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Do agricultural machinery services promote village farmland rental markets? Theory and evidence from a case study in the North China plain

Yan Liu [a], Nico Heerink [b], Fan Li [c], Xiaoping Shi [a,*]

[a] China Academy of Resources, Environment and Development & College of Public Administration, Nanjing Agricultural University, Nanjing, China
[b] Development Economics Group, Wageningen University & Research, Wageningen, the Netherlands
[c] Macro Agriculture Research Institute, College of Economics and Management, Huazhong Agricultural University, Wuhan, China

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ABSTRACT

The rapidly increasing availability of agricultural machinery services in rural China may promote development in the farmland rental market, but it can also hamper it. This study provides a theoretical and empirical examination of how and to what extent agricultural machinery services affect the participation of smallholders in farmland rental markets. In the theoretical part, a price band model for quasi-fixed inputs is developed and applied to analyse the responses of smallholders with varying land endowments to changes in the demand for land due to the increased availability of machinery services. The empirical analysis is based on survey data collected from 2041 smallholders in Handan Prefecture in the North China Plain. The availability of machinery services for crop management activities (fertilisation, spraying and irrigation) was found to have a significant positive effect on the renting in of land and a significant negative effect on the renting out of land. The availability of machinery services for basic activities (ploughing, seeding and harvesting) had no significant effect on land rental decisions. These results imply that policies aimed at promoting markets for agricultural machinery services may sometimes frustrate policies aimed at stimulating farmland rentals among smallholders.

1. Introduction

Mechanisation and the expansion of farm size are increasingly affecting agricultural development in many developing and transitional economies, including China. Due to the large outflows of rural labourers to urban areas in China, machinery is increasingly being used on expanding farms to enhance agricultural incomes (Kung, 2002; Deininger and Jin, 2005; Otsuka, 2013; Wang et al., 2016a). To meet this growing demand, the markets for both machinery services and farmland rental have undergone rapid development in recent years (Yang et al., 2013; Li et al., 2019; Qiu et al., 2021).

The sale of rural land is prohibited in China. For this reason, smallholders commonly rely on land rental to expand or reduce the size of their farms. Farmland is formally owned by the village collective, with use rights being distributed and periodically reallocated to households in the village, based on the number of family members and/or labourers in a household (e.g., Qu et al., 1995). As a result, rural land in China was cultivated by 251.7 million farm households, with an average holding size of 6.33 mu (i.e., 0.42 ha[1]) in 2018 (MARA, 2018). A well-functioning land rental market is usually seen as an important precondition for increasing average farm size and agricultural income, as it allows farmers with higher agricultural ability to gain access to additional farmland, while allowing those with less agricultural capacity to earn income from other sources (Li et al., 2019).

The cultivation of larger farms usually requires the use of more and/or larger machines. In China, operators of large farms not only invest more in machinery on average, they often also provide machinery services to others (Ji et al., 2012; Yang et al., 2013; Zhang et al., 2017). The provision of machinery services facilitates access to agricultural machinery for farmers who cannot afford to purchase machines, as well as to those whose farms are too small for profitable use of own machinery (Baudron et al., 2015; Mottaleb et al., 2017). In recent years, the rapid development of the market for machinery services has greatly accelerated the pace of mechanisation in rural China (Wang et al., 2020; Qian et al., 2022). Despite an increasing shortage of agricultural labour, the use of machinery services has allowed many farmers to undertake profitable cropping activities and even to cultivate larger farms (Zhang et al., 2017; Tang et al., 2018).

* Corresponding author.
E-mail address: serena2@njau.edu.cn (X. Shi).

[1] One hectare equals 15 mu.

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Most studies of the relationship between mechanisation and land rental markets focus, either explicitly or implicitly, on the ownership of agricultural machinery. Investments in machinery are considered as a way to alleviate agricultural labour shortages and reduce labour drudgery and are assumed to incentivise farmers to expand farm size (e.g., Ji et al., 2012; Van den Berg et al., 2007; Wang et al., 2016b). A positive relationship between possession of machinery and farm size expansion has indeed been found in empirical studies on China (Wang et al., 2020; Zhang et al., 2021), Ghana (Houssou and Chapoto, 2015) and Indonesia (Yamauchi, 2016).

Another line of research focuses on agricultural machinery services, describing its emergence and rapid development, examining the determinants of supply and demand, and assessing its effect on crop income, farm productivity and household welfare in China (Yang et al., 2013; Yi et al., 2019; Deng et al., 2020; Qiao, 2020; Chen et al., 2022), other parts of Asia (Mottaleb et al., 2017; Chaya et al., 2019; Justice and Biggs, 2020; Belton et al., 2021) and Africa (Baiyegunhi et al., 2019). The effect of using machinery services may differ from that of using self-owned machinery, because machinery services have a larger potential to alleviate labour pressure of smallholders throughout the entire agricultural production process (tillage, sowing, weeding, harvesting, etc.). Small and fragmented farms make it difficult for smallholders to invest in agricultural machinery. Most agricultural machines have strong asset specificity; they cannot easily be adapted for other purposes. If smallholders purchase all the agricultural machinery they need, it would greatly increase the economic burden (Zhang et al., 2017; Yu et al., 2021).

Some recent studies examined the effect of agricultural machinery services on farmers' farmland rental decisions in China. Usage of agricultural machinery services could relieve the economic constraints brought by scale operation, thereby facilitating farmers' transfer-in land. Moreover, agricultural machinery services can act as transmitters of agricultural technologies that require specialised agricultural machinery, such as soil deep ploughing, soil measurement, fertilisation formula or precision agriculture (Qing et al., 2019). Usage of agricultural machinery services, especially when provided by skilled workers who operate efficiently, can thereby reduce smallholders' technical limitations of agricultural production and promote farmers' land transfers and scale expansion (Qiao, 2020; Yu et al., 2021). Some recent studies provide empirical tests of this relationship. Qiu et al. (2021) found that the development of agricultural machinery services reduces the probability that smallholder farmers exit from agricultural production through land abandonment, but increases the probability through land renting-out. Qian et al. (2022) focused on relatively large-scale farmers and found that farmers buying more agricultural machinery services have a lower probability to transfer-out land and tend to transfer-in more land. Yu et al. (2021) found that agricultural machinery services have a significantly positive and robust effect on both the incidence and area of rice farmers' land transfer-in.

In China, policymakers regard mechanisation and development of the land rental market as complementary goals in the promotion of agricultural development (Wang et al., 2011; Li et al., 2019; Qian et al., 2022). As argued below, the relationship between the increased availability of agricultural machinery services and development of the land rental market may not always be complementary. Under certain conditions, the use of machinery services may even reduce the amount of land transferred within villages. As a consequence, policies that promote the simultaneous development of both markets may need to be adjusted in order to account for the potentially counteracting effects of policies aimed at promoting agricultural machinery services and the development of the farmland rental market. To strengthen consistency in policy making, science-based evidence is needed on the effects of smallholders' usage of agricultural machinery services on participation in land markets either as lessors, lessees or non-participants.

The objective of this study is to conduct a theoretical and empirical examination of how and to what extent agricultural machinery services affect the participation of smallholders in land rental markets. To this end, we present a price band model for quasi-fixed inputs (e.g., land) and apply it to analyse the impact of land endowments and demand for farmland (as affected by the availability of machinery services and other factors) on the participation of rural households in land rental markets. A dataset collected amongst 2041 smallholders in 130 villages in the North China Plain was used to conduct an empirical test of relationships between the availability of machinery services and land rental decisions. A major finding is that the availability of machinery services for crop management activities has a significant negative effect on the renting out of land by smallholders. This study contributes to the available literature by (1) presenting a price band model for quasi-fixed inputs (e.g. farmland) and applying it to analyse responses to the availability of agricultural machinery services; and by (2) providing empirical evidence that policies promoting agricultural machinery services may conflict with policies aimed at promoting land rental markets.

The remainder of the paper is organised as follows. Section 2 discusses the development of the price band model for the land rental decisions (and use of other quasi-fixed inputs) by households and its application to the analysis of the ways in which machinery services affect the participation of households in land rental markets. The sampling and data collection methods and the empirical strategy are discussed in Section 3, followed by a presentation and discussion of the empirical results in Section 4. The paper concludes with a discussion of the implications and limitations of the main findings (Section 5).

