. *, **, *** denote significance at the 10%, 5% and 1% levels, respectively. The determinants include logarithm of GDP per capita, the share of primary industry and secondary industry output on GDP, logarithm of total population, the share of non-agricultural population, logarithm of working population, the share of primary industry and secondary industry workers, logarithm of government revenue and expenditure.