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Price decline, land rental markets and grain production in the North China Plain

Qian Wang
College of Economics and Management, Northwest A&F University, Yangling, China and
Soil Physics and Land Management Group, Wageningen University and Research, Wageningen, The Netherlands
Fan Li
Development Economics Group, Wageningen University and Research, Wageningen, The Netherlands
Jin Yu
College of Economics and Management, Northwest A&F University, Yangling, China, and
Luuk Fleskens and Coen J. Ritsema
Soil Physics and Land Management Group, Wageningen University and Research, Wageningen, The Netherlands

Abstract
Purpose – This study examines the heterogeneous correlations between rural farmers' land renting behavior and their grain production when they experienced a significant price decline.
Design/methodology/approach – We used well-timed panel data obtained from a two-round survey held in 2013 and 2017 among 621 households in the North China Plain. The empirical analyses were conducted by using the pooled ordinary least squares (OLS) and fixed effects models.
Findings – Rural tenants were having heterogeneous responses in land renting behavior and agricultural production when there was a price decline. A group of optimistic tenants (as professional farmers) were more likely to enlarge the farm scale for grain production through land rental markets but decrease variable investment levels (and subsequently decreased productivity) to cope with price decline. In contrast, nonprofessional farmers (the other rural tenants) were rather pessimistic about market performance, and they significantly decreased their grain production area to cope the price decline, but there was no decrease in grain productivity through reducing variable inputs.
Originality/value – This study contributes to the extant literature on the relationship between farmers' land renting-in behavior and agricultural production. By dividing the tenants into professional and nonprofessional farmers, we argue that there is a significant heterogeneous correlation between rural tenants' land renting behavior and grain production when farmers experience a price decline.

Keywords Price decline, Land rental market, Grain production, Heterogeneous strategies, North China Plain
Paper type Research paper

1. Introduction

A crucial challenge to achieve sustainable agricultural growth in many developing countries is the efficient utilization of limited land resources. Developing countries, in general, are

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smallholder farming countries with fragmented farmland in each household (Hazell *et al.*, 2010), and the land use efficiency is rather low (Otsuka *et al.*, 2016; Foster and Rosenzweig, 2017). Land consolidation through land rental markets is an important approach to solve land fragmentation (Du *et al.*, 2018). Policymakers in developing countries have been enthusiastic about the development of land rental markets, regardless of whether the land is privately or collectively owned (Holden and Otsuka, 2014).

The land rental market has attracted substantial attention from scholars worldwide since land can be transferred from low-productive to high-productive households and subsequently improve agricultural productivity and land use efficiency (Chamberlin and Ricker-Gilbert, 2016). A large number of early studies focused on the determinants of smallholders' land renting behavior (e.g. off-farm employment, Jin and Deininger, 2009; land tenure security, Holden and Otsuka, 2014), and the effect of land rental markets on smallholder's agricultural production (Gautam and Ahmed, 2019). However, these early studies often treated all tenants as a homogeneous group in agricultural production without considering the potential heterogeneous nature of farmers' land using behavior. Without identifying these heterogeneous natures, findings about land renting behavior and the effect of land rental behavior on agricultural productivity could become rather inconsistent. For instance, when more resources and labors are allocated to cash crops, tenants' renting-in land for cash crop production might decrease grain productivity (Govereh and Jayne, 2003).

Among the heterogeneous natures of the tenants, one particular issue that stands out is how tenants respond to the agricultural commodity price change, particularly when a price decline happens. The agricultural commodity price is an important determinant affecting farmers' comparative advantage in agricultural production (Dawe and Timmer, 2012), so there is no doubt that the price change will affect farmers' agricultural production and land rental behavior. There are two things attracting our attention. First, households' land rental behavior may not change as fast as the agricultural commodity price because it is often acknowledged that the land rental contract has a sticky nature in terms of duration and compensation under the supervision of local governments and village committees (Tang *et al.*, 2019). This sticky nature of the land rental contact indicates that once the land rental contract is signed, changes in agricultural commodity prices could not affect the enforcement of the contract easily without mutual agreements. If the renegotiation cost (or contact cost) is prohibitively high, both the lessor and tenant will have to adjust to the new environment (both market and climate environment) until the rental contract ends. Since lessors and tenants cannot instantly cope with market risks (such as a price decline) efficiently, land rental markets might not always achieve a highest efficiency in agricultural production.

Second, previous studies showed that agricultural commodities price volatility could exert a detrimental effect on households' resource allocation and investment decisions like purchasing a farming machine or hiring labors in agricultural production (Ceballos *et al.*, 2017). This is particularly relevant when farmers experience a significant price decline (Zhou and Koemle, 2015). Under a constrained budget, whether tenants should invest in renting-in land or variable inputs (such as chemical fertilizer) is becoming a crucial decision, which is also closely linked to the heterogeneous natures of the tenants and how they conduct their agricultural production.

Despite the significance of the agricultural commodity price change, almost no studies specifically examined the heterogeneous relationship between tenants' land renting behavior and agricultural productivity considering the dynamic fluctuation in agricultural commodity prices (Jin and Jayne, 2013; Gautam and Ahmed, 2019). Therefore, taking the advantage of a well-balanced panel data collected in 2013 and 2017, and a general grain price decline since 2014 in China, in this paper we examine the potential heterogeneous correlations between rural tenants' land renting behavior and their grain production when farmers experienced a grain price decline. To achieve this goal, we used pooled ordinary least squares (OLS) regressions and fixed effects models to conduct the empirical analyses with panel survey data of 621 households from the North China Plain.

The contribution of our study can be summarized as follows. First, regarding the literatures, it is one of few studies that investigate the correlation between smallholders' land renting behavior and grain productivity considering the dynamic commodity price changes. Although previous empirical studies intensively examined the role of land rental markets in agricultural production in developing countries, most of these studies did not consider the dynamic nature (or market risks) of agricultural sector. Second, from the policy perspective, disentangling the relationship between agricultural commodity price, land rental markets and agricultural production could improve our understanding on the heterogeneous natures about domestic land rental markets and its relationship with grain production when price changes. In addition, at the microlevel, it can help policymakers to formulate their agricultural policy under different market price conditions by helping them figure out the potential relationship of agricultural commodity price decline, land rental markets and agricultural production, which would benefit both lessors and tenants.

The rest of the paper is organized as follows. In Section 2, we provide some background about the recent grain price decline in China since 2014 and the rapid promotion of land rental markets in the North China Plain, and then we establish our analytical framework. In Section 3, we present the sampling and data collection process. We present the empirical strategies in Section 4, and the results in Section 5. We conclude in Section 6.

2. Background and analytical framework

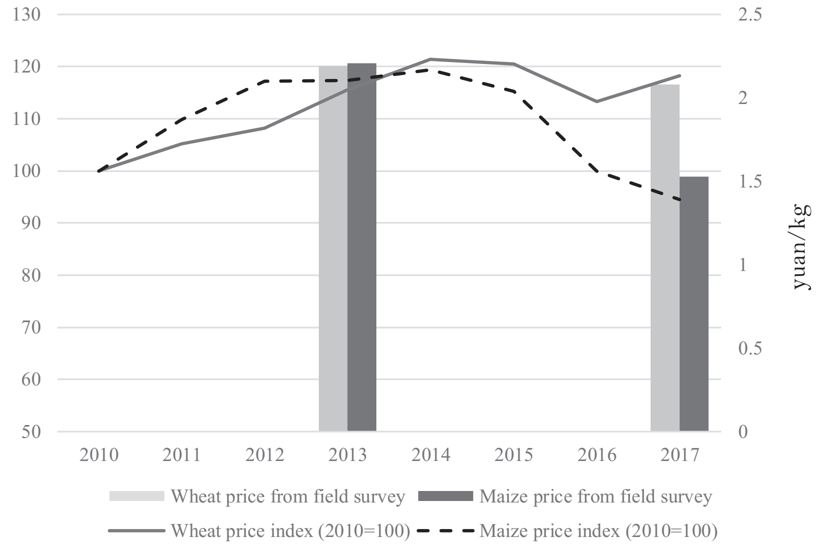
2.1 Grain price decline in China

A significant decline in grain price, particularly in maize, has been observed in China since 2014 (Figure 1, more details of grain price decline can be found in the descriptive results section). The cause of such a price decline could be attributed to two main factors. First, joining the World Trade Organization (WTO) in 2001 greatly improved China's international market accessibility (Arnade *et al.*, 2017; Garred, 2018), which not only enabled China to export more labor-intensive agricultural products, but also exposed its domestic grain market to the international market (Hertel *et al.*, 2007). Since 2012, the international grain price has been dramatically declining (Bellmann and Hepburn, 2017), posing a significant challenge to Chinese domestic grain producers (Zhou and Koemle, 2015).

Second, the recent change in China's national grain supporting policy has further aggravated the downturn in maize price (Huang and Yang, 2017). The grain reserve in China had been growing steadily since 2000 due to the price support program (Liu *et al.*, 2017) [1]. By 2013, the national grain storage reached its peak, and the cost of storing a huge amount of grain became enormously high. In 2014, the Chinese central government drastically lowered its national maize reserve, placing a downward pressure on the maize price (NDRC, 2015). In 2015, the government lowered the temporary storage price of maize, and subsequently in 2016, the national supporting policy for maize was replaced by the new "market purchases" policy (Anderson-Sprecher and Ji, 2016). Although there were more factors affecting China's domestic grain price decline (Tadasse *et al.*, 2016), what we concern about is that a significant price decline has been widely observed among rural smallholders in China.

