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The polarization and constraints of scale farming in China under the impact of rising wages

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ABSTRACT

For small-peasant economy countries in Asia, scale farming, characterized by land transfer, helps achieve scale economies and improve productivity. However, the scale farming development is hindered by the increasing farm labor cost because of the rising wages. Based on a panel dataset of 458 tenant farmers in Jilin, Jiangsu, and Sichuan provinces in China, we investigate heterogeneity in the impact of rising wages on tenant farmers' farm size and machinery investment of different initial farm sizes. Additionally, we further analyze the different constraints they face in adapting to wage increases. Our results show the antithetical impact of rising wages on tenant farmers with different farm sizes. This results in the polarization of tenant farmers' farm size in China. Meanwhile, tenant farmers face various constraints in the adjustment process of farm size and machinery investment. Specifically, large-scale tenant farmers increase their farm size and invest in agricultural machinery given the rising wages. The extent of this adjustment depends on farming seasons and their liquidity. In contrast, small-scale tenant farmers reduce their farm size and machinery investment. Their choices are limited by the availability of off-farm employment opportunities. Therefore, the government should consider the heterogeneity of tenant farmers and help mitigate the constraints they face to promote the development of scale farming.

1. Introduction

Small-scale family farms dominate throughout Asia, with very few exceptions. Traditional small-scale family farms face the challenges of market accessibility and the risk of food safety owing to "small production". Practices have shown that an effective way to fundamentally solve the contradiction between small-scale production and markets is to develop various forms of scale farming (Gao et al., 2012; Otsuka et al., 2013). Developing scale farming and accelerating the transformation of traditional agriculture have become inevitable pathway for small-peasant economy countries (Huang & Ding, 2016; Wang et al., 2020). China's industrialization and urbanization are characterized with the migration of rural labor to cities or suburban cities and the scale farming expanded from a traditional small-peasant production (Zhong et al., 2013). Land titling program implemented in the early of 2010 s also encourages the transfer of land to tenant farmers from smallholders or villages to engage in scale farming while the land transfer contract specifies the rent in cash or the sharecropping (Bu & Liao, 2022). China's third agricultural census in 2016 indicated that 3.98 million tenant farmers were engaging in scale farming (NBSC, 2017).

The rapid rise in wages in Asia's agricultural sector is the challenge to scale farming which more likely to rely on hired labor

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(Otsuka et al., 2016). Economic growth, urbanization, and the transformation of economic structure in Asia have induced increasing real wages in urban and nonagricultural sectors as well as in rural and agricultural sectors (Yamauchi, 2016). In his work, the yearly average real agricultural wage growth rate in Indonesia was 23.12 from 2007 to 2010. During 2007–2012, real agricultural wage in India increased by 6.8% per year, which was the fastest growth span since 1991 (Gulati et al., 2014). China has also experienced sharp wage increases in recent years (Cai & Du, 2011; Kwan et al., 2018; Wang et al., 2016b; Zhang et al., 2011). Overall, agricultural wage remained comparatively low, being about 18 yuan/day (2.6 US$/ day) in 2000–2003, but have been increasing rapidly since 2003 (NDRC, 2021). Wage in the agricultural sector has risen to 137 yuan/day (20 US$/ day) till 2020, with an average annual growth rate of about 13% (NDRC, 2021). Agricultural wage become the most important component of agricultural production cost (Wang et al., 2016a; Zhong, 2016). Obviously, operating large farms request the hired labor (Otsuka et al., 2016). The rapid rise in real agricultural wage accelerates the cost of hiring labor and thus reduces the profits of scale farming (Arimoto & Sakane, 2021).