2. Theory

Assume that rural households are endowed with three agricultural production factors: land, labour and capital (e.g., agricultural machinery). In the short term, the quantity of each factor that a household possesses is fixed. Household may adjust its use of these factors by land rentals, labour hiring and using or providing machinery services. These factors may thus be regarded as 'quasi-fixed inputs'. Labour and capital are assumed to be substitutes in agricultural production, while land and capital (and land and labour) are considered complements.

Assume that there is no land sales market, as is the case in rural China. Rural households may nevertheless change the size of their farms through the land rental market. They can choose to rent land in, rent land out or remain autarkic. These household options are illustrated in Fig. 1. The land supply (S_l) of the household is fixed, while the land (i.e., operational farm size) demand (D_l) is a declining function of the market price (land rent). If the land rental market functions perfectly and there

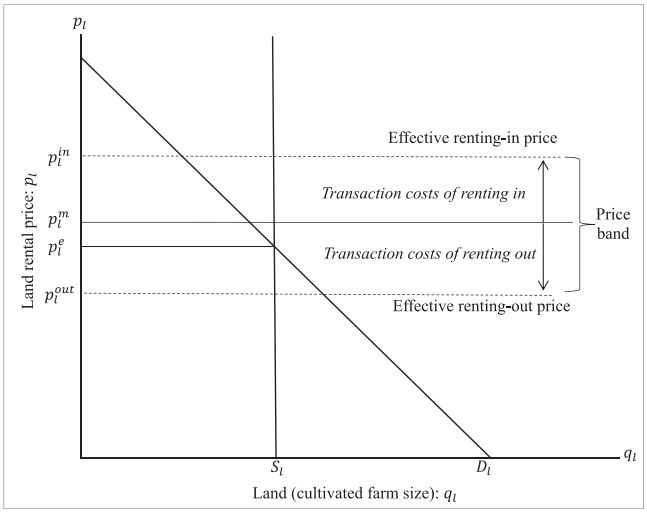

Fig. 1. Price band and land rental market participation decision of a rural household,
Source: Adapted from Figure 6.2 in Sadoulet and De Janvry (1995).

are no transactions costs, a household would remain autarkic only if the market price (p_l^m) is equal to the household's internal equilibrium price (p_l^e): the price that balances the household supply of and demand for land.

In China and elsewhere, however, the environments in which smallholders are typically located tend to be characterised by market failures. Transaction costs incurred in land rentals include the costs involved in obtaining information on market conditions, searching and screening potential partners, negotiating contracts (whether formal or informal), and agency costs arising from opportunistic behaviour on the part of tenants and/or lessors (Skoufias, 1995; Jin and Deininger, 2009; Ma et al., 2020).[2] In contrast to farmland rental markets – which are characterised by immobile subjects of transaction, low transaction frequency and limitations regarding potential partners – markets for agricultural machinery services and labour are characterised by mobility of the subject of transaction, greater transaction frequency and more diversified suppliers. The rate of participation in land rental markets in our sample was only 25.8 % (see Table 1), which was much lower than the rate of participation in agricultural machinery services markets (see Table 2) and off-farm labour markets.[3] It can therefore be assumed that the transaction costs in markets for agricultural machinery services and labour are much lower than those in land rental markets. This study therefore focuses on the land rental market, assuming that the more flexible labour and agricultural machinery services markets adjust for the failures occurring in the less flexible land market (Ray, 1998: Ch.11).

The presence of transaction costs may cause failures in and suppress the development of land rental markets (Zhang et al., 2004; Wang et al., 2015). For lessees, the effective price on which they base their decisions to rent in land is equal to the market rent plus the transaction costs associated with renting in land: p_l^{in}. Likewise, for lessors, the effective renting out price is equal to the market rent minus the transaction costs associated with renting out: p_l^{out}. Transaction costs therefore create a 'price band' between the effective prices for renting in and renting out (see Fig. 1).[4] If the subjective equilibrium land rent (p_l^e) falls within the price band, households will neither rent out nor rent in land. In such a case, the marginal benefit of land for a given household exceeds the effective renting-out price (p_l^{out}) and is lower than the effective renting-in price (p_l^{in}). A rational household will therefore remain autarkic.

Assume, for reasons of simplicity, that different households have similar land demand curves and that they face similar transaction costs and market prices for land rentals. In such a case, a household's participation in the land rental market depends on its land endowments. In rural China, a household's land endowment consists of the contracted land that it receives from the village collective. In Fig. 2, three households with different land supply curves (i.e. contracted land areas) are shown. Given the effective price of renting in land (p_l^{in}), the household with land supply S_l^1 will rent in I_l^1 land. For that household, the marginal value product of the rented land exceeds the marginal costs (i.e., the effective renting-in price, or p_l^{in}). The household with land supply S_l^3 will rent out O_l^3 land. For that household, the marginal value product of the rented-out land is lower than the effective renting-out price (p_l^{out}) of that land. Households with equilibrium prices that fall within the price band (like the household with land supply S_l^2) are expected to remain autarkic.

As demonstrated by these two figures, land rental markets selectively fail for different households (see also Chapter 6 in Sadoulet and De Janvry, 1995). Whether a household will or will not remain autarkic depends on its own land resources, the market price of land rentals and the transaction costs that the household faces in using the land rental market.

The next step in the analysis consists of examining the impact of changes in land demand on participation in the land rental market. A household's demand for land is positively affected by its possession of machinery and labour resources, as well as by the availability of machinery services and agricultural labour on local markets. It is negatively affected by the effective prices (i.e., market price plus transaction costs) of labour and machinery services. The effect of a demand shift (e.g., due to an increase in the availability of machinery services or a decrease in the effective price of such services) on land rentals is examined in Fig. 3. When the demand curve shifts to the right (from D_l to D_l'), the subjective equilibrium land rent increases for all three households shown in the figure. The household with land supply S_l^1 would rent in more land ($I_l^1{}'$ instead of I_l^1). The household with land supply S_l^2 would remain autarkic, and the household with land supply S_l^3 would stop renting out land and become autarkic. As illustrated by the figure, the relationship between agricultural machinery services and land rentals is not always complementary. Households that were renting out land before the change occurred may no longer do so, and they may start cultivating all of the contracted land that has been allocated to them.

In conclusion, according to the price band model for quasi-fixed inputs developed in this section, an increase in the availability of machinery services can either increase or decrease the total amount of land transacted in the land rental market. Case-specific empirical research is needed in order to assess whether the relationship is complementary or inverse.

3. Data and estimation method

3.1. Data collection

The empirical analysis is based on data from a survey of rural households and village leaders in Handan City, Hebei Province in the North China Plain were used. Most of the farmers in the region grow double-cropped winter wheat/summer maize.

The survey was conducted in February 2018, immediately after the Chinese New Year, to maximise the response rate. Most rural-urban migrants return around to their hometowns for a few weeks to celebrate the new year. During this period, they can often find time to participate in a survey before returning to their urban jobs. Topics addressed in the household questionnaire included farm input use, agricultural output, production factor endowments, factor markets participation and other information about the 2017 agricultural season. Village leaders were interviewed about village-level agricultural endowments, basic characteristics of the land rental market, the machinery services market and related issues during the year 2017.

A multi-stage random sampling method was applied to select the villages and households to be interviewed in four adjacent counties – Feixiang, Jize, Qiu and Quzhou – in Handan City, a prefecture-level city in Hebei Province. All townships in the four counties were selected, except one Hui minority autonomous township in Qiu County and four townships in Quzhou County where agricultural extension training was provided over a longer period via the Science and Technology Backyard (STB) platform (Zhang et al., 2016). For the village-level sample, townships in these four counties were divided into three groups according to the number of villages in the township (i.e., 1–10, 11–20 and $>$ 20 villages). Two, four or six villages were randomly selected from these three groups, respectively. Within each selected village, 16 households were chosen at random for the interviews from the list of villagers. Eight villages were dropped from the sample because most of

[2] If existing regulations restrict transferability or completely outlaw certain contract types, these regulations may be interpreted as infinite transaction costs.

[3] 65.4% of the interviewed households had at least one member who earned off-farm income in 2016.

[4] We ignore the presence of fixed transaction costs and focus on variable transaction costs. For incorporating fixed transaction costs into a price band model, see Key et al. (2000).