2.2 The rapid promotion of land rental markets in China

The Chinese government has been promoting land rental markets since the early 1990s (Deininger and Jin, 2005). However, only recently have land rental markets started to develop rapidly. Data from the National Bureau of Statistics of China (NBSC, 2002, 2010) showed that



Source(s):
1) Wheat and maize market price indexes were collected from National Bureau of Statistics of China (NBSC2017) (http://data.stats.gov.cn/easyquery.htm?cn=C01)
2) Market prices of local wheat and maize were obtained from authors' field survey

Figure 1.
Changes of grain price from 2010 to 2017

the percentage of farmland transferred in land rental markets was only 9.5% in the year 2001 and about 19% in 2008. By 2016, however, about 35% of farmland was transferred, involving 70m households (Wei and Yan, 2017) [2].

As in many fast growing developing countries, China's land rental markets experience a rapid promotion for two reasons. First, the Chinese central government's continuous progress in securing land tenure rights, such as passing new land tenure security laws, implementing land certification programs, has considerably eased the land contractors' concerns on property rights (Ma *et al.*, 2013; Wang *et al.*, 2015) and greatly increased their willingness to rent-out land. For instance, Cheng *et al.* (2016) found that China's land certificate program has increased the number of rent-out households by about 4.9% since 2009, and the size of rented-out land per transaction has increased by about 0.37 *mu*. Second, uneven regional development accompanied with rising real wages in the manufacturing sector encouraged a significant share of rural labor forces to migrate to urban cities (Wang *et al.*, 2011). This has significantly increased rural households' eagerness to rent-out land (Ji *et al.*, 2018). All these efforts have significantly increased the *ready-to-rent-out* land in rural areas (Wang *et al.*, 2018).

2.3 A growing heterogeneity in land rental markets

From the land demand side, there has been a growing number of entrepreneurial farmers who are motivated to change the traditional agricultural production into a modern agribusiness like family farm (Tan *et al.*, 2013) and professional cooperatives (Deng *et al.*, 2010). These entrepreneurial farmers have been actively involved in land rental markets for agricultural production. In fact, the Chinese central and local governments have been training and educating the so-called "*Professional farmers (PFs)*" since 2015 to ensure a sustainable and modernized agricultural production (State Council, 2018). Various policies and programs, such as farming skill training, machinery services, market accessing and financial supporting programs, have been implemented to aid *PFs* in agricultural production (Wang, 2013). In 2017, the Chinese central government allocated 1.5bn *yuan* to subside 1 m *PFs* (Li, 2017).

However, in practice, there were no clear definition and criteria in distinguishing *PFs* from others. In general, *PFs*, vaguely defined by the policy, are those who are motivated to become professional in managing agricultural production as an agribusiness, and namely their income are mainly from agricultural production (Li and Li, 2013). Other qualitative studies described *PFs* as "...having capital, mastering technology, and being good at management in farming" (Wang, 2013). Maximizing agricultural profit is *PFs*' primary goal in doing farming work, and a significant part of the profit can be achieved by the economies of scale through renting-in more land. Thus, enlarging farm size through land rental markets is crucial to *PFs*' agricultural production (Huang and Yang, 2017; Ji *et al.*, 2018).

Counter to the progressive development of *PFs*, many field studies have observed another group of tenants who also rent-in land but are not motivated (or able) to engage in agricultural production competitively (Su *et al.*, 2018). Those farmers are traditional smallholders engaging in agricultural production for self-consumption, and in many cases are left-behinds to take care of the remaining farms (Han and Zhong, 2011). The cause of such phenomenon was partially due to the rapid increase in off-farm employment (Qian *et al.*, 2015; Ye *et al.*, 2017), and personal relationship (*Renqing*) is a main concern when they rent-in land (Chen *et al.*, 2017). Moreover, under China's current land protection policies, rural smallholders cannot abandon their land for longer than a certain period [3]. Since most migrated rural smallholders still wish to return to their hometowns in the future, it is rational for them to rent-out land to relatives or friends (mostly those left-behinds who are not able to migrate with an off-farm job) for a small or no compensation to secure their claim of the land (Deininger and Jin, 2008; Gao *et al.*, 2012). In this case, we categorized this type of tenants as *nonprofessional farmers (non-PFs)* since they also rent-in certain land for agricultural production but due to different reasons. In fact, some anecdotal studies (Wu and Ye, 2016; Su *et al.*, 2018) showed that this type of land renting was much more prevalent than *PFs* in rural China.

2.4 Analytical framework

To theoretically analyze how *PFs* and *non-PFs* might behave differently when they experienced a significant price decline, we developed a simple analytical framework to capture the essential heterogeneous decision-making process. Assume that farmers are producing in two periods, the present period ($t = 1$) and the future period ($t = 2$), and the objective is to maximize its total revenue in two periods:

$$\max E(\pi_{\text{total}}) = E(\pi^1) + E(\pi^2) \tag{1}$$

$$E(\pi^t) = p^t g(I_o^t, I_{\text{land}}^t; H_i^t) - r_o^t I_o^t - r_{\text{land}}^t I_{\text{land}}^t \tag{2}$$

$$\text{s.t. } r_o^t I_o^t + r_{\text{land}}^t I_{\text{land}}^t = C^t \tag{3}$$

$$p_E^t = p_E^{t-1} + \beta(p^{t-1} - p_E^{t-1}) \tag{4}$$

In the above Eqn (1), $E(\pi^1)$ and $E(\pi^2)$ are the expected profit from the first and the second period [4]. In each period, profit is generated with Eqn (2), in which grain price is determined exogenously, and the profit from grain production is mainly determined by two inputs–namely land (I_{land}^t) and all other variable inputs (I_o^t). r_o^t is the price for other inputs at time *t*, and r^t_{land} is the rent of land at time t; C^t is the budget line for the year t (Eqn (3)). Households decide how to allocate their total budget in land investment and other variable input investments. Following Nerlove's (1958) model, households' expected market price for grain products is derived from Eqn (4), in which β captures the effect of the gap between previous actual price and expected grain price. We assume that in period 1 actual grain price p^1 is lower than farmers previous expectation p^1_E ($p^1 < p^1_E$, thus a price decline is defined), and farmers only have their expected future market price p^2_E in period 2.

Under this general framework, we first examine how *non-PFs* and autarkic farmers respond to a market price decline, which we assume that both *non-PFs* and autarkic farmers quickly adjust their price expectation to p^1 after price decline observed (so that $\beta = 1$ and farmer's early expected high price p^1_E plays no effects on their second period price expectation, and $p^2_E = p^1$). Maximizing the two-period profit of the rural farmers is essentially the same as one period model with the same constraint. Taking the standard profit maximization calculus, from the first-order condition (FOC) we can derive the following the result as:

$$\frac{\partial g}{\partial I_{\text{land}}} = \frac{(1-\lambda)r^t_{\text{land}}}{p^1} \tag{5}$$

$$\frac{\partial g}{\partial I_o} = \frac{(1-\lambda)r^1_o}{p^1} \tag{6}$$

This result indicates that if there is a negative grain price decline $p^1 < p^1_E$, *non-PFs* or autarkic farmers with pessimistic expectation would reduce the land to the level where marginal contribution of the land to total revenue equals to the marginal cost of land (as in Eqn (5)). The same logic also applies to the other inputs (I_o). Thus, an overall decrease of farm size for grain production among *non-PFs* and autarkic farmers should be observed. Regarding the variable inputs (such as chemical fertilizer), since autarkic farmers did not rent in land and *non-PFs* only rented-in land to secure land tenure for their relatives or friends, they are more likely operating as subsistence farmers; thus, we might not be able to observe a significant decrease of fertilizer application for grain production.

However, *PFs* might show a significant different response to the price decline. First, to *PFs* the previous price decline ($p^{t-1} - p^{t-1}_E$) might have limited effect over their long-term expectations about the grain market performance (so that β is close to zero). This might be because they are not only enjoying benefits from government policies like subsidy program (Yi *et al.*, 2015) and grain supporting price (Anderson-Sprecher and Ji, 2016) but also having access to market-based tools to hedge against price risk such as insurance (Gilbert and Morgan, 2010). Thus, despite the previous price declined, *PFs* might in fact still expect a high price (as what he has expected earlier) in the second period. In this case, the objective function of rural farmers could be rewritten as follows:

$$E\left(\pi^{\text{total}}\right) = p^1 g\left(I^1_o, I^1_{\text{land}}; H^t_i\right) + p^2_E g\left(I^2_o, I^1_{\text{land}}; H^t_i\right) - r^1_o\left(I^1_o + I^2_o\right) - 2r^1_{\text{land}} I^1_{\text{land}} \tag{7}$$

$$\text{s.t. } r^1_o I^1_o + r^1_{\text{land}} I^1_{\text{land}} = C^1 \tag{8}$$

$$r^1_o I^2_o + r^1_{\text{land}} I^1_{\text{land}} = C^2 \tag{9}$$

$$p^2_E = p^1_E > p^1 \tag{10}$$

In Eqn (7), we assume that the price for all variable inputs stay constant over two periods ($r^1_o = r^2_o$); and land contract is rather sticky (Fabella, 2016), which means that once the land rental contract is signed, both rent and size of the rented land will be fixed for both periods of time, thus, $r^1_{\text{land}} = r^2_{\text{land}}$ and $I^1_{\text{land}} = I^2_{\text{land}}$. Rural farmers have to decide whether to rent-in land at period 1 and subject to the budget constraints of both periods. There will be rather limited choice space of rural farmers in terms of renting-in land (Liu, 2019). The FOC reveals the following result:

$$\frac{\partial g}{\partial I_{\text{land}}} = \frac{(1 - \lambda^1 - \lambda^2) r^1_{\text{land}}}{p^1 + p^2_E} \tag{11}$$

$$I^1_o = \frac{C^1 - r^1_{\text{land}} I^1_{\text{land}}}{r^1_o} \tag{12}$$

This result (as in Eqn (11)) indicates that if there is a negative grain price decline, *PFs* will further increase their farm size through land rental markets even when there was a temporary price decline because of high expectation over the long-term grain market price and constraints of the sticky land contract, so that over the two periods the marginal contribution of the land to total revenue would be equal to the marginal cost of renting-in land. However, due to the budget constraints and the increase of rented-in land in period 1, Eqn (12) shows that *PFs* will have its variable inputs (I^1_o) an upper maximum limitation. If the optimal value (as shown in Eqn (6) is higher than the upper limit (Eqn (12)), then we might observe a lower productivity due to under level of variable inputs investment.