In response to rising cost of hiring labor, tenant farmers prefer to use labor-saving technology, such as larger machinery to replace labor, which is usually accompanied by an expansion of scale (Hayami & Ruttan, 1970). Tenant farmers having little possibility to substitute the higher factor price will be forced to lower their farm size and switch to nonagricultural industries. Many studies have discussed how farmers adapt to rising wages through input substitution and adjustment of crop structure (Kislev & Peterson, 1982; Li et al., 2017; Qiao, 2017; Tian et al., 2019; Wang et al., 2016a; Wang et al., 2020). However, only few have explored heterogeneous responses in the farm size adjustment, especially tenant farmers. This hinders us from clarifying the trend of tenants' farm size and the development of scale structure of scale farming in the context of rising wages in agriculture.

Some studies on the scale adjustment of smallholders provide enlightenment for our research (Wang et al., 2016b; Yamauchi, 2016). However, these studies do not consider the constraints that farmers face when they adapt to rising wages through farm size adjustment and machinery investment. Zheng and Xu (2016) demonstrated that ruggedness can determine whether machine is adopted in the production. Their study suggested that without considering the terrain endowment, the estimated results of the substitution between labor and machine are biased. However, this study does not investigate the simultaneous decision on farm size and machinery in the production. In general, gains from the use of mechanized inputs increase with scale (Foster & Rosenzweig, 2022), farm size expansion and large-scale mechanization are complementary for farms in response to save high-cost labor.

An increase in real wages increases the labor cost, thereby decreases comparative advantage in a labor-intensive farming system which is widely observed in many Asian countries (Otsuka et al., 2013). High income countries in Asia (for example, Japan and South Korea) have retained small farms and lost their comparative advantage in agriculture and turn to massively import grains. If China, as well as other populous Asian countries such as India, Vietnam and Indonesia, becomes major importers of grains in future, world grain prices will rise and poverty is likely to deepen (Otsuka et al., 2016). Therefore, it is particularly important to explore the constraints faced by tenant farmers in responding to rising wages, which will help us to adopt policy measures to promote the development of scale farming and enhance the comparative advantage in Asian agriculture.

This study focuses on the grain production to analyze the heterogeneous responses in terms of scale adjustment and machinery investment of tenant farmers with different initial farm size to adapt to rising wages. More importantly, we analyze the different constraints faced by tenant farmers in response to rising wages to obtain policy implications for expanding scale farming. This study contributes to the existing literature in three ways.

First, we analyze the polarization of tenant farmers due to the different initial farm size. That is tenant farmers either engaged in scale farming and specialized in agricultural production or reduce their farm size and work off the farm. Our study also helps to predict the trend of scale farming in China. The existing literature mainly explore the impact of rising wage on the expansion of farm size ignoring the heterogeneous behavior of those specialized in off-farm employment due to the constraint of small initial farm size (Wang et al., 2016b; Yamauchi, 2016).

Second, we further analyses the different constraints that tenant farmers faced in adapting to wage increases, which is still missing in existing studies. Given the generally slow development speed of scale farming in Asia, it is important to identify the constraints that tenant farmers face in coping with rising wages. Specifically, we focus on the nature and economic reproduction attributes of agricultural production and investigate three vital constraints, farming season, liquidity, and off-farm employment opportunity. The research results will not only help Chinese government to alleviate the constraints faced by tenant farmers in coping with rising wages and accelerate the development of scale farming, but also provide useful enlightenment for the transformation of other small-peasant economy countries in Asia.

Third, we use tenant farmer data with large mean and variance of farm size to solve the problem that previous studies are subject to small farm size. The unique data is conducive to observe the differences in scale adjustment and machinery investment behaviors of tenant farmers with different initial farm sizes in response to wage increases and facilitates us to study the polarization of tenant farmers.

The remainder of this paper is organized as follows. The next section introduces the conceptual framework. Section 3 presents the data source and descriptive statistics. Section 4 discusses the empirical strategy and Section 5 presents the empirical results. The conclusion and policy implication are in Section 6.