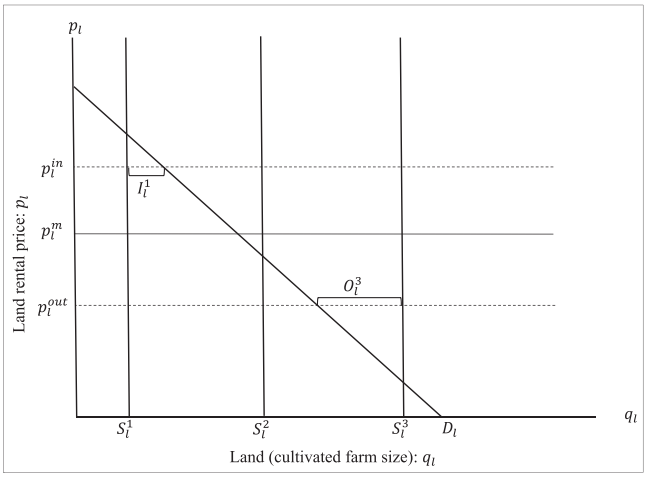

Fig. 2. Price band and land renting of households with different land endowments.

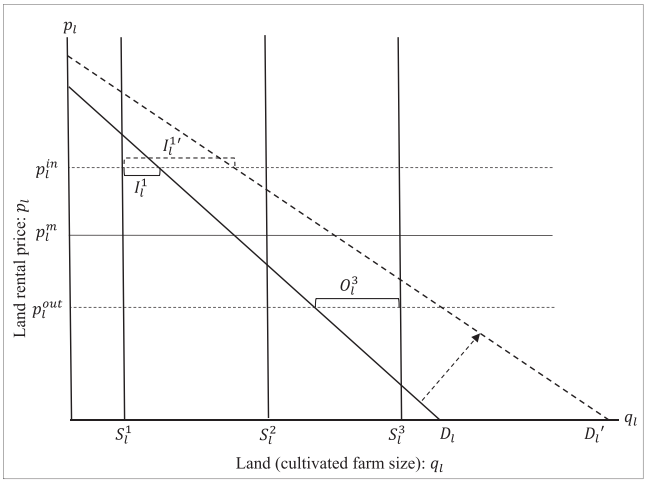

Fig. 3. Price band and land rentals under a demand shift.

the households in those villages had rented out their land to agricultural enterprises or cooperatives. The resulting dataset includes information on 2080 households living in 130 villages. The information provided for 39 households was not complete, and these households were therefore dropped from the sample. The sample used for this study thus consists of 2041 households. Of these households, 1918 (94.0 %) reported having been involved in crop production in 2017. An overview of the sample composition is provided in Table A1 in the Appendix.

3.2. Model specification

The focus of the empirical analysis is on the impact of the rapidly rising market for agricultural machinery services on farmland rentals. The third quasi-fixed input (hired labour) is not included in the model, as it can be regarded as an endogenous variable. The estimation results can therefore be interpreted as estimates of the reduced-form equation, showing the total effect of the availability of machinery services on land rental decisions. More specifically, the results indicate the direct effect plus the indirect effect going from the availability of machinery services to land rental through changes in the amount of hired labour (see e.g., Hong et al., 2020 for a similar approach).

Following Li et al. (2019) and Ma et al. (2020), household decisions on participation in the land rental market have been conceptualised as two decisions: (1) a participation decision (i.e., whether to rent in land, rent out land or remain autarkic) and (2) an intensity decision (i.e., how much land to transfer if a household participates). The following specifications were used to estimate the factors affecting these two decisions:

$$R_{ji} = \alpha_{j1} + \alpha_{j2}\mathbf{MS}_{ai} + \alpha_{j3}\mathbf{P}_i + \alpha_{j4}\mathbf{L}_i + \alpha_{j5}\mathbf{HHR_i} + \alpha_{j6}\mathbf{HH_i} + \alpha_{j7}\mathbf{TC_i} + \varepsilon_{ji} j = 1, 2 \quad (1)$$

$$S_{ji} = \beta_{j1} + \beta_{j2}\mathbf{MS}_{ai} + \beta_{j3}\mathbf{P}_i + \beta_{j4}\mathbf{L}_i + \beta_{j5}\mathbf{HHR}_i + \beta_{j6}\mathbf{HH_i} + \beta_{j7}\mathbf{TC_i} + u_{ji} j = 1, 2 \quad (2)$$

where $R_{1i} = 1$ when household i rented land in, otherwise $= 0$; $R_{2i} = 1$ when household i rented land out, otherwise $= 0$; S_{1i} is the share of rented-in land in the total cultivated land area; S_{2i} is the share of rented-out land in the total contracted land area. The rented-out land area cannot exceed a household's contracted land area. To deal with this natural upper limit, the share – and not the size – of the contracted land that is rented out is used as the dependent variable in the equation for the intensity of renting out. For reasons of consistency, the share of the rented-in land in the total cultivated land area is used as the dependent variable in the equation for the intensity of renting in. The values of α and β are unknown coefficients, while ε_{ji} and u_{ji} are random disturbance terms with a mean of 0.

The variable $\mathbf{MS}_{ai}$ is a vector indicating the availability of machinery services for household i. It is assumed that the availability of machinery services for a given household is closely related to the actual use of machinery services by other households in the same village. For this reason, the mean value of the shares of activities involving the use of machinery services by the other households interviewed in the same village is used as a proxy for the availability of machinery services for household i. Given the wide variations in the use of machinery services between basic agricultural activities and crop management activities (see Table 2), activities involving machinery services are subdivided into these two major types. The availability of machinery services is expected to have a positive impact on the renting in of land and a negative impact on the renting out of land (see Section 2).

The variable $\mathbf{P}_i$ is a vector of the market prices for machinery services and land rentals faced by household i. The average price paid for machinery services in basic activities (ploughing, seeding and harvesting) paid by the other households interviewed in the same village is used as a measure of the market price of these machinery services. Unfortunately, the dataset contains too few observations to do the same for machinery services in crop management activities. It may be assumed that the market prices for these two main types of services are highly correlated. The average price of land rentals in a village was obtained by requesting this information from village leaders in the village survey. Both the prices of machinery services and the market prices of land rentals are expected to have negative effects on the renting in of land and positive effects on the renting out of land.

The variable $\mathbf{L}_i$ is a vector of land endowment variables (i.e., contracted land size and number of contracted plots) for household i. Contracted land refers to the farmland with long-term use rights distributed by the village collective to households living in the village. Households usually receive use rights for several plots with different soil qualities (Tan et al., 2006). Contracted land size is expected to have a negative impact on the renting in of land and a positive impact on the renting out of land (see Section 2). The effect of the number of plots on land rental decisions is indeterminate. When the number of plots is larger at a given contracted land size, the average plot size is smaller. This makes these plots less attractive for land rental. At the same time, however, farmers with many plots may want to consolidate their land in order to facilitate the use of machinery by renting in plots adjacent to their own plots and renting out others.

The variable $\mathbf{HHR_i}$ is a vector of other resources (i.e., labour and capital endowments) of household i. Labour endowment is measured by the number of family members aged 16 and older, excluding students.

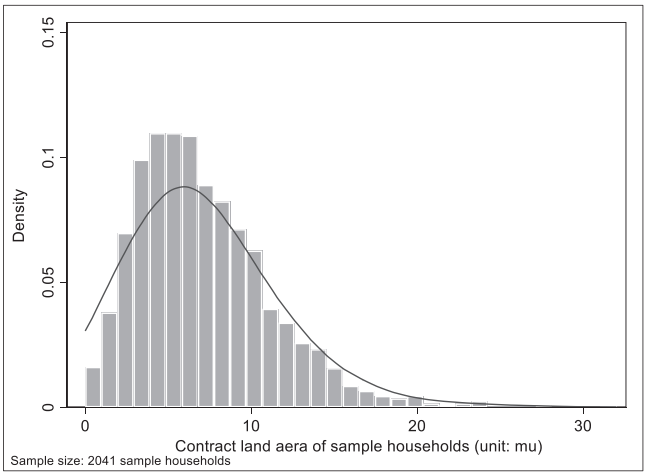

Fig. 4. Distribution of contracted land of surveyed households, Source: Authors' survey.

Capital endowment is measured by four indicators: access to formal credit from banks and the number of tractors, harvesters and crop management machines (e.g., sprayers or pumps), the three main types of agricultural machinery used in the region. The data collected in the household survey did not allow the calculation of an asset index that could account for all productive farm assets. Following studies by Sadoulet and De Janvry (1995), Hong et al. (2020) and other scholars, we assume that these endowments can be regarded as exogenous determinants of variable input decisions (in this case, land rental decisions). Labour and capital endowments are expected to have positive effects on the renting in of land and negative effects on the renting out of land.