Summarizing the above analysis, we could infer that there is an important difference in grain production and market performance between *PFs* and *non-PFs* (and/or autarkic farmers). *PFs* that have a higher expectation toward the future grain market performance are more motivated to benefit from the long-run investments, such as increase area of land rented in and secure long-term land rental contracts. While *non-PFs* are less optimistic toward future grain market performance and are more responsive to the short-term price decline, simply examining the overall correlations between smallholders' land renting-in behavior and their agricultural production might yield some contradicting results since renting-in land might associate with the increase (Yao and Hamori, 2019) or decrease of agricultural productivity (Liu *et al.*, 2019). In this study, we intend to distinguish rent-in households into *PFs* and *non-PFs*, so that we can better capture the heterogeneities between these two groups of tenants and examine the heterogeneous correlations of farmers' land renting-in behavior and their agricultural productivity when they experience a price decline.

3. Data

3.1 Sampling and data collection

The data sets we used in this study were collected from two provinces—Henan and Shandong—in the North China Plain (NCP) [5]. We chose these two provinces for two specific reasons. First, the NCP plays a vital role in China's food sufficiency and security. These two provinces together produced about 17% of the total grain output in 2016 (NBSC, 2017). Second, the farming systems in both provinces are characterized by smallholders with an average farm size of approximately 0.6 ha per household (Zhang *et al.*, 2016). Land transfer has been prevalent after the implementation of a series of policies in the NCP, and lessons drawn from this region could be extended to a much broader scope of China.

We adopted two general principles–the majority principle (major grain producing regions) and the non-neighboring principle (sampled regions should not be adjacent to each other)–to conduct the sampling to ensure a wide representativeness. We first listed all prefectures within each province according to the total grain output (both maize and wheat) in 2012 (NBSC, 2013). We chose two major wheat and maize production prefectures. Following the same protocol, we sampled counties within each prefecture. Eight major grain-producing counties in Henan and Shandong provinces were sampled. Within eight counties, we sampled 21 villages according to the total wheat and maize outputs, and the share of land transferred in 2013. Within each village, we randomly sampled 10–40 households proportional to the village population. In total, 621 households were sampled for the survey. Within these sampled households, there were 499 wheat producers and 445 maize producers in 2013. A detailed sample descriptive analysis is presented in Table 1.

The first-round household survey was carried out in July 2013, immediately after the wheat harvesting period in the NCP [6]. The household questionnaire was administrated with three blocks of information. In the first block, we gathered detailed households' demographic information, including each member' age, education, employment condition, participation in agricultural activities, migrant status, and family size, number of elders, school-aged children, etc. All these variables were used as potential control variables. In the second block, we collected detailed land information, including their contracted land (farm size and number of plots), operational land and renting land (area, rental price, payment forms, and land usage). Specifically, we asked the household head how much land has been contracted since the last village land reallocation. With the detailed land renting information, we could classify if households rented-in land for grain or nongrain production. In the third block, we collected detailed information about the costs of all related farming inputs and final outputs. The inputs include seeds, fertilizers, pesticide and herbicide usage, machinery services and labor costs. With regard to outputs, total outputs and yield of wheat and maize were collected. In addition, we have also collected detailed information related to households' sales price of grain products. We specifically asked how much per kg of wheat (or maize) was sold after their harvest in 2013 [7]. It has to be specifically emphasized that the price we collected in the field survey was farmer's actual sales price, and this sales price might be significantly different from their previous expectations (as we have shown in Section 2.4: Analytical framework).

Moreover, we conducted an interview with a village leader (or accountant) to get basic information about the village general social and geographical characteristics, such as distances from the nearest township and county seat to control for the specific locality effects. The sampling and field survey were administrated with the help of village cadres, with no sensitive topic in the questionnaire to be worried about.

3.2 Follow-up survey and attrition analysis

The follow-up survey was conducted in a similar structure in July 2017. We rechecked household demographic characteristics and the land rental behavior. In addition, we collected their inputs and outputs from grain production in 2017. In particular, to measure if a household has experienced price decline, we compared the grain sales price in 2013 and 2017 to see if each household has indeed experienced some price decline. If the sales price of wheat or maize was lower in 2017 than 2013, the surveyed household was categorized as the group that had experienced a price decline. Otherwise, the surveyed household experienced no price decline. Despite the general trend of grain price decline, rural households could still sell their grain products at a better price than others from the same villages. It was concerned that farmer's ability might affect their final observed sales prices; however, we expect farmer's ability would not change so quickly from 2013 to 2017. This variability of price differences in

	# Of villages	# Of households	Total sample Wheat production households	Maize production households	Households had land rented-in # Of households	Wheat production	Maize production
2013	21	621	499	445	221(35.59%)	181(36.37%)	169(36.37%)
2017	21	550	365	323	111(20.18%)	73(20.18%)	69(16.40%)

Source(s): Authors' survey

Table 1. Sample distribution in NCP in 2013 and 2017

fact enables us to study the heterogeneous correlations between land renting behavior, variable input investments and grain productivities among *PFs* and *non-PFs* when they experience a price decline.

To keep the tracking rate, we adopted the following protocol. First, we contacted all sample households by telephone to make appointments. If a household could not be reached, then the village cadres were asked to assist enumerators in reaching them. After this round of follow-up survey, we surveyed 435 households. Second, we visited the remaining households that we could not contact using their registered addresses to continue the follow-up survey. Finally, we tracked 550 households out of 621 households. All these households were surveyed again with the same questionnaire. Detailed sample descriptions are presented in Table A1.

Of the missing 71 households (11%) from the baseline survey, many were due to temporary absences. For instance, there were 20 households' members visiting their children or relatives in other places. Other reasons included traveling to nearby cities and working as a temporary employee in the county seat. It is worth noting that, if the missing households were not randomly distributed between rent-in and nonrent households, our estimation might be biased due to attrition. To examine if the missing households were randomly distributed, we conducted the attrition analyses. First, we excluded sampled households if they were not grain producers in both rounds of survey, thus having 546 grain producers in total who were engaged in grain production in 2013. Second, we conducted a group of *t*-tests on all the baseline covariates between the tracked 484 grain producers and the missing 62 grain producers (Appendices, Table A2). Third, we conducted a *probit* regression, where the left-hand side was a dummy variable indicating whether an individual household was missing in the follow-up survey. On the right-hand side, we controlled all the first-round survey variables. We further controlled for the county- or township-fixed effect. Regression results are presented in the appendices (Table A3). From both attrition analyses (*t*-test and *probit* regression), we can see that the missing households in the follow-up survey are rather random; therefore, the subsequent analysis will not be affected by sample attrition [8].

4. Estimation strategy

4.1 Defining professional farmers

Given the difficulty of identifying *PFs* and *non-PFs* in the land rental market directly, we first need to find an appropriate proxy according to certain observed characteristics, which could capture the essential heterogeneous nature of *PFs* and *non-PFs*. To simplify our study, we first exclude rural smallholders who rented-in land mainly for nongrain production [9]. This restriction enables us to focus on grain producers' land renting behavior and their productivity changes. With the rest of smallholders who rented-in land for grain production, we defined *PFs* and *non-PFs* according to the amount of rent they paid as a core indicator. Specifically, if a household rented-in land for grain production with a rent higher than 3,000 *yuan* per ha (about USD 462 per ha or 200 *yuan* per *mu*), it was more likely to be a *PF*. Otherwise, if a household rented-in land for grain production with a rent less than 3,000 *yuan* per ha, it was defined as a *non-PF*.