2. Conceptual framework

Farmers can adapt to rising wages either through input substitution, such as using larger machinery and expanding farm size (Wang et al., 2016b), or becoming part-time farmers by reducing farm size and switching to off-farm employment (Tian et al., 2019; Zheng & Xu, 2017). An introduction of large-scale mechanization is difficult in the presence of rigidities in land reallocation. The marginal productivity of machines depends on landholding size (Otsuka et al., 2013). Initial endowment of farm size is crucial in farmers'

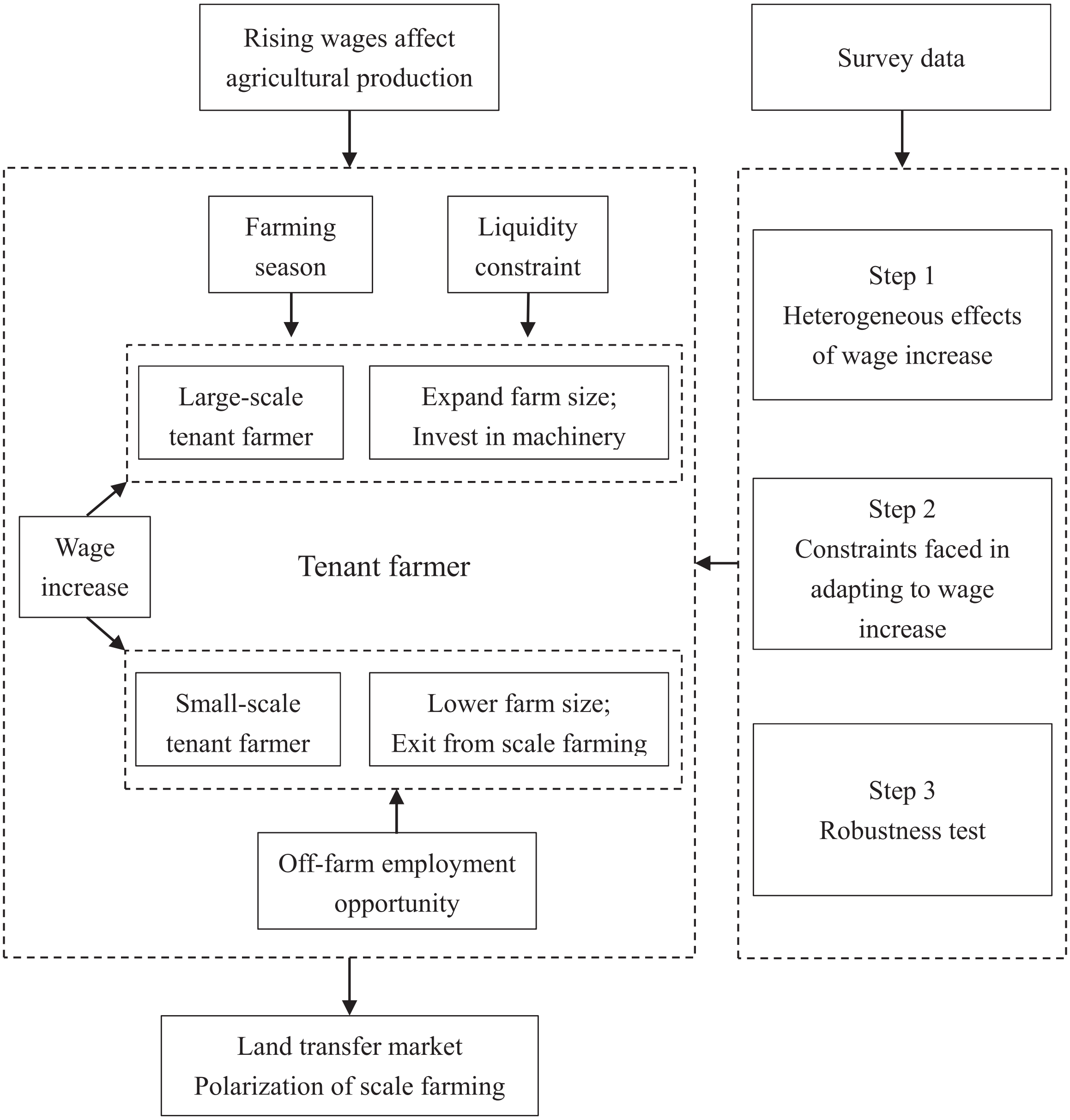

Fig. 1. Conceptual framework.