The variable $\mathbf{HH_i}$ is a vector of characteristics of the head of household *i*, including age, gender, educational level and village cadre status. The age, gender and education of the household head may influence participation in the land rental market through several channels, including experience, access to non-agricultural employment and risk preference (Byron et al., 2014). Household heads belonging to the village cadre may have better access to a variety of resources that affect their land rental decisions (Wang et al., 2011). The effects of household head characteristics on the renting in and renting out of land are unclear a priori.

The variable $\mathbf{TC_i}$ is a vector of variables reflecting transaction costs in the land rental market. Despite their importance to the functioning of markets in general and land rental markets in particular, the measurement of transaction costs remains a challenging and complex issue. One commonly applied approach is to use important underlying factors (e.g. access to credit, age of the decision-maker, social capital, tenure security and trust) as proxies (Ricker-Gilbert and Chamberlin, 2018; Ma et al., 2020). In addition to credit access, the age of the household head and village cadre memberships, which are already included in the model for other reasons (see above), two indicators of land tenure security and one indicator of trust among village households were added to the model as proxies for transaction costs in the land rental market. To clarify and protect the security of rural land rights, the Chinese government launched a new round of rural land registration in 2013. Modern techniques were used to measure the contracted plots of each rural household, as well as to register these plots in a database. County-level governments subsequently issued land certificates to individual households as legal proof of their land use rights. This registration process was still ongoing at the time of our survey, and not all rural households had received land certificates. The registration procedure is determined by the local government, and it is unlikely to be affected by individual household characteristics. A dummy variable indicating whether land rights had been registered after 2013 is included in the model as an indicator of tenure security. For the same reason, the model includes a dummy variable indicating whether land had not been reallocated since the second round of land allocation in the village in 1998. Although the reallocation of land within a villages is almost completely prohibited by the Chinese government in order to promote tenure security, it still occurs in some areas (Ho and Lin, 2003; Ren et al., 2019). Trust is measured according to whether a respondent reported believing that most people living in the same village group could be trusted. Trust and tenure security are expected to reduce transaction costs. The indicators of these factors are therefore expected to have positive effects on the renting in and renting out of land.

3.3. Empirical strategy

The dependent variables in Eq. (1) are dummy variables, whereas the dependent variables in Eq. (2) are limited variables ranging from 0 to 1. A binary regression (Probit) model is used to estimate Eq. (1), and a fractional response (Fractional logit) model is used to estimate Eq. (2).

One common approach in the existing literature is to treat participation decisions concerning the renting in and renting out of land as independent decisions, and to estimate the factors affecting these two decisions separately (e.g., Kung, 2002; Deininger and Jin, 2005; Qian et al., 2020). In practice, however, these decisions are likely to be related: farmers who rent in land usually do not rent out land, and farmers who rent out land are unlikely to rent in land. Moreover, a large share of land rentals in rural China take place between households living in the same village (e.g., Ma et al., 2020). Local agro-ecological conditions and other unobserved characteristics may therefore influence both the amount of land that is rented in and the amount that is rented out. These potential relationships between renting-in and renting-out decisions should be taken into account in the estimation of Eqs. (1) and (2). A bivariate Probit model is used to estimate the two equations for participation in the land rental market, and the Wald test is applied to test for potential correlations between the two error terms (Li et al., 2019). When the null hypothesis of no correlation between ε_{1i} and ε_{2i} in Eq. (1) cannot be rejected, two separate Probit models are applied. A seemingly unrelated regression (SUR) model is used to estimate the two equations for the intensity of land rental. This model estimates the parameters of the two equations simultaneously, such that the parameters of each single equation also take the information provided by the other equation into account. The correlation between the residuals in Eq. (2) is tested by applying the Breusch-Pagan test. If the null hypothesis of no correlation cannot be rejected, two separate fractional logit models are estimated.

As explained in Section 3.1, the dataset used for this study includes information from 2041 rural households living in 130 villages. Decisions made by smallholders living in the same village may be related to each other to some extent through factors that are not reflected in the models. Moreover, the land rental market is a typically local market, with most transactions taking place within the same village. For these reasons, cluster-adjusted standard errors are used in estimating Eqs. (1) and (2).

4. Results

4.1. Descriptive analysis

In this section, we first present and discuss descriptive data on contracted land area and land rental market participation of the households that were interviewed for this study. It is followed by a description of the degree of mechanisation in various planting activities, distinguishing between own machinery use and use of mechanisation services and between basic activities such as ploughing or seeding and crop management activities such as fertilising or pesticides spraying. Finally, we present descriptive statistics of all variables used in the regression analyses. This descriptive analysis is meant to provide more insight into the importance of the two main phenomena examined in this study, land

Table 1
Participation of land rental market by interviewed households.

Household land rental decision (%)	
Renting in	11.22
Renting out	13.23
Renting in and out	1.37
Autarkic	74.18
Farm size (mu)	
Mean contracted land area[a]	7.18
Mean cultivated farmland area[b]	7.94
Mean rented-in land area[c]	7.77
Mean rented-out land area[d]	4.22
Rented land shares (%)	
Share of rented-in to total cultivated land	12.13
Share of rented-out to total contracted land	8.14

Notes:
[a]For 2013 households that owned contracted land.
[b]For 1960 farm households.
[c]For 243 households that rented in (incl. 14 net renting-in households).
[d]For 279 households that rented out (incl. 9 net renting-out households).
Source: Authors' survey

rentals and agricultural mechanisation services, as well as relevant background information that may be used for interpreting the results of the statistical analyses.

4.1.1. Land endowments and land rental participation

The distribution of the contracted land area (i.e., the land allocated by the village collective to a household residing in the village) is presented in Fig. 4. The median contracted farm size is about 5–7 mu (i.e., < 0.5 ha).[5] Participation in the land rental market, farm size and rented land ratios of the households in the sample are summarised in Table 1. In the 2017 agricultural season, 25.8 % of the households reported participating in the land rental market. Of the households in the sample, 11.2 % reported renting in additional land, with 13.2 % renting out land and 1.37 % both renting in and renting out land. The average area of additional land rented in by a household (7.94 mu) was considerably larger than the average area of land rented out (4.22 mu). Participation in the land rental market increased the average cultivated farm size of the households interviewed from 7.18 to 7.94 mu.

On average, 8.14 % of all contracted land was rented out, and 12.1 % of all cultivated land was rented in by the farmers participating in the survey. Nationwide, rented land accounted for 33.8 % of all cultivated land in 2017 (MARA, 2018). Participation in the land rental market was thus relatively unpopular amongst households in the four counties in which the survey was conducted.

The land rental data indicate a considerable imbalance between the totals of rented-in and rented-out areas in the sample. This is a common phenomenon in surveys of farmland rentals, particularly in China, because households that rent out all their contracted land have often migrated elsewhere and cannot be interviewed. Although we attempted to minimise this imbalance by conducting the survey immediately after the Chinese New Year, it is possible that some households in the selected villages had rented out all of their land and did not return home for the holiday. For this reason, the data may be subject to selection bias if the increased availability of machinery services had stimulated these households to rent out their land. This issue is addressed in Section 4.3 below.

4.1.2. Mechanisation

The degree of mechanisation in various planting activities is summarised in Table 2. Cultivation activities for maize and wheat are divided into two groups: (1) basic activities (including ploughing, seeding and harvesting), which are usually carried out with machines in the region; and (2) crop management activities (including fertilisation, spraying and irrigation), which are often performed manually. In the research area, ploughing and seeding are generally combined for maize cultivation.[6] For this reason, 11 activities (five basic activities and six crop management activities) are distinguished in the wheat-maize double-cropping system. As can be seen in the table, with the exception of irrigation, the farmers surveyed did not commonly make use of machinery that they owned. Machinery services were especially likely to be used for basic activities. The rates of machinery services utilization varied from 79.9 % to 89.7 % for basic activities and from 0.6 % to 10.6 % percent for crop management activities. Machinery services for basic activities (e.g., harvesting) have become popular in rural China in recent years (Yang et al., 2013; Zhang et al., 2017). The use of machinery services for crop management (e.g., drone spraying) has emerged more recently, and it is still less common (Wang et al., 2017).

Table 2
Mechanisation of interviewed farm households.