We used the rent of farmland for grain production as the main proxy because it serves the best to capture the essential heterogeneous nature of *PFs* versus *non-PFs*. First, the rent that rural tenants have to pay is directly related to their expectations toward the future grain market price. Farmers with a high price expectation are more willing to pay a high rent to secure their rented-in land and might rent-in more land as a long-term investment. While farmers with a low expectation will either be an autarkic farmer who did not transfer land or a tenant that rented in with a minimum rent. Second, from the land supply side, our study was conducted in the NCP, in which both geographical and climatic conditions were much similar. The local cropping structure (winter wheat and summer maize rotation) was rather homogeneous. Thus, we were less concerned if the rent was determined by those climatic-geographical and/or cropping structure factors. Further, the NCP is a typical smallholder dominant farming area (Zhang *et al.*, 2016), and off-farm employment is rather prevalent for rural farmers (Wang *et al.*, 2019). As long as the rent is higher than the reservation rent, it is rather a reflection of the tenants' willingness in renting-in land. Third, we mainly focused on grain producers instead of cash crop producers. Transportation or other related infrastructures might affect the rent of land for cash crops; however, it plays limited effect on the rent of land for grain production. We used 3,000 *yuan* per ha as the threshold since many recent studies in the NCP have shown that a rent below was often associated with the kinship-based land rental transaction (He *et al.*, 2016; Shang *et al.*, 2016). From our field interview, *PFs* were more willing to pay a relatively higher rent to maintain a longer period of rental contract to secure their investments and to reduce the uncertainty about the future. This is particularly the case when there is weak third-party contract enforcement (Ghatak and Pandey, 2000).

Further, to serve as a robustness check, we defined *PFs* and *non-PFs* according to the area of rented-in land. As we have mentioned in Section 2, to achieve economies of scale, *PFs* often rent in more land than *non-PFs*. In our analysis, if a household rented-in farmland with an area larger than 0.6 ha, we defined it as a *PF*; otherwise, it was defined as a *non-PF*. We used the area of 0.6 ha as a threshold for two specific concerns. First, the average area of the contracted land per household in rural NCP is about 0.6 ha (Appendices, Table A1). Renting-in more than 0.6 ha farmland indicates that smallholders had almost doubled their farm size from at least two lessors. This is often difficult to be achieved through the kinship-based land rental transactions. Second, from our field observations, we found a significant discontinuity in rent when the area of rented-in land exceeded 0.6 ha. Such a jump of rent indicates that there might be a transition from the kinship-based land rental contract to a relatively market-based one. In general, the market-based land rental contract between the lessor and tenant is more rigid (Fabella, 2016), which might be in fact preferred by *PFs*. If both definitions could capture the heterogeneities of *PFs* versus *non-PFs*, we expect consistent correlations to be observed from both analyses.

4.2 Price decline and rural households' land renting strategy

To investigate the heterogeneous relationship of *PFs* and *non-PFs*' land renting-in behavior after the observed price decline in 2017, we first focused on the change in area of the rented-in land, where rented-out land was recorded as negative rented-in. Particularly, we calculated the change in the total area of rented-in land using the following equation:

$$\Delta I_{ij} = \Delta S_{ijt=2017} - \Delta S_{ijt=2013} \tag{13}$$

where $\Delta S_{ijt=2017} = S^{\text{in}}_{ijt=2017} - S^{\text{out}}_{ijt=2017}$ and $\Delta S_{ijt=2013} = S^{\text{in}}_{ijt=2013} - S^{\text{out}}_{ijt=2013}$ are the net area of rented-in land in year 2017 and 2013, respectively [10]. Since we also investigated the usage of the rented-in land, we further calculated the change in rented-in land for grain production.

To examine the heterogeneous renting strategies between *PFs* and *non-PFs* when there was an observed price decline, we first conducted the following regression:

$$\Delta I_{ij} = \alpha_0 + \alpha_1 R^{PFs}_{ijt=2013} + \alpha_2 R^{non-PFs}_{ijt=2013} + \alpha_3 S^{PD}_{ijt=2013} + \beta M'_{ijt=2013} + \vartheta_j + \varepsilon_{ij}, \tag{14}$$

where subscripts i and j represent the i^{th} household from j^{th} village, while $R^{PFs}_{ijt=2013}$ and $R^{non-PFs}_{ijt=2013}$ are variables that indicate whether household i from village j were *PFs* or *non-PFs* in 2013. We categorized $S^{PD}_{ijt=2013}$ as a dummy variable, it equals to 1 if the sampled farmer's grain sales price in 2017 was lower than 2013; otherwise, it equals to 0. Although we observe an overall grain price decline in 2014 in the NCP, the sales price of each individual household in 2017 might not always lower than in 2013. $M'_{ijt=2013}$ is a vector of household and village characteristics in 2013 that might potentially be correlated with household's renting behavior (a detailed list of control variables is presented in Appendix Table A1). ϑ_j is a vector of township dummies to control the locality-specific effects. Since our sampled households are naturally nested (or clustered) within several villages, we cluster the error term ε_{ij} at the village level in all regressions to control the potential intracluster correlation (Kerry and Bland, 1998; Killip *et al.*, 2004).

4.3 Price decline, land renting-in and grain productivity

To examine the potential heterogeneous relationship of *PFs* and *non-PFs* (versus the autarkic farmers) and their grain productivity with the presence of price decline, we used the following empirical models with grain producers who experienced a price decline and those who did not, respectively. The model is as follows:

$$Y_{ijt} = \alpha_0 + \alpha_1 R_{ij}^{PFs} + \alpha_2 R_{ij}^{non-PFs} + \beta M_{ij}^{'} + \delta_t + \vartheta_j + \varepsilon_{ijt} | S_{ijt}^{PD} = 1/0 \tag{15}$$

where Y_{ij} is the outcome that we are interested in, i.e. grain productivity and fertilizer usage [11], while $M_{ij}^{'}$ is the aforementioned vector of household and village characteristics [12]. δ_t is a year dummy variable used to capture all the rest difference due to different years, being equal to 1 in 2017 and 0 in 2013. $S_{ijt}^{PD} = 1/0$ indicates whether the sampled smallholder has experienced a price decline. α_1 and α_2 are the main coefficients that attract our attention. If the coefficients derived from both regression models are significantly different, we would expect that there is a significant heterogeneous correlation between land renting-in behavior and grain productivity among *PFs* and *non-PFs*.

To further examine the potential heterogeneous correlations between *PFs' (and non-PFs')* land renting-in behavior and grain productivity when the price decline happens, we make variables R_{ijt}^{PFs} (and $R_{ijt}^{non-PFs}$) interact with S_{ijt}^{PD} in Eqn (16) to capture the interactive correlation of both factors and tenants' grain productivities. The model specifies as follows:

$$Y_{ijt} = \alpha_0 + \alpha_1 R_{ijt}^{PFs} + \alpha_2 R_{ijt}^{non-PFs} + \alpha_3 S_{ijt}^{PD} + \alpha_4 \left(R_{ijt}^{PFs} \times S_{ijt}^{PD} \right) + \alpha_5 \left(R_{ijt}^{non-PFs} \times S_{ijt}^{PD} \right) + \beta M_{ij}^{'} + \delta_t + \vartheta_j + \varepsilon_{ijt} \tag{16}$$

where $(R_{ijt}^{PFs} \times S_{ijt}^{PD})$ and $(R_{ijt}^{non-PFs} \times S_{ijt}^{PD})$ capture the interactive correlation of land renting-in and tenants' grain productivity among *PFs* and *non-PFs* when experienced a price decline. Empirically, we first ran a pooled OLS regression, assuming that the independent variables in the model correlated with the outcomes in a linear way. Second, to reduce the potential bias due to omitted unobservable households' characteristics, we further ran both regressions using a household level fixed effects (FE) model.

5. Results

5.1 Descriptive results

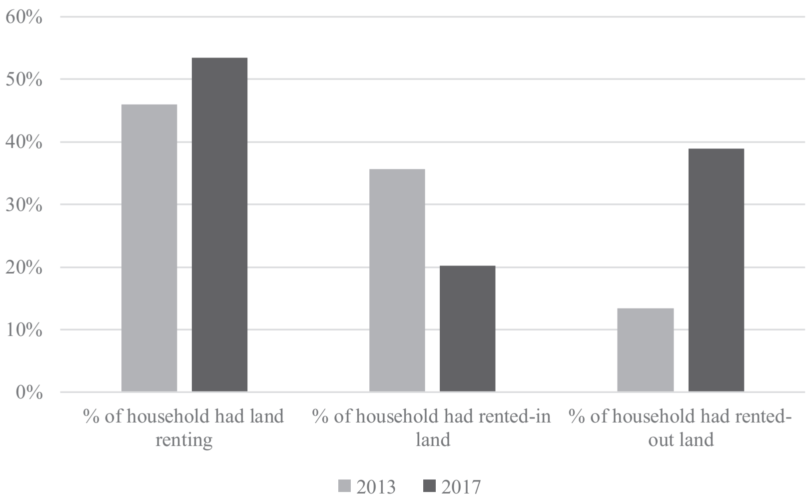
In Figure 1, both the national grain price index and our field observations show the consistent trend of grain price decline. This is particular to maize price, which fell by 32% from 2.2 *yuan* per kg in 2013 to 1.5 *yuan* per kg in 2017 (the decline in wheat price was slightly lower). Assuming that maize could yield 7395 kg per ha on average, with the price decline, rural household were losing about 5176.5 *yuan* per ha from maize production. Moreover, this loss could be even higher, if we added the loss from wheat production.

In terms of tenants' land renting behavior (including both renting-in and renting-out), the land rental market participation rate was about 46% in 2013, which slightly increased to 53%

in 2017 (Figure 2). However, the land rental market experienced a significant structural change, with more households in the NCP motivated to rent out farmland instead of renting-in in 2017.