adaptive behavior (Foster & Rosenzweig, 2011; Wang et al., 2020; Yamauchi, 2016). It is uneconomic for small-scale tenant farmers to introduce large machinery, which is indivisible to some extent and cannot be used efficiently on small-scale farms (Chen & Lan, 2020). Large-scale tenant farmers reply on the substitution between labor and machine to conduct the production operations at a lower cost (Foster & Rosenzweig, 2022). Compared to the small-scale counterpart, large-scale tenant farmers benefit from scale economies due to machine use increases in the scenario of increased cost of labor. If optimal farm size could be achieve through market mechanism (for example, land rental activity), only efficient large-scale tenant farmers survive and expand farm size simultaneously (Otsuka et al., 2016). In addition, making an investment in capital equipment will incur a large amount of sunk costs that small farms are unwilling and unable to afford (Yi et al., 2019). Put it simply, hypothesis 1 is large-scale tenant farmers are more likely to make the machine investment. Conversely, the rational small-scale tenant farmers are forced to reduce their farm size as well as investment in machinery.

However, the production of tenant farmers is under various constraints making them adapt the different strategies responding to wage increases (Binswanger & Singh, 2018). First, the impact of rising wages on farm size and machinery investment may be constrained by farming season. Agricultural production is highly influenced by farming season (Paudel et al., 2019). For example, delay in farming season will lead to the yield reduction as well as affect product quality (Xu et al., 2013; Yao et al., 2011). Production operations must be done in shorter time span in regions with tight farming seasons. Here, we hypothesize that tenant farmers respond to wage increases by expanding farm size, they allocate more labor into agricultural production each day in areas with tight farming seasons than in areas with loose farming seasons. This induces additional supervision costs of hired labor and may offset the benefit from scale economies. If so, tenant farmers are less likely to expand the farm size responding to wage increases. In addition, the farming season constraint on large-scale tenant farmers is more significant than that for the counterpart. It is well documented that the supervision cost of large-scale tenant farmers rises higher than that of small-scale tenant farmers after scale expansion due to the higher cost of labor input. The farming season constrains machinery investment in the following two aspects. On the one hand, farm size and machinery investment usually change synchronously. The constraint of farming season on farm size will indirectly reflect in machinery investment. So tight farming season may also discourage tenant farmers from responding to wage increases by investing in machinery. On the other hand, in areas with loose farming seasons, tenant farmers can cope with labor shortage in the busy farming season by adjusting the operation of agricultural production. That is, the necessity to respond to wage increases through machinery investment diminish. We denote the seasonal effect which can be summarized by the following hypothesis 2: The more flexible the farming season is, the fewer constraints farmers face in handling rising wages by expanding scale especially for large-scale tenant farmers. However, the effect on machinery investment remains uncertain.

Second, the impact of rising wages may be also constrained by liquidity. As the decisions to increase farm size and invest in agricultural machinery are interdependent (Li et al., 2013; Wang et al., 2015; Wang et al., 2020), tenant farmers face short-term, rapidly increasing capital needs to respond to wage increases through scale expansion. From the aspect of land endowment, tenant farmers have to pay more land rent. Large-scale tenant farmers face greater liquidity constraint because they already pay more rent than small-scale tenant farmers. From the substitute of labor and machine, when farm size increases, decline in marginal costs of long-term investments in agricultural machinery will motivate farmers to spend a large amount of money purchasing machinery (Yi et al., 2019). Similarly, large-scale tenant farmers need additional funding to invest more powerful machinery. We denote the liquidity constrains which can be summarized by the following hypothesis 3: Liquidity constrains tenant farmers especially large-scale tenant farmers from responding to wage increases by paying rent to expand scale and investing in machinery. Farmers with lower liquidity constraints are more likely to respond to wage increases by increasing farm size and machinery investment.