	Basic activities			Crop management activities		
	Ploughing	Seeding	Harvesting	Fertilising	Spraying	Irrigation
Wheat cultivation[a]						
Mechanisation (%)	94.09	94.09	95.55	9.59	12.65	52.94
Own machinery (%)	7.17	6.54	5.91	2.37	12.02	43.98
Machinery services (%)	86.92	87.55	89.64	7.22	0.63	8.96
Machinery services cost (100 CNY/mu)[b]	0.57	0.23	0.64	0.35	0.37	0.47
Maize cultivation[c]						
Mechanisation (%)	93.81		83.17	12.23	12.7	51.14
Own machinery (%)	4.13		3.29	1.59	12.01	42.93
Machinery services (%)	89.68		79.88	10.64	0.69	8.21
Machinery services cost (100 CNY/mu)	0.24		0.86	0.22	0.23	0.45

Notes:
[a] For 1896 households growing wheat in 2017
[b] Exchange rate in 2017: 1 USD = 6.75 CNY (Chinese yuan) (NBS, 2018)
[c] For 1889 households growing maize in 2017. The mechanised ploughing and seeding of maize are usually carried out in combination, and they are displayed in the Seeding column.
Source: Authors' survey

[5] One mu equals 1/15 ha.

[6] The roots of maize remain in the soil after harvest. It requires at least one time ploughing to remove or pulverise the roots for wheat seeding. Because wheat roots are relatively soft, the land can be ploughed and seeded with maize directly after harvest.

Table 3
Summary statistics and expected coefficient signs for the variables included in the model.

Variables	Definition	No. of obs.	Mean	Std. Dev.	Min	Max	VIF[a]	Expected signs	
								In	Out
Dependent variables									
Rented in	= 1 if the household rented in land; otherwise = 0	2041	0.12	0.33	0	1			
Rented out	= 1 if the household rented out land; otherwise = 0	2041	0.14	0.34	0	1			
Rented in land share	Share of cultivated land rented in	243	0.46	0.25	0.03	1			
Rented out land share	Share of contracted land rented out	279	0.63	0.30	0.03	1			
Machinery services									
Availability of basic machinery services	Share of basic activities (ploughing, seeding, harvesting) in which machinery services were used in the cultivation of wheat and maize; mean value for other households interviewed in the same village	2041	0.90	0.07	0.57	1	1.05	+	–
Availability of crop management machinery services	Share of crop management activities (fertilising, spraying, irrigation) in which machinery services were used in the cultivation of wheat and maize; mean value for other households interviewed in same village	2041	0.22	0.13	0	0.58	1.07	+	–
Prices									
Price of basic machinery services	Average cost of each basic activity in maize and wheat cultivation; mean value for other households interviewed in same village (100 CNY/mu)	2041	0.50	0.05	0.39	0.64	1.11	–	+
Land rental price	Average village-level land rental price (100 CNY/mu); reported by village leader	2041	0.47	0.17	0.15	1.20	1.06	–	+
Household endowments									
Land area	Area of contracted land (mu/household)	2013	7.18	4.12	0.5	32	1.52	–	+
Plot	Number of contracted plots	2013	3.28	1.92	1	15	1.39	+ /-	+ /-
Labour	Number of family members aged 16 or older, excluding students	2041	3.34	1.36	1	10	1.10	+	–
Credit	= 1 if the household could obtain a bank loan; otherwise = 0	2041	0.19	0.40	0	1	1.04	+	–
Tractor	Number of tractors owned	2041	0.14	0.39	0	3	1.08	+	–
Harvester	Number of harvesters owned	2041	0.01	0.10	0	2	1.02	+	–
Crop management machinery	Number of crop management machines owned	2041	0.33	0.76	0	6	1.07	+	–
Household characteristics									
Age	Age of the household head (years)	2041	57.75	10.44	27	87	1.11	+ /-	+ /-
Gender	= 1 if the gender of household head was male; otherwise = 0	2041	0.94	0.23	0	1	1.08	+ /-	+ /-
Education	Education of household head (years)	2041	6.95	3.60	0	16	1.18	+ /-	+ /-
Village cadre	= 1 if household head was a village cadre member; otherwise = 0	2041	0.06	0.24	0	1	1.06	+ /-	+ /-
Transaction cost									
Land registration	= 1 if the village had registered land rights since 2013; otherwise = 0; reported by village leader	2041	0.95	0.23	0	1	1.05	+	+
Land reallocation	= 1 if the village had not reallocated land since 1998; otherwise = 0; reported by village leader	2041	0.95	0.23	0	1	1.04	+	+
Trust	= 1 if respondent reported believing that most people living in the same village group could be trusted; otherwise = 0	2041	0.93	0.25	0	1	1.03	+	+

Exchange rate in 2017: 1 USD = 6.75 CNY (Chinese yuan) (NBS, 2018).
Notes: [a] VIF tests the degree of multicollinearity amongst the independent variables.
Source: Authors' survey

Agricultural machinery services are provided almost entirely by private machinery owners living in or outside the same village. Agricultural companies and agricultural machinery cooperatives played only a minor role in the provision of machinery services to the farmers included in the sample. For example, 99.1 % of all wheat harvesting services were provided by private machinery owners.

4.1.3. Descriptive statistics

Summary statistics for the variables included in the models are presented in Table 3. The 28 households in the sample that both rented in and rented out land were classified as renting-in (14 households), renting-out (9 households) or autarkic (5 households), based on the net area of land rented. As a result, 12 % of all households in the sample rented in land, while 14 % rented out land. On average, renting-out households rented out 46 % of their contracted land, whereas renting-in households rented an average of 63 % of their cultivated land. Both rental share variables had a maximum of 1.00, indicating that some households had no contracted land and were cultivating only rented land, while other households were renting out all of their land.

On average, the farm households in the sample used machinery services for 90% of their basic wheat and maize cultivation activities, as well as for 22 % of their crop management activities. The average share of basic activities carried out using machinery services ranged from 57 % to 100 %. Greater variation was observed in the use of machinery services for crop management activities, which ranged from 0 % to 58 % of these activities, with 351 farmers (18 % of all farm households) not using these services at all. For the 130 villages included in the survey, the average price of machinery services used in basic activities ranged from 39 to 64 Chinese yuan (CNY) per mu, with an overall average of 50 CNY per mu.[7] The average village-level land rent ranged from 150 to 1200 CNY per mu, with an average of 465 CNY per mu.

The mean area of contracted land was 7.2 mu (almost 0.5 ha), with sizes ranging from 0.5 to 32 mu for households with contracted land. Some of the households interviewed (28 in all) had no contracted land. Most of these households had been formed or had moved to the village after the latest round of land reallocation. There was also considerable variation in the number of contracted plots held by the households included in the survey, ranging from 1 to 15, with an average of 3.3. The number of labourers in a family ranged from 1 to 10, with an average of 3.3. Only 19 % of the households interviewed reported being able to obtain bank loans. The majority of the households thus had no access to formal credit. The average machinery ownership per 100 farm households amounted to 14 tractors, 1 harvester and 33 crop management machines.

Household heads were predominantly male and relatively old, with

[7] One USD = 6.75 CNY (in 2017); one yuan per mu equals 2.22 USD per ha.

Table 4
Regression results, basic model.

		Rental decision (Bi-Probit)		Rented area shares (SUR)	
		In (1)	Out (2)	In (3)	Out (4)
Availability of basic machinery services		0.11	-0.24	0.03	-0.12
		(0.83)	(−1.39)	(0.53)	(−1.53)
Availability of crop management machinery services		0.14**	-0.18*	0.06*	-0.10**
		(2.00)	(−1.74)	(1.89)	(−2.29)
Price of basic machinery services		-0.53***	-0.12	-0.33***	-0.23*
		(−2.62)	(−0.43)	(−3.85)	(−1.95)
Land rental price		-0.00	-0.00	-0.00	-0.00
		(−0.11)	(−0.33)	(−0.08)	(−0.62)
Land area		-0.00**	0.01***	-0.01***	0.00***
		(−2.06)	(3.68)	(−5.13)	(3.17)
Plot		0.00	-0.03***	-0.00*	-0.02***
		(0.47)	(−4.86)	(−1.87)	(−6.93)
Labour		0.01	-0.01	0.00	-0.01**
		(1.20)	(−1.10)	(1.52)	(−2.30)
Credit		0.00	0.01	0.01	0.01
		(0.21)	(0.32)	(0.63)	(0.47)
Tractor		0.08***	-0.06**	0.07***	-0.03**
		(5.10)	(−2.37)	(6.60)	(−2.06)
Harvester		-0.12	-0.04	-0.05	-0.02
		(−1.33)	(−0.51)	(−1.35)	(−0.46)
Crop management machinery		-0.01	-0.04***	0.00	-0.02***
		(−0.69)	(−2.76)	(0.05)	(−3.33)
Age		-0.00***	0.00***	-0.00***	0.00***
		(−3.72)	(3.35)	(−2.98)	(4.10)
Gender		0.04	-0.03	0.02	-0.05**
		(1.18)	(−0.84)	(1.48)	(−1.99)
Education		-0.00	-0.00	-0.00	-0.00
		(−0.58)	(−0.78)	(−0.75)	(−0.23)
Village cadre		-0.04	-0.04	-0.02	-0.03
		(−1.21)	(−1.04)	(−1.34)	(−1.33)
Land registration		0.04	0.00	0.03*	0.01
		(1.04)	(0.02)	(1.75)	(0.47)
Land reallocation		-0.02	0.01	-0.01	-0.02
		(−0.41)	(0.29)	(−0.66)	(−0.77)
Trust		0.00	0.04	0.00	0.03
		(0.17)	(1.33)	(0.11)	(1.26)
Wald test (rho = 0)[a]	Chi2(1)	80.52***			
	Prob > chi2	(0.00)			
Breusch-Pagan test[b]	Chi2(1)			26.14***	
	Prob > chi2			(0.00)	
Log pseudo-likelihood		-1438.99			
R^2				0.05	0.06
No. of obs.		2041	2041	2041	2041