In Table 2, we compare *PFs*, *non-PFs*, and autarkic households in terms of land usage, grain productivity and fertilizer cost in 2013 and 2017, respectively. Compared to *non-PFs*, *PFs* rented much more land in both 2013 and 2017 (Table 2, rows 2 and 11, columns 3 and 4). In terms of grain productivity, we found that in 2013 both *PFs* and *non-PFs* had significantly higher productivity than autarkic smallholders (about 511.897-527.836 kg per ha, Table 2, row 4); while in 2017 *non-PFs* still had higher productivity than autarkic smallholders, however, *PFs* showed a lower productivity than autarkic farmers (Table 2, row 13). With regard to farmers' chemical fertilizer input, descriptive results in Table 2 indicate that both *PFs* and *non-PFs* had significant higher fertilizer input in maize than autarkic smallholders (Table 2, row 8), while this difference disappeared in 2017 (Table 2, row 17). The reduction was particularly standing out among *PFs* (from 2801.282 *yuan* per ha to 2171.049 *yuan* per ha, Table 2, column 3, row 8 and 17). On the other hand, one interesting point we noted is that the average fertilizer cost in all types of households in fact decreased from 2013 to 2017. This reduction in chemical fertilizer may be partially due to the recent "zero-growth (in chemical fertilizer and pesticide)" policy for green agricultural development (MoA, 2015). This descriptive analysis intuitively indicates that there might be a heterogeneous correlation between tenants' renting-in land and their grain productivity among *PFs* and *non-PFs*.

As for the changing status of *PFs* between 2013 and 2017, we noticed that there were 85 *PFs* and 50 *non-PFs* in 2013 (as shown in Table 2). In 2017, 49 tracked *PFs* changed their status to *non-PFs* or autarkic smallholders, while another 22 new *PFs* appeared among the tracked households. Meanwhile, 41 tracked *non-PFs* changed their status to *PFs* or autarkic smallholders, and 15 tracked autarkic smallholders became *non-PFs* in 2017. In sum, among the tracked households 71 households changed their *PF* status, and 56 households changed



Note(s): There was one type of household that had land both rented-in and rented-out. Therefore, the percentage of households who had land renting behaviors does not equal the sum of percentage of households had land rented-in and rented-out
Source(s): Author's survey

Figure 2. Percentage of household had rented-in (and -out) land in 2013 and 2017

	Total (1)	Autarkic (2)	PFs (3)	Non-PFs (4)	Households with rented-in land for nongrain production (5)	Rent-out households with grain production (6)
Year of 2013						
1. Area of contracted land (ha)	0.454	0.469	0.324***	0.415	0.617**	0.471
2. Area of rented-in land (ha)	0.299	0.000	2.220***	0.377***	3.427***	0.000
3. Cultivated area of wheat (ha)	0.663	0.428	1.560***	0.664***	0.737***	0.290***
4. Productivity of wheat (kg per ha)	6699.592	6550.103	7077.939***	7062.000***	6475.000	6755.208
5. Fertilizer use of wheat (yuan per ha)	2737.189	2673.522	2784.848	2855.762	2917.065*	2727.364
6. Cultivated area of maize (ha)	0.657	0.315	1.393***	0.643***	1.648***	0.271
7. Productivity of maize (kg per ha)	7395.456	7319.787	7695.524***	7288.517	7606.338	7144.42
8. Fertilizer use of maize (yuan per ha)	2601.887	2481.875	2801.282***	2784.832**	2671.705	2643.99
9. Number of observations	503	282	85	50	49	37
Year of 2017						
10. Area of contracted land (ha)	0.610	0.601	0.5222	0.576	0.887***	0.521
11. Area of rented-in land (ha)	0.329	0.000	5.351***	0.692***	2.603***	0.000
12. Cultivated area of wheat (ha)	1.002	0.532	4.401***	0.778**	1.944***	0.238***
13. Productivity of wheat (kg per ha)	7065.453	7092.459	6968.951	7432.229	6750.000	6957.404
14. Fertilizer use of wheat (yuan per ha)	2301.174	2314.664	2221.866	2418.574	2053.377	2310.624
15. Cultivated area of maize (in ha)	0.921	0.444	4.218***	0.792***	1.950***	0.203***
16. Productivity of maize (kg per ha)	7291.449	7219.55	7422.970	7775.535**	7125.000	7314.818
17. Fertilizer use of maize (yuan per ha)	2210.267	2194.821	2171.049	2249.375	1978.71	2332.981
18. Number of observations	367	235	42	21	12	57

Note(s): (a) ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$
(b) Autarkic farmers are those who did not rent-in or rent-out any farmland over the years
(c) PFs and non-PFs are all rural farmers who rented-in land mainly for grain production. While farmers who rented-in land for nongrain crop production will be categorized as rented-in land for nongrain production (column 5)
(d) The value in column 5 (rented-in land for nongrain production) might be larger than other four columns due to the fact that there were 13 households who rented-in land was mainly for nongrain production, however, they do still have a substantial size of rented-in land for grain production
Source(s): Authors' survey

Table 2.
Descriptive analysis of PFs, non-PFs and autarkic households in 2013 and 2017

their *non-PF* status from 2013 to 2017. These changes provide us with sufficient variation to examine the relationship of tenants' being a *PF* (or *non-PF*) and their grain production.

5.2 Multivariate results

5.2.1 Heterogeneous land renting strategies. The results of Table 3 were obtained by running Eqn (14). We found that *PFs* significantly increased the area of rented-in land in year 2017 as a strategic investment to consolidate farmland (about 0.424 ha, Table 3, row 1, column 2). On the contrary, no significant increase in the rented-in land among *non-PFs* could be detected (Table 3, row 2, columns 1 and 2). However, by examining the area of rented-in land for grain production, we found no significant change among *PFs* (no significant increase, Table 3, row 1,

	Changes of land area rented-in between 2013 and 2017		Changes of land area rented-in for grain production between 2013 and 2017	
	(1)	(2)	(3)	(4)
Panel 1: Defined by the rent of land rented-in for grain production				
Treatment variables				
1. Whether a PF in 2013 (R^{PFs}), 1 = yes	0.434**	0.424**	−0.004	−0.075
	(0.176)	(0.184)	(0.161)	(0.183)
2. Whether a non-PF in 2013 ($R^{\text{non-PFs}}$), 1 = yes	0.022	0.038	−0.181*	−0.191*
	(0.090)	(0.077)	(0.097)	(0.112)
3. Whether rented-in land for nongrain production, 1 = yes	0.328*	0.430*	0.526**	0.565**
	(0.194)	(0.228)	(0.241)	(0.274)
4. Experienced a price decline (S^{PD}), 1 = yes	0.106	0.022	0.189	0.122
	(0.117)	(0.183)	(0.165)	(0.155)
5. *Household grain productivity in 2013*	*Yes*	*Yes*	*Yes*	*Yes*
6. *Household characteristics*	*Yes*	*Yes*	*Yes*	*Yes*
7. *Township dummies*	–	*Yes*	–	*Yes*
Constant	−0.153	0.425	−0.578**	0.121
	(0.294)	(0.466)	(0.293)	(0.455)
Observations	388	388	388	388
R-squared	0.578	0.585	0.239	0.259
Panel 2: Defined by the area of land rented-in for grain production				
Treatment variables				
8. Whether a PF in 2013 (R^{PFs}), 1 = yes	0.799**	0.706**	−0.207	−0.347
	(0.344)	(0.329)	(0.339)	(0.349)
9. Whether a non-PF in 2013 ($R^{\text{non-PFs}}$), 1 = yes	0.026	0.010	−0.132**	−0.207***
	(0.077)	(0.071)	(0.062)	(0.069)
10. Whether rented-in land for nongrain production, 1 = yes	1.075**	1.223**	−0.228	−0.267
	(0.464)	(0.541)	(0.224)	(0.262)
11. Experienced a price decline (S^{PD}), 1 = yes	0.090	−0.008	0.204	0.113
	(0.101)	(0.147)	(0.164)	(0.158)
12. *Household grain productivity in 2013*	*Yes*	*Yes*	*Yes*	*Yes*
13. *Household characteristics*	*Yes*	*Yes*	*Yes*	*Yes*
14. *Township dummies*	–	*Yes*	–	*Yes*
Constant	−0.277	0.394	−0.564	0.032
	(0.272)	(0.461)	(0.293)*	(0.505)
Observations	388	388	388	388
R-squared	0.607	0.615	0.224	0.247

Note(s): Robust-clustered standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$
Source(s): Authors' survey

Table 3. Price decline and changes of land area rented-in in the NCP

columns 3 and 4), whereas *non-PFs* show a slight decrease in grain production areas (Table 3, row 2, columns 3 and 4).

As a robustness check, in panel 2 when defining *PFs* and *non-PFs* according to the area of rented-in land for grain production, we found consistent results (as shown in Table 3, panel 2). We found an increase of about 0.706 ha in the rented-in land among *PFs* (Table 3, row 8, column 2), and a significant decrease in the rented-in land area used for grain production (Table 3, row 8, columns 3 and 4). Both results clearly indicate that *PFs* increased the area of land through rental markets in 2017; however, the increased land was not used for grain production; whereas *non-PFs* had no significant change of rented-in land area during this period. Further, from both models, we noticed that S^{PD} (dummy variable, if the sampled household has experienced a price decline) had no significant correlations with area of rented-in land (Table 3, rows 4 and 11). This result indicates that after considering the potential heterogeneous responses of *PFs* and *non-PFs* in land rental behavior, the land rental contract was rather stable despite that farmers experienced a grain price decline.