Third, the impact of rising wages varies by the availability of off-farm employment opportunities. Theoretically, tenant farmers may also lower their farm size and switch to nonagricultural industries responding to rising wage. However, if they do not have access to off-farm employment, they are forced to continue engaging in scale farming and bear high labor cost (Xie & Lu, 2017). The increase in availability of off-farm employment opportunities will increase the probability that the tenant farmers respond to wage increases by downsizing farm size and executing nonagricultural transition. However, the effect is different for tenant farmers subject to the initial farm sizes. For large-scale tenant farmers, the specialization of agricultural production as well as the investment in agricultural fixed assets is higher, leading to the high cost of switching to nonagricultural industries. Therefore, even if there are off-farm employment opportunities, they may not easily give up agricultural production and switch to nonagricultural sectors. However, for small-scale tenant farmers, the specialization of agricultural production and the opportunity cost of switching to nonagricultural industries is lower, so the availability of off-farm employment opportunities has a greater impact on their behavior choices in response to the increased wage. Therefore, we put forward hypothesis 4: Small-scale tenant farmers with higher availability of off-farm employment opportunities are more likely to respond to wage increases by decreasing farm size and machinery investment.

In conclusion, the effect of wage increase on scale adjustment and machinery investment of tenant farmers with different farm sizes and the constraints they face when adopting adaptive behaviors are shown in Fig. 1.

3. Data source and descriptive statistics

In this study, we use the stratified random sampling method to collect the panel data of tenant farm in 2013 and 2018. First, we identify 13 major grain-producing provinces in China as the population to meet our objective of exploring the dynamics of land scale farming in China.[1] The report published by MOA showed that more than two thirds of the scale farmers conduct the grain production and three quarters of them are located in the major grain-producing provinces (MOA, 2014). The stylized fact is characterized as the mechanization and scale farming of grain production in the major grain-producing provinces, where land/labor ratio is high. Second, the 13 major grain production provinces are categorized into four comprehensive grain production regions and in each of the regions, we randomly selected one province as the sampled provinces by using stratified sampling method.[2] Note that, Jiangsu and Anhui are located in Huang-Huai-Hai region and Middle and lower Yangtze River region. To consider the representative of the grain production in the two comprehensive grain production regions, we randomly choose Jiangsu as the sampled province. Finally, our sampled provinces are Jilin from Northeast region, Jiangsu from Huang-Huai-Hai region and Middle and lower Yangtze River region, and Sichuan from Southwest region. Third, we randomly selected sample counties within the sample provinces and correspondingly, sample towns within the sample counties. All administrative villages in the sample towns were surveyed. In a village, we use the household roster with the help of the village leader to identify the production structure of each household and randomly selected farmers who grow corn or rice from the roster. Locations of surveyed counties in the three sampled provinces are shown in Fig. 2.

[1] Major grain-producing provinces include Heilongjiang, Jilin, Liaoning, Inner Mongolia, Hebei, Henan, Shandong, Jiangsu, Anhui, Hubei, Hunan, Jiangxi, and Sichuan.

[2] Comprehensive grain production regions include Northeast region, Huang-Huai-Hai region, Middle and lower Yangtze River region, and Southwest region. The comprehensive grain production regions generally reveal the most basic regional differences of grain production. Thanks very much for the reviewer's query on the sample reasonability.