Average marginal effects are reported for Rental decision, coefficient estimates for Rented area share; clustered z values in parentheses.
The symbols ***, ** and * indicate significance (p = 0.01, p = 0.05 and p = 0.10, respectively).
Notes:
[a]: Wald test of independent equations (rho = 0).
[b]: Breusch-Pagan test of independence.
Source: Based on authors' survey

an average age of 57.8 years. On average, they had completed 7.0 years of education, and 6 % were members of the village cadre. These characteristics are fairly similar to those of rural household heads in other parts of China (e.g., Li et al., 2019).

For the majority of the households interviewed, the land use rights were registered at the time of the survey (95 %), and most (95 %) had not experienced any land reallocations since 1998. Formal tenure security was thus relatively high. The same could be said for the level of trust, with 93 % of all respondents indicating that they believed most people living in the same village group could be trusted.

4.2. Regression results

The estimated average marginal effects and diagnostic test results are reported in Table 4. For the first decision (i.e. participation in the land rental market), a Wald test indicated that the null hypothesis of no correlation should be rejected. A Bi-Probit model was therefore used to estimate the two equations for land rental participation. For the second decision (i.e. intensity of participation), a Breusch-Pagan test indicated that the null hypothesis of independence between the two error terms should be rejected. A SUR model was therefore used to estimate the equations for the share of rented land.

4.2.1. Machinery services

With regard to the primary focus of this study, machinery services, the results indicate that the availability of machinery services for basic activities (ploughing, seeding, harvesting) had no significant effect on either the renting in or the renting out of land. One plausible explanation for this finding is that the households participating in the survey reported using machinery services almost universally for basic activities (see Table 2).

Interestingly, the results for the availability of machinery services for management activities (fertilising, spray and irrigation) pointed to different conclusions. As discussed in Section 4.1.2, these services were applied on a smaller scale and exhibited greater variation amongst the farmers participating in the survey. According to the estimation results, these services had a significant positive effect on the renting in of land and a significant negative effect on land renting out. These empirical findings are consistent with the expectations depicted in Fig. 3 and with recent findings of Qian et al. (2022). When the demand for land increases due to an increase in the availability of machinery services, farm households that rent in land (like Household 1) could be expected to rent in more land, while autarkic households (like Household 2) are likely to remain autarkic or start renting in land, and farm households that rent out land (like Household 3) could be expected to rent out less land or become autarkic. In other words, machinery services could be expected to have a positive effect on both the decision to rent in land and the share of rented land in the cultivated land, while having a negative effect on both the decision to rent out land and the share of contracted land that is rented out. The regression results for crop management machinery services provide empirical support for these expectations. The estimated marginal effects indicate that the negative effects on the renting out of land were somewhat stronger than the positive effects on the renting in of land.

The price of machinery services for basic activities is assumed to reflect the price of crop management activities as well (see Section 3.2). According to the estimation results, the price of machinery services had a significant negative impact on the likelihood of renting in land, as well as on the shares of land that are rented in and rented out. The negative effects on the renting in of land were consistent with *a-priori* expectations. At the same time, however, higher prices for machinery services could be expected to induce more farmers to rent out their land or to rent out more land, given the higher costs of crop cultivation. Contrary to this expectation, the results indicate that machinery-services prices had a negative impact on the share of land rented out. This finding may have been due to a decrease in demand for land rental at the village level.

4.2.2. Other explanatory variables

With regard to the control variables, households with relatively large contracted farms were more likely to rent out land and to rent out a larger share of their land, while also being less likely to rent in land and to rent in a smaller share of their cultivated land. These findings are consistent with the expectations depicted in Fig. 2, and they imply that the village land rental market has promoted greater equality in the distribution of land amongst farmers (for a similar conclusion, see Deininger and Jin, 2002). Controlling for contracted land area, households with more plots were significantly less likely to rent in or rent out

land, in addition to renting out a smaller share of contracted land. These findings suggest that smaller plots were less popular in the land rental market, either because demand was lower or because the plots were less suited to the use of machinery. One surprising finding is that the average rental price of land in villages had no significant effect on decisions on either the renting in or the renting out of land. One potential explanation is that the rental prices reported by the village leaders did not accurately reflect the land rentals taking place between relatives and friends at no cost, which remains a common phenomenon in large parts of rural China (e.g., Wang et al., 2015; Ma et al., 2020).

With regard to the other household resources, as expected, tractor ownership had a significant positive impact on the likelihood of renting in land, as well as on the share of cultivated land that is rented in. It also had a significant negative impact on the likelihood of renting out land, as well as on the share of cultivated land that is rented out. Interestingly, possession of crop management machinery had a negative effect on the likelihood of farmers to rent out land, as well as on the share of contracted land that is rented out, while having no significant effects on decisions concerning the renting in of land. One potential explanation is that crop management machinery is particularly likely to be owned by relatively large farmers (i.e., those depicted on the right side of Fig. 3).[8] In addition, possession of a harvester did not significantly affect decisions concerning either renting in or renting out, whereas the size of the household labour force had a negative effect on the share of the cultivated land that is rented out. The former result is probably related to the very small incidence of harvester ownership (only 1 %) amongst the farmers in the sample (see Table 2). The negative effect of household labour force size on the renting out of land is consistent with a priori expectations, as well as with the fact that households with more labourers are generally assigned more contracted land.[9] Finally, the regression results suggest that access to formal credit did not pose a significant obstacle to participation in the land rental market for the farmers participating in the survey.

Age and gender were the only characteristics of household heads to have any significant effect on land rental decisions. Higher age of the household head had a negative effect on the renting in of land and a positive effect on the renting out of land. This finding implies that younger household heads were more active in expanding the size of their farms than older household heads. Gender was significantly related only to the share of land rented out, with male household heads renting out smaller land shares than their female counterparts. No significant effects were found for the education of the household head or for the village cadre membership of household heads. Variables relating to the quantity and quality of household labour have commonly been identified as important factors affecting the land rental decisions of smallholder farmers in rural China. The findings of this study suggest that the rapid development of the market for agricultural machinery services in recent years has reduced the importance of agricultural labour to the land rental decisions of smallholders.

Finally, the results provide some weak evidence that land registration affected land rental. The estimated coefficient for this variable was positive and significantly different from 0 ($p = 0.10$) in the equation for the share of land rented in, but not in the other three equations. The results also did not identify any significant effects for the other two proxies for transaction costs (i.e., land reallocation and trust). As mentioned in Section 3.2, transaction costs are notoriously difficult to measure. The estimated coefficients for some of the explanatory variables in our model – and particularly those for credit access and the age and cadre membership of the household head – may partly reflect transaction costs involved in land rental markets (Skoufias, 1995; Ricker-Gilbert and Chamberlin, 2018). Moreover, there was relatively little variation amongst the households in the sample with regard to the registration of land, the absence of land reallocations and trust towards people living in the same village group (see Table 3), thus implying a possible lack of precision in the estimates of the corresponding coefficients.