5.2.2 Price decline, renting-in land and grain productivity. Table 4 shows a significant heterogeneity in *PFs'* and *non-PFs*' grain productivity. We found that among farmers who experienced no price decline, *PFs* are associated with a significantly higher grain productivity compared to the autarkic smallholders; while *non-PFs* did not show any differences in grain productivity (Table 4, rows 1 and 2, column 1). Examining this correlation among farmers who experienced a price decline, we found that, interestingly, *PFs* did not show any significant positive correlation with grain productivity, whereas *non-PFs* were performing much better compared to the autarkic smallholders (Table 4, rows 1 and 2, column 2). This result indicates that when tenants experience no price decline *PFs* might have a significant higher productivity than *non-PFs* and the autarkic smallholders. However, when there is a price decline, this correlation does not persist.

We further ran Eqn (16) with pooled OLS and household level FE models and with *PFs* and *non-PFs* interactions with price decline, respectively. The results showed a significant negative correlation between *PFs* and their grain productivity (about 0.318–0.339 standard deviations, Table 4, row 3, columns 3 and 4) when they experienced a price decline. Both pooled OLS and FE models showed consistent results (the coefficient $\alpha_4 = -0.339$ from the FE model was relatively larger and significant at the 10% level (Table 4, row 3, column 4). For *non-PFs*, we did not find such a significant correlation with grain productivity (Table 4, row 4, columns 3 and 4) [13].

Results from our robustness analysis (defined according to the area of rented-in land) were all consistent. Using both pooled OLS and FE models, the interaction terms of $R_{ijt}^{PFs} \times S_{ijt}^{PD}$ in Eqn (16) were all negative (Table 4, row 13, columns 3 and 4) [14], suggesting that *PFs* show a lower productivity when experienced a price decline. Consistent results were also observed for *non-PFs*.

5.2.3 Price decline, renting-in land and the fertilizer input. Following our analytical framework, to examine whether such a negative correlation between *PFs* and their grain productivity was due to the reduction of variable inputs, we further examined the correlations between tenants (*PFs* and *non-PFs*) and their chemical fertilizer inputs when experienced a price decline (Table 5). The pooled OLS regression results showed that fertilizer input per ha among *PFs* was about 0.370 standard deviations lower when they experienced a price decline (Table 5, row 3, column 3), whereas *non-PFs* showed no significant negative correlation in the fertilizer input (Table 5, row 4, column 3). Results from the FE models further showed a clear and significant negative correlation in fertilizer input among *PFs* when experienced a price decline (−0.429 standard deviations, Table 5, row 3, column 4). In the robustness analysis (Table 5, panel 2), we found a significant negative correlation in chemical fertilizer input among *PFs* when experienced the price decline (Table 5, row 13, columns 3 and 4). However, no significant negative correlation was observed among *non-PFs* (Table 5, row 14, columns 3 and 4).

	Experienced no price decline, $S^{PD} = 0$ (1)	Experienced a price decline, $S^{PD} = 1$ (2)	Pooled OLS (3)	Pooled FE model (4)
Panel 1: Defined by the rent of land rented-in for grain production				
Treatment variables				
1. Whether a PF (R^{PFs}), 1 = yes	0.283***	0.189	0.378***	0.418***
	(0.083)	(0.143)	(0.075)	(0.139)
2. Whether a non-PF ($R^{non\text{-}PFs}$), 1 = yes	0.081	0.342**	0.042	−0.121
	(0.100)	(0.133)	(0.133)	(0.147)
3. $R^{PFs} \times S^{PD}$			−0.318*	−0.339*
			(0.156)	(0.179)
4. $R^{non\text{-}PFs} \times S^{PD}$			0.329	0.762***
			(0.234)	(0.287)
5. Experienced a price decline (S^{PD}), 1 = yes			0.218	−0.077
			(0.189)	(0.132)
6. Rented-in for nongrain production, 1 = yes	0.148	0.538***	0.210	−0.072
	(0.172)	(0.152)	(0.133)	(0.223)
7. Year dummy, 1 = 2017	−0.035		−0.063	0.054
	(0.189)		(0.210)	(0.122)
8. Crop type, 1 = wheat	*Yes*	*Yes*	*Yes*	–
9. *Household characteristics*	*Yes*	*Yes*	*Yes*	*Yes*
10. *Township dummies*	*Yes*	*Yes*	*Yes*	–
Constant	−0.820*	0.074	−0.441	−0.592
	(0.429)	(0.483)	(0.360)	(0.681)
Observations	1,041	589	1,630	1,630
R-squared	0.195	0.349	0.189	0.072
Panel 2: Defined by the area of land rented-in for grain production				
Treatment variables				
11. Whether a PF (R^{PFs}), 1 = yes	0.116	0.192	0.218*	0.270
	(0.138)	(0.154)	(0.113)	(0.183)
12. Whether a non-PF ($R^{non\text{-}PFs}$), 1 = yes	0.214**	0.311**	0.242**	0.093
	(0.085)	(0.112)	(0.104)	(0.133)
13. $R^{PFs} \times S^{PD}$			−0.169	−0.199
			(0.188)	(0.207)
14. $R^{non\text{-}PFs} \times S^{PD}$			0.041	0.287
			(0.186)	(0.243)
15. Experienced a price decline (S^{PD}), 1 = yes			0.215	−0.031
			(0.185)	(0.132)
16. Rented-in land for nongrain production, 1 = yes	0.127	0.531***	0.189	−0.085
	(0.174)	(0.155)	(0.141)	(0.223)
17. Year dummy	−0.033		−0.057	0.030
	(0.187)		(0.205)	(0.123)
18. Crop type, 1 = wheat	*Yes*	*Yes*	*Yes*	–
19. *Household characteristics*	*Yes*	*Yes*	*Yes*	*Yes*
20. *Township dummies*	*Yes*	*Yes*	*Yes*	–
Constant	−0.809*	0.090	−0.429	−0.627
	(0.423)	(0.479)	(0.357)	(0.686)
Observations	1,041	589	1,630	1,630
R-squared	0.193	0.349	0.184	0.050

Note(s): Robust-clustered standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$; the *R*-square reported in fixed effect model (column 4) are within *R*-square, which is different from the pooled OLS model (column 3) within an overall *R*-square
Source(s): Authors' survey

Table 4. Land renting-in and grain productivity in the NCP

To further investigate whether the negative correlation in grain productivity among *PFs* was associated with the reduction in variable inputs (particularly, chemical fertilizer), we conducted a serial mediation analysis (Wen *et al.*, 2004). First, we ran a regression of grain productivity using R^{PFs} and $R^{non-PFs}$. Afterward, when the coefficient of R^{PFs} was

	Nondrop (1)	Drop (2)	Pooled OLS (3)	Pooled FE model (4)
Panel 1: Defined by the rent of land rented-in for grain production				
Treatment variables				
1. Whether a PF (R^{PFs}), 1 = yes	0.251*	0.184	0.403***	0.747***
	(0.133)	(0.128)	(0.140)	(0.175)
2. Whether a non-PF ($R^{non\text{-}PFs}$), 1 = yes	0.136	0.129	0.213	0.173
	(0.096)	(0.347)	(0.130)	(0.152)
3. $R^{PFs} \times S^{PD}$			−0.370**	−0.429**
			(0.161)	(0.201)
4. $R^{non\text{-}PFs} \times S^{PD}$			−0.071	0.256
			(0.253)	(0.349)
5. Experienced a price decline (S^{PD}), 1 = yes			0.031	−0.174
			(0.118)	(0.145)
6. Rented-in for nongrain production, 1 = yes	0.226	−0.144	0.171	0.092
	(0.202)	(0.127)	(0.191)	(0.245)
7. Year dummy	−0.536***		−0.468***	−0.358***
	(0.121)		(0.123)	(0.132)
8. Crop type, 1 = wheat	*Yes*	*Yes*	*Yes*	–
9. *Household characteristics*	*Yes*	*Yes*	*Yes*	*Yes*
10. *Township dummies*	*Yes*	*Yes*	*Yes*	–
Constant	0.948*	−0.644	0.469	−0.128
	(0.462)	(0.473)	(0.282)	(0.566)
Observations	1,041	589	1,630	1,630
R-squared	0.107	0.212	0.134	0.226
Panel 2: Defined by the area of land rented-in for grain production				
Treatment variables				
11. Whether a PF (R^{PFs}), 1 = yes	0.316*	−0.032	0.507***	0.929***
	(0.168)	(0.144)	(0.159)	(0.184)
12. Whether a non-PF ($R^{non\text{-}PFs}$), 1 = yes	0.163**	0.308	0.248**	0.283**
	(0.075)	(0.288)	(0.115)	(0.142)
13. $R^{PFs} \times S^{PD}$			−0.619***	−0.773***
			(0.160)	(0.207)
14. $R^{non\text{-}PFs} \times S^{PD}$			0.031	0.208
			(0.212)	(0.290)
15. Experienced a price decline (S^{PD}), 1 = yes			0.048	−0.115
			(0.120)	(0.147)
16. Rented-in for non-grain production, 1 = yes	0.224	−0.158	0.154	0.086
	(0.208)	(0.131)	(0.193)	(0.244)
17. Year dummy	−0.544***		−0.487***	−0.393***
	(0.122)		(0.122)	(0.135)
18. Crop type, 1 = wheat	*Yes*	*Yes*	*Yes*	–
19. *Household characteristics*	*Yes*	*Yes*	*Yes*	*Yes*
20. *Township dummies*	*Yes*	*Yes*	*Yes*	–
Constant	0.922*	−0.624	0.441	−0.116
	(0.462)	(0.485)	(0.297)	(0.566)
Observations	1,041	589	1,630	1,630
R-squared	0.107	0.217	0.137	0.229

Note(s): Robust-clustered standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$; the R-square reported in fixed effect model (column 4) is within R-square, which is different from the pooled OLS model (column 3) within an overall R-square
Source(s): Authors' survey

Table 5.
Households' land renting-in and fertilizer cost in NCP

significant, then we ran a regression of fertilizer input using R^{PFs} and $R^{non-PFs}$ as explaining variables. Finally, we ran regression of grain productivity using R^{PFs} and $R^{non-PFs}$, and fertilizer costs as explaining variables. If all coefficients in step 3 were significant, then a mediating effect would be verified, otherwise the Sobel test should be carried out. Table 6 presents the results of the mediation analysis. The Sobel test produced a value of 1.292, which was significantly higher than the threshold (0.97), with about 11% of the total effects mediated through the adjustment of fertilizer reduction among *PFs*.

The above results further reinforced our findings that there is a significant heterogeneity among rural tenants. Rural tenants with a higher expectation of the grain market in the long run will strategically increase their land area (as a long-term investment) even to sacrifice their temporary productivity by reducing variable inputs (short-term benefits) when they experienced a price decline. While rural tenants with low expectations of grain market might simply behave same as subsistence farmers. When they experienced a price decline, they might simply reduce the farm size for grain production. These rural tenants are farmers who rent-in land either because of limited ability to work off-farm or rent-in land to help their relatives and friends to keep the land farmed.

6. Conclusion and discussion

In this study, we examine the potential heterogeneity in the relationship between rural tenants' land rental behavior and their grain production when they experienced a price decline in the NCP. The current land rental market might present two heterogeneous types of tenants–professional farmers (*PFs*) and nonprofessional farmers (*non-PFs*). *PFs* are the farmers who are fully engaged in grain production and are managing their farm as a kind of small agribusiness. They are motivated to rent-in land to enlarge their agribusiness and have a rather positive expectation about the grain market performance in the long run. While *non-PFs*, as a type of tenants in land rental markets, are those who rent-in land might be due to their limited ability to work off-farm, and land tenure security concerns among their relatives or friends. They are not motivated to run their farm as an agribusiness and overall have a rather lower expectation about the grain market performance in the long run. These two types of tenants are essentially different in motivations and expectations about the long-run grain market performance, and thus are having heterogeneous responses (or strategies) when they experienced a price decline. *PFs* continuously increase their farm size through land rental markets to reach its long-term optimal level. Under the budget constraint, increasing rented-in land when they experienced a price decline might lead to a reduction over variable inputs, which subsequently decreased their grain productivity. While *non-PFs* show no significant change in land renting behavior. This might be partially due to the fact that *non-PFs* are not enthusiastically engaged in agricultural production, and renting-in land was primarily for securing the land tenure rights for land lessors. Moreover, *non-PFs* do not show a negative correlation with their grain productivity and the variable inputs might be due to the fact that they are more subsistence farmers (Yang *et al.*, 2018).

Variable	Step 1	Step 2	Step3	*Z* value of sobel test	Mediating effect	Mediating effect/total effect
R^{PFS}	0.324**	0.618***	0.288**	1.292	0.036	0.110
	(0.128)	(0.161)	(0.130)			
Fertilizer cost			0.058			
			(0.042)			

Note(s): Robust-clustered standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

Table 6. The mediating effect of PFs' fertilizer input on grain productivity

Given the importance of land rental markets and the potential detrimental effect of price decline on agricultural production, understanding rural households' heterogeneous expectations and their heterogeneous responses by balancing the short-term and long-term investments are crucial for future policy designers to improve the land use efficiency through land rental markets. To ultimate the performance of land rental markets, a grain price warning system should be built, and price information should be well-communicated within rural grain producers to facilitate their decision-making regarding the participation in land rental markets. Additionally, comprehensive agricultural services should be provided to grain producers (particularly to *PFs*) to improve their agricultural profitability without sacrificing productivity when there is a serious grain price decline.

Although our study has been carefully conducted, there are still a number of unsolved issues that deserve a more careful examination. First, it is rather difficult to distinguish between *PFs* and *non-PFs* in the field. We used both the rent and the area of rented-in land as proxies, these indicators might not be accurate, which could underestimate (or overestimate) the true relationship between *PFs*' and *non-PFs*' land rental behavior and their agricultural productivity. A more accurate indicator for *PFs* and *non-PFs* should be designed to capture such underlying differences. Second, employing only two-round panel data provides us with a limited opportunity to explore the dynamic correlations between grain price volatility, household land renting behavior and agricultural productivity. In addition, a large survey sample with continuous measurement of price volatility might be better to examine the causal relationship of *PFs*' and *non-PFs*' land rental behavior and their grain productivity when experienced a price decline. We expect both the magnitude and length of the price decline to have more profound and heterogeneous effects on land rental markets and agricultural productivity.

Notes

1. China's central government has implemented a grain price support program to protect grain producers' profitability since 2004. However, it has gradually removed this price protection mechanism since 2013 (Cao *et al.*, 2017). For a period of time there was a coexistence of market price and policy price for wheat and maize. In our study, we refer to smallholders' sales market price since by then most farmers could not sell directly at a reserved price, and farmers cannot always enjoy the policy price.

2. It is not allowed in China to trade farmland property rights, since the land property right is owned by the village communities, and no specific individual owns the property right (Du and Sun, 2011). However, rural households can transfer the land-use rights to other rural households and/or organizations, while retaining land contractual rights.

3. According to the recent "The Law of Land Administration of China," rural households who have abandoned their cultivated farmland for more than two years will not be entitled to the corresponding land.

4. To simplify the theoretical analysis, we assume no value discount over time since these factors are essentially same across *PFs* and *non-PFs*. Land is categorized as the one of the fix investments, while all other inputs categorized as variable inputs (assume that complete labor, machinery, fertilizer and other variable inputs markets).

5. The NCP is the largest alluvial plain in East Asia, and it is one of the fastest growing urban areas in the world (Bren *et al.*, 2017).

6. In the NCP, the farming structure is characterized by the rotation of winter wheat and summer maize. By the time we conducted the survey, farmers had just finished wheat harvest in June and planted summer maize. We collected information on the previous season of maize, which was from June 2012 to harvest in October 2012. For wheat, it was the crossover year from October 2012 to June 2013.

7. Although there was a policy price (or floor price policies) about wheat and maize (canceled in 2016) set by the National Food and Strategic Reserves Administration, the price we asked in both surveys was farmer's sales price. In our study, we did not specifically focus on the policy prices because

almost no farmers directly sold to the national reserve company (but rather to a middle-agent), and most of the rural farmers did not directly enjoy this policy price.

8. Although from *t*-test we found some slight differences in two baseline variables (e.g. area of the contracted land, distance from the nearest county), in *probit* regression analysis, none of these variables were statistically significant. We noticed that households who rented-in land with a low price had slightly significant values, and the coefficient was relatively larger than other coefficients; however, after we compare our results with the results obtained with different imputation methods, our results are rather stable.
9. Farmers who rented-in land for cash crop production might show a significant different orientation in land rental market due to their specific demands on certain characteristics of the land and their different land usages. In our study, we focus on grain producers; thus, if a household rented-in land for nongrain production, we recorded it as cash crop farmers. This is different from the national "new professional farmer training" program, in which large scale professional farmers was specially trained to produce high-value crops (Yan *et al.*, 2019).
10. When the area of rented-in land is less than the rented-out land in a single year, the value will be negative. In our data, there are only a limited number of households that have both rented-in and rented-out land simultaneously.
11. To further explain the changes in grain productivity, we also examined the effect of renting-in land on households' fertilizer input. Many studies showed that with the adoption of a more science-based approach in agriculture, inputs such as fertilizer would play a much more significant role in shaping agricultural productivity (Subbarao, 1985).
12. Particularly, we also indicated whether households had parts of their farmland rented-out as a binary variable. Households who had completely rented-out their farmland were not included in our analysis, since they did not participate in any farming activities.
13. In fact, the fixed effects model showed a significant increase in agricultural productivity among *non-PFs* after the price decline (Table 4, row 4, column 4).
14. The coefficient of the fixed effects model was negative (as shown in Table 4, row 13, column 4), but it was statistically significant only at the 15% significance level. It might be the case that the farmers who had rented-in land larger than 0.6 ha were stressed rent-in.