4.3. Robustness checks

To this point, the empirical analysis has addressed only potential correlations between decisions concerning the renting in and renting out of land (i.e. between ε_{1i} and ε_{2i} in Eq. (1)) and between the share of land rented in and rented out (i.e., between u_{1i} and u_{2i} in Eq. (2)). Another potential source of selection bias may have been the correlation between land rental decisions and the corresponding shares of land rented (i.e., the correlation between ε_{1i} and u_{1i} and/or between ε_{2i} and u_{2i}). Such correlations are likely to have occurred if unobserved characteristics affecting land rental decisions also affect the share of land rented, thus introducing self-selection bias (e.g., Tang et al., 2019; Zhou et al., 2019). In addition, as mentioned in Section 3.1, some households that had migrated and were renting out their land could not be interviewed, thus also leading to potential sample-selection bias.

A Heckman selection model (Heckman, 1979) was used to test for possible selection bias. Application of this model requires having at least one variable that is expected to influence the probability of participation but not the corresponding share of land rented. This variable is referred to as the 'exclusion restriction' (Certo et al., 2016). Following Ma et al. (2020), we used past off-farm employment experience on the part of the household head before 2017 as an exclusion restriction. We thus assumed that households with off-farm experience would be more likely to participate in land rentals, as they would face lower sunk transaction costs. Once a household decides to participate, however, the past off-farm experience of the household head should not affect the area of the land rented. Of the households in the sample, 59.7 % indicated that the household head had been involved in off-farm employment before 2017. This variable was included in the first stage of the Heckman model.

The results (reported in Table A2) identify off-farm employment experience of the household head as a significant predictor of the probability of a household to rent out land (z-value = 3.00; $p = 0.003$), although the estimated coefficient of the inverse Mills ratio (IMR) was not significantly different from 0 (z-value = −1.28; $p = 0.20$). For the renting in of land, neither the estimated coefficients for off-farm employment experience (z-value = 0.84; $p = 0.40$) nor IMR (z-value = 0.46; $p = 0.65$) were significantly different from 0. These findings indicate that the null hypothesis of no selection bias cannot be rejected. Similar conclusions have been drawn from the application of Heckman models in previous studies on rental markets for arable and forest land in rural China (Tang et al., 2019; Zhou et al., 2019; Ma et al., 2020).

Two fractional logit models were estimated to assess the robustness of the results for land rental shares. Fractional logit models may be applied when the value of the dependent variable varies between 0 and 1, as is the case with the shares of land rented in this study. The application of two fractional logit models ignored potential correlations between the shares of land rented in and rented out. The results (reported in Table A3) confirm the main conclusion (see Section 4.2.1) that the availability of agricultural machinery services in management activities had a significant positive effect on the renting in of land and a significant negative impact on the renting out of land, with the price of machinery services having a negative effect on the renting in of land.

Finally, only 25.82% of the households in the sample reported participating in land rental markets (see Table 1). A large number of 0 values in a dependent variable may reduce the explanatory power of the regression results. Eqs. (1) and (2) were therefore estimated for the subsample of households that did report participating in land rental markets. Given that the households in the subsample either rented in or

[8] The correlation coefficient of operational farm size and possession of crop management machinery was 0.06 (significant at 0.01 level).

[9] The correlation coefficient of household labour force and contracted land area was 0.27 ($p = 0.01$).

rented out farmland, two separate Probit models were estimated, instead of the Bi-Probit model. According to the results (are reported in Table A4), the R^2 values of the land rental share functions increased from 0.05 to 0.20 and from and 0.06–0.18, respectively. The main conclusions that can be drawn from the estimation results remain unchanged.

5. Conclusion

The use of machinery services in crop cultivation has been rapidly gaining popularity amongst Chinese smallholders faced with large outflows of rural labourers. It has allowed large groups of farmers to expand the operational scale of their farms through land rentals, thereby enhancing their income from farming. At the same time, however, the use of machinery services may also hamper the development of village land rental markets by reducing the supply of land offered by lessors. This study provides a theoretical and empirical examination of how and to what extent agricultural machinery services affect the participation of smallholders in land rental markets. Using a price band model for quasi-fixed inputs, we show that household land resources largely determine the land rental responses to the increased availability of machinery services when land rental markets are characterised by relatively large transaction costs. Households that were autarkic or that had already rented additional land are likely to respond by renting (more) land for cultivation. In contrast, households that were renting out land before machinery services became available at affordable prices are likely either to stop renting out land and start cultivating all the contracted land or to rent out a smaller share of their land. The impact of machinery services on the development of land rental markets is therefore an empirical matter that depends on a variety of factors, including the initial distribution of land resources.

Based on data collected in 2018 amongst 2041 smallholders in four counties in Handan City on the North China Plain, we argue that a distinction should be made between machinery services for basic activities (ploughing, seeding and harvesting), which were used by almost all farmers in the region, and machinery services for crop management activities (fertilising, spray and irrigation), which were used by around one fifth of the farmers. The results of the regression analyses indicate that the availability of basic machinery services did not significantly affect land rental decisions. This finding is consistent with the fact that machinery services for basic activities were used by most of the farmers interviewed. The availability of these services did not seem to be a major limitation for households surveyed. In contrast, machinery services for crop management activities were used by small proportions of the farmers interviewed. These services had a significant positive effect on the renting in of land and a significant negative effect on the renting out of land. Moreover, the price of machinery services had a significant negative effect on the renting in of land.

The insights gained from this case study are also likely to be relevant to other parts of the North China Plain and other regions where agricultural machinery services have developed, where smallholder farmers are predominant and where land transfer markets are active. In particular, the findings imply that the development of the market for agricultural machinery services does not always need to coincide with development of the land rental market. In fact, our findings indicate that the negative effects of the availability of machinery services for crop management activities on the renting out of land are somewhat stronger than the positive effects on the renting in of land. In such cases, policies aimed at promoting the development of markets for agricultural machinery services may obstruct policies aimed at stimulating land rentals among smallholders. Policymakers should be aware of these potential trade-offs when designing instruments to promote regional agricultural development.

The finding that agricultural machinery services reduce the renting out of land suggests that agricultural labour shortages have been alleviated. It also suggests that smallholders will remain important as the agricultural producers in the near future. Although almost all smallholders in the region purchased machinery services for basic agricultural activities, the usage of machinery services for crop management activities was much more limited. This suggests that mechanisation policies may shift focus towards promoting services in activities like fertilisation, pesticides spraying and irrigation as a way to further reduce labour shortages and encourage farm size expansion.

Interestingly, households with more plots in a given contracted land area were found to have a smaller probability to rent in or rent out land. Hence, smaller plots appear to be less popular in the land rental market. Policies aimed at reducing land fragmentation may therefore not only contribute to agricultural productivity and efficiency by facilitating agricultural machinery use, but also by facilitating land transfers.

A few limitations should be taken into account when interpreting and generalising the results of our study. First, in the attempt to maximise the response rate, the survey was conducted immediately after the Chinese New Year, when many rural-urban migrants can be found and interviewed in their hometowns. Nevertheless, some households with formal residence (*hukou*) in the villages surveyed may have migrated and rented out all of their contracted land to others. If these households did not return to their home villages for the Chinese New Year, they could not be interviewed. For this reason, even though the selection bias in our study is likely to be smaller than in similar studies for Chinese villages, it is still likely to be present. Future research should consider other methods for further reducing this bias. Second, the research for this study was carried out in a relatively flat land area, which was dominated by small farms with fairly low rates of participation in the land rental market. More research should be conducted in other parts of rural China, where use of machinery may be more problematic and/or where land rental markets are more developed, in order to examine the generalisability of the main findings. Finally, this study examines only the rentals of smallholder households. In recent years, the Chinese government has actively encouraged land rental by farmers' co-operatives and by large farmers and companies from outside the village. Some of these relatively new actors in land rental markets may also be providers of agricultural machinery services. Taking these developments into account is likely to provide a more complete picture of contemporary relationships between the markets for machinery services and land rentals.

Data availability

Data will be made available on request.

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Appendix

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Table A1
Sample composition.