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Corresponding author
Jin Yu can be contacted at: yujin@nwsuaf.edu.cn

Appendix

Variables	Survey in 2013 # of obs	Mean	St.d	Survey in 2017 # of obs	Mean	St.d
Outcome variables						
1. Productivity of wheat (kg per ha)	499	6699.592	1002.095	365	7065.453	1163.819
2. Productivity of maize (kg per ha)	445	7395.456	1113.352	323	7291.449	1081.675
3. % of households had rented-in	621	0.356	0.479	550	0.202	0.402
4. % of households had rented-out	621	0.134	0.341	550	0.389	0.488
5. Area of rented-in land (ha)	221	0.961	1.852	111	1.318	2.069
6. % of land had rented-in for grain production	621	0.219	0.414	550	0.120	0.325
7. Size of rented-in land for grain production	136	0.658	1.184	66	1.387	2.069
8. % of PFs had land rented-in with high price	621	0.138	0.346	550	0.082	0.274
9. % of non-PFs had land rented-in with low price	621	0.081	0.272	550	0.038	0.192
10. % of PFs had land rented-in with large scale	621	0.058	0.234	550	0.065	0.248
11. % of non-PFs had land rented-in with small scale	621	0.161	0.368	550	0.054	0.227
12. % of households had land rented-in for cash crops	621	0.137	0.344	550	0.082	0.274
Household Characteristics						
13. Area of the contracted land (ha)	621	0.554	0.557	550	0.551	0.591
14. # of the contracted plots	621	2.753	1.700	550	2.505	1.507
15. Age of household head (years)	621	52.153	11.404	550	56.193	10.945
16. Education level of the household head (years)	621	8.063	3.272	550	7.062	3.111
17. Family size	621	4.084	1.364	550	4.104	1.635
18. # of migrant workers	621	1.478	1.112	550	1.673	1.294
19. # of agricultural labor	621	2.005	0.864	550	1.624	1.101
20. Whether household had an elder (above 65 years old), 1 = yes	621	0.238	0.426	550	0.296	0.457
21. Whether household had school-aged children, 1 = yes	621	0.451	0.498	550	0.531	0.499
22. Whether household head was a village leader, 1 = yes	621	0.055	0.228	550	0.082	0.274
23. Whether household joined an agricultural cooperative, 1 = yes	621	0.110	0.313	550	0.115	0.319
24. Agricultural machinery endowment (in thousand yuan)	621	10.707	38.676	550	12.457	67.536
25. Agricultural subsidy (in thousand yuan)	621	0.879	2.176	550	1.357	4.767
26. Distance from the nearest township (km)	621	6.443	6.312	550	5.086	5.471
27. Distance from the nearest county (km)	621	22.809	12.866	550	22.537	12.722

Source(s): Author's survey

Table A1. Description of samples and variables in 2013 and 2017

	Tracked Mean	Tracked S.e	Non-tracked Mean	Non-tracked S.e	Difference	S.e
Outcome variables						
1. Productivity of wheat (kg per ha)	6650.403	127.372	6706.571	47.977	−56.167	136.108
2. Fertilizer use per ha of wheat (yuan per ha)	2686.600	95.792	2744.366	36.081	−57.767	102.362
3. Productivity of maize (kg per ha)	7333.864	153.071	7403.783	56.285	−69.919	163.091
4. Fertilizer use per ha of maize (yuan per ha)	2573.977	120.359	2605.661	44.256	−31.684	128.238
Treatment variables						
5. Rented in land for grain production with high price, 1 = yes	0.226	0.046	0.149	0.017	0.077	0.049
6. Rented in land for grain production with low price, 1 = yes	0.048	0.037	0.097	0.013	−0.049	0.039
7. Rented in land for grain production with large scale, 1 = yes	0.065	0.032	0.066	0.011	−0.002	0.034
8. Rented in land for grain production with small scale, 1 = yes	0.210	0.049	0.180	0.018	0.030	0.052
9. Rented in land for non-grain production in 2013, 1 = yes	0.065	0.040	0.120	0.014	−0.055	0.043
10. Rented-out land in 2013, 1 = yes	0.097	0.037	0.093	0.013	0.004	0.039
11. Sales price of wheat (yuan per kg)	2.186	0.026	2.188	0.009	−0.002	0.028
12. Sales price of maize (yuan per kg)	2.066	0.013	2.074	0.005	−0.008	0.014
Household characteristics						
13. Area of the contracted land (ha)	0.405	0.066	0.554	0.024	−0.149**	0.070
14. # of contracted plots	2.742	0.203	2.811	0.073	−0.069	0.216
15. Age of household head (years)	51.048	1.413	52.614	0.506	−1.565	1.501
16. Education level of the household head (years)	8.081	0.416	7.996	0.149	0.085	0.442
17. Family size	4.065	0.170	4.169	0.061	−0.105	0.181
18. # of migrant work within household	1.516	0.140	1.517	0.050	−0.000	0.149
19. # of agricultural labor within household	2.194	0.099	2.083	0.035	0.111	0.105
20. Whether household had an elder (above 65 years old), 1 = yes	0.210	0.054	0.236	0.019	−0.026	0.057
21. Whether household had school-aged children, 1 = yes	0.387	0.063	0.465	0.023	−0.078	0.067
22. If the household head was a village leader, 1 = yes	0.081	0.029	0.054	0.011	0.027	0.031
23. If household joins an agricultural cooperative, 1 = yes	0.081	0.037	0.093	0.013	−0.012	0.039
24. Agricultural machinery endowment (in thousand yuan)	11.396	5.222	11.390	1.869	0.006	5.546
25. Agricultural subsidy (in thousand yuan)	0.806	0.293	0.974	0.105	−0.167	0.311
26. Distance from the nearest town (km)	22.173	1.653	22.560	0.592	−0.388	1.756
27. Distance from the nearest county (km)	3.919	0.698	5.814	0.250	−1.895**	0.741
Observations	484		62			

Note(s): Robust clustered-standard error in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
Source(s): Authors' survey

Table A2.
Results of *t*-test for attrition analysis

	Households missing in 2017 field survey, 1 = yes			
	(1)	(2)	(3)	(4)
Treatment variables				
1. Rented in land for grain production with a high rent, 1 = yes	0.008	−0.058		
	(0.188)	(0.190)		
2. Rented in land for grain production with a low price, 1 = yes	−0.473*	−0.502*		
	(0.258)	(0.256)		
3. Rented in land for grain production at a large scale, 1 = yes			−0.188	−0.253
			(0.323)	(0.340)
4. Rented in land for grain production at a small scale, 1 = yes			−0.176	−0.243
			(0.158)	(0.152)
5. Rented in land for non-grain production,1 = yes	−0.021	−0.056	−0.018	−0.056
	(0.285)	(0.283)	(0.276)	(0.273)
6. Sales price of wheat in 2013 (yuan per kg)	0.150	0.177	0.185	0.210
	(0.391)	(0.406)	(0.383)	(0.397)
7. Sales price of maize in 2013 (yuan per kg)	−0.477	−0.657	−0.529	−0.707
	(0.749)	(0.717)	(0.741)	(0.707)
Household characteristics				
8. Area of the contracted land in 2013 (ha)	−0.348	0.002	−0.390	−0.011
	(0.251)	(0.363)	(0.258)	(0.363)
9. # of contracted plots in 2013	0.002	−0.007	0.008	−0.002
	(0.060)	(0.076)	(0.060)	(0.074)
10. Age of household head in 2013 (years)	−0.012	−0.012	−0.013	−0.013
	(0.008)	(0.008)	(0.008)	(0.008)
11. Education level of the household head in 2013 (years)	0.004	0.004	0.002	0.003
	(0.036)	(0.036)	(0.036)	(0.036)
12. Family size in 2013	−0.024	−0.031	−0.018	−0.027
	(0.087)	(0.088)	(0.085)	(0.087)
13. # of migrant work within household in 2013	−0.036	−0.039	−0.033	−0.037
	(0.113)	(0.123)	(0.112)	(0.123)
14. # of agricultural labor within household in 2013	0.136	0.116	0.133	0.111
	(0.096)	(0.096)	(0.095)	(0.095)
15. Whether household had an elder (above 65 years old) in 2013, 1 = yes	0.134	0.164	0.125	0.161
	(0.269)	(0.277)	(0.270)	(0.277)
16. Whether household had school-aged children in 2013, 1 = yes	−0.214	−0.215	−0.205	−0.210
	(0.190)	(0.197)	(0.192)	(0.199)
17. If household head a village leader in 2013, 1 = yes	0.342	0.332	0.355	0.341
	(0.309)	(0.314)	(0.315)	(0.325)
18. If household joined an agricultural cooperative in 2013, 1 = yes	0.090	−0.003	0.136	0.035
	(0.489)	(0.527)	(0.483)	(0.519)
19. Agricultural machinery endowment in 2013 (in thousand yuan)	0.000	0.000	0.000	0.001
	(0.001)	(0.001)	(0.002)	(0.002)
20. Agricultural subsidy in 2013 (in thousand yuan)	−0.022	−0.026	−0.021	−0.026
	(0.046)	(0.057)	(0.046)	(0.058)
21. Distance from the nearest town (km)	−0.001	−0.001	−0.001	0.002
	(0.005)	(0.013)	(0.006)	(0.013)
22. Distance from the nearest county (km)	−0.030	−0.048	−0.037	−0.053
	(0.024)	(0.032)	(0.025)	(0.033)
23. *County dummies*	*Yes*	–	*Yes*	–
24. *Township dummies*	–	*Yes*	–	*Yes*
Constant	0.358	0.680	0.359	0.745
	(1.744)	(1.818)	(1.721)	(1.783)
Observations	546	502	546	502

Note(s): Robust-clustered standard errors in parentheses, ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$
Source(s): Authors' survey

Table A3. Attrition analysis results

Supplementary material

The supplementary material is available online for this article.