County	Total in county		Selected for survey		
	Townships	Villages	Townships[a]	Villages[b]	Households[c]
Feixiang	9	263	9	48	765
Jize	7	169	7	35	553
Qiu	7	217	6	21	319
Quzhou	10	342	6	26	404
Total	33	991	28	130[d]	2041[e]

Note:
[a] For the township-level sample, a Hui minority autonomous township in Qiu County and four townships in Quzhou County where agricultural extension training was provided over a longer period via the Science and Technology Backyard (STB) platform were excluded (Zhang et al., 2016).
[b] For the village-level sample, townships were divided into three groups according to the number of villages in the township (i.e., 1–10, 11–20 and > 20 villages). Two, four or six villages were randomly selected from these three groups, respectively.
[c] For the household-level sample, 16 households were chosen at random for the interviews from the list of villagers.
[d] Eight villages were dropped from the sample because most households rented out land to agricultural enterprises or cooperatives.
[e] 39 questionnaires with incomplete information were excluded from the sample.

Table A2
Regression results, Heckman selection model.

	Rented in		Rented out	
	First stage rental decision	Second stage rental share	First stage rental decision	Second stage rental share
	(1)	(2)	(3)	(4)
Basic machinery services availability	0.12	-0.05	-0.22**	0.69**
	(1.16)	(−0.15)	(−2.05)	(2.18)
Crop management machinery services availability	0.13**	0.18	-0.19***	0.30
	(2.25)	(0.57)	(−3.32)	(1.43)
Price of basic machinery services	-0.50***	-1.20	-0.04	-0.34
	(−3.06)	(−0.99)	(−0.22)	(−0.82)
Land rent	-0.00	0.00	-0.00	-0.00
	(−0.14)	(0.49)	(−0.45)	(−0.40)
Land area	-0.00**	-0.03***	0.01***	-0.02**
	(−2.25)	(−3.05)	(4.57)	(−2.27)
Plot	0.00	-0.03***	-0.03***	-0.00
	(0.65)	(−3.14)	(−6.34)	(−0.04)
Labour	0.01	0.02	-0.01	-0.02*
	(1.16)	(1.29)	(−1.05)	(−1.68)
Credit	0.00	0.02	0.00	0.02
	(0.08)	(0.46)	(0.21)	(0.36)
Tractor	0.08***	0.18	-0.06**	0.10
	(5.03)	(1.05)	(−2.43)	(1.21)
Harvester	-0.12	-0.30	-0.05	-0.09
	(−1.27)	(−0.85)	(−0.54)	(−0.32)
Crop management machinery	-0.01	0.00	-0.04***	-0.02
	(−0.67)	(0.14)	(−3.03)	(−0.46)
Age	-0.00***	-0.00	0.00***	0.00
	(−3.00)	(−0.14)	(4.28)	(0.16)
Gender	0.04	0.16	-0.03	-0.12*
	(1.08)	(1.42)	(−1.01)	(−1.77)
Education	-0.00	-0.00	-0.00	0.01*
	(−0.68)	(−0.22)	(−0.89)	(1.66)
Village cadre	-0.04	0.08	-0.04	-0.02
	(−1.31)	(0.65)	(−1.19)	(−0.20)
Land registration	0.04	0.18	0.00	-0.03
	(1.28)	(1.60)	(0.08)	(−0.41)
Land reallocation	-0.01	-0.03	0.02	-0.17**
	(−0.47)	(−0.49)	(0.56)	(−2.10)
Trust	0.00	0.04	0.05	-0.08
	(0.13)	(0.73)	(1.47)	(−0.93)
Off-farm employment experience	0.01		0.05***	
	(0.84)		(3.01)	
Inverse Mills ratio (IMR)	0.24		-0.28	
	(0.65)		(−1.28)	
No. of obs.	2041		2041	

Average marginal effects are reported for Rental decision, coefficient estimates for Rented area share; z values in parentheses.
The symbols ***, ** and * indicate significance (p = 0.01, p = 0.05 and p = 0.10, respectively).

Table A3
Regression results, agricultural machinery services on land rented shares (Fractional logit model).

	Rented-in share	Rented-out share
	(1)	(2)
Basic machinery services availability	0.02	-0.12*
	(0.45)	(−1.65)
Crop management machinery services availability	0.06**	-0.09**
	(2.13)	(−2.12)
Price of basic machinery services	-0.34***	-0.19
	(−3.60)	(−1.52)
Land rent	0.00	-0.00
	(0.07)	(−0.64)
Land area	-0.01***	0.01***
	(−4.38)	(3.31)
Plot	-0.00	-0.03***
	(−1.61)	(−5.49)
Labour	0.01**	-0.01*
	(2.22)	(−1.75)
Credit	0.00	0.01
	(0.54)	(0.63)
Tractor	0.04***	-0.04*
	(5.71)	(−1.93)
Harvester	-0.06	-0.05
	(−1.26)	(−0.78)
Crop management machinery	0.00	-0.04***
	(0.15)	(−3.58)
Age	-0.00***	0.00***
	(−3.05)	(3.59)
Gender	0.03	-0.03
	(1.45)	(−1.59)
Education	-0.00	-0.00
	(−0.53)	(−0.17)
Village cadre	-0.03	-0.03
	(−1.58)	(−1.24)
Land registration	0.03*	0.01
	(1.92)	(0.30)
Land reallocation	-0.01	-0.01
	(−0.61)	(−0.57)
Trust	0.01	0.03
	(0.49)	(1.12)
R^2	0.07	0.08
No. of obs.	2041	2041

Average marginal effects are reported, with z values in parentheses.
The symbols ***, **, and * indicate significance at the 1 %, 5 % and 10 % levels, respectively.
Source: Based on authors' survey.

Table A4
Regression results, agricultural machinery services on land rental with participated subsample.

	Rental decision (Probit)		Rented area shares (SUR)	
	In	Out	In	Out
	(1)	(2)	(3)	(4)
Basic machinery services availability	0.78*	-0.78*	0.28*	-0.20
	(1.86)	(−1.86)	(1.73)	(−0.90)
Crop management machinery services availability	0.62**	-0.62**	0.23***	-0.24**
	(2.51)	(−2.51)	(2.58)	(−2.05)
Price of basic machinery services	-0.66	0.66	-0.46*	-0.04
	(−1.10)	(1.10)	(−1.91)	(−0.11)
Land rent	0.01	-0.01	0.01	-0.01
	(0.42)	(−0.42)	(0.84)	(−0.79)
Land area	-0.03***	0.03***	-0.02***	0.01*
	(−3.74)	(3.74)	(−6.73)	(1.78)
Plot	0.06***	-0.06***	0.00	-0.05***
	(3.81)	(−3.81)	(0.25)	(−5.10)
Labour	0.02	-0.02	0.01	-0.03**
	(1.19)	(−1.19)	(1.26)	(−2.53)
Credit	-0.03	0.03	-0.01	0.02

(continued on next page)

Table A4 (*continued*)

		Rental decision (Probit)		Rented area shares (SUR)	
		In	Out	In	Out
		(1)	(2)	(3)	(4)
		(−0.57)	(0.57)	(−0.33)	(0.59)
Tractor		0.29***	-0.29***	0.18***	-0.14***
		(3.78)	(−3.78)	(6.08)	(−3.49)
Harvester		-0.11	0.11	-0.07	-0.05
		(−0.34)	(0.34)	(−0.36)	(−0.21)
Crop management machinery		0.09**	-0.09**	0.05**	-0.08***
		(2.23)	(−2.23)	(2.56)	(−3.30)
Age		-0.01***	0.01***	-0.00***	0.01***
		(−4.33)	(4.33)	(−3.69)	(5.15)
Gender		0.11	-0.11	0.06	-0.15**
		(1.12)	(−1.12)	(1.28)	(−2.40)
Education		-0.00	0.00	-0.00	0.01
		(−0.36)	(0.36)	(−0.40)	(1.40)
Village cadre		-0.04	0.04	-0.04	0.01
		(−0.33)	(0.33)	(−0.63)	(0.08)
Land registration		0.13	-0.13	0.09*	-0.07
		(0.80)	(−0.80)	(1.68)	(−0.95)
Land reallocation		-0.01	0.01	-0.01	-0.08
		(−0.09)	(0.09)	(−0.24)	(−1.24)
Trust		-0.08	0.08	-0.02	0.03
		(−0.84)	(0.84)	(−0.45)	(0.45)
Breusch-Pagan test[a]	Chi2(1)			329.570***	
	Prob > chi2			(0.00)	
Log pseudolikelihood		-309.48	-309.48		
R^2				0.20	0.18
No. of obs.		522	522	522	522

Average marginal effects are reported for Rental decision, coefficient estimates for Rented area share; and z values in parentheses.
The symbols ***, **, and * indicate significance at the 1 %, 5 % and 10 % levels, respectively.
Notes:
[a]: Breusch-Pagan test of independence.
Source: Based on authors' survey.

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