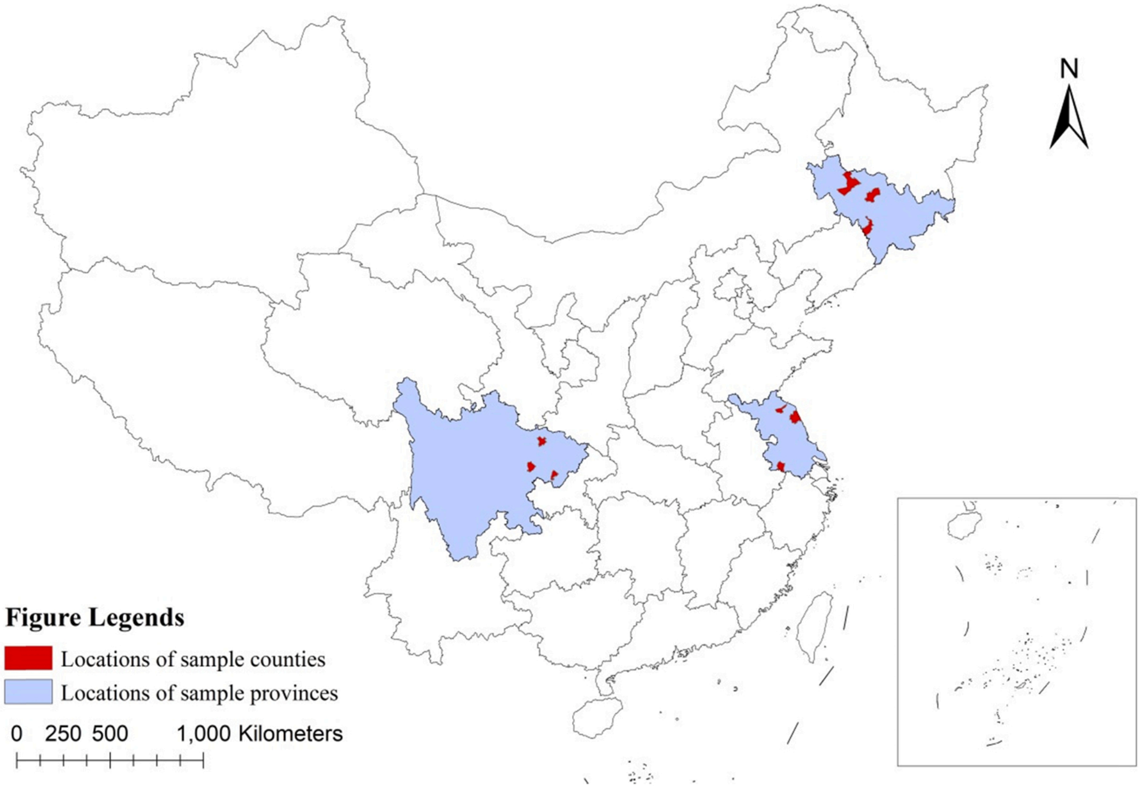

Fig. 2. Locations of surveyed counties in the three sampled provinces.

Table 1
Definition and descriptive statistics of variables.

			2013		2018	
Variable	Mean	SD	Mean	SD	Mean	SD
Land and non-land farm assets						
Cultivated land (mu)	148	261.0	97	137.8	200	334.7
Rent-in land (mu)	134	262.3	82	139.2	187	336.0
Total value of machinery (10 thousand yuan)	19.8	71.7	5.5	13.0	34.2	98.6
Total power of machinery (horsepower)	114	275.1	46.3	90.8	182	366.0
Wages and constraints						
Agricultural wage (yuan)	160	45.2	141	31.3	180	48.2
Nonagricultural wage (yuan)	305	59.8	276	37.8	335	63.2
Farming season (day)	20.1	7.8	20.1	7.8	20.1	7.8
Car (1 = have; 0 = none)	0.36	0.48	0.24	0.43	0.48	0.50
Urban housing (1 = have; 0 = none)	0.17	0.37	0.12	0.33	0.21	0.41
Proportion of off-farm household labor (%)	32.8	30.1	32.5	30.3	33.1	29.9
Proportion of off-farm income (%)	35	36	37.1	37.5	32.9	34.5
Characteristics of villages						
Land area per household (mu)	8.4	8.2	8.3	8.0	8.5	8.4
Land rent (yuan/mu)	478	303.7	461	297.9	494	308.8
Price of mechanization service (yuan/mu)	90.8	32.2	96.7	35.4	84.9	27.4
Subsidy policy (1 = yes; 0 = no)	0.39	0.49	0.31	0.46	0.48	0.50
Land transfer rate (%)	32.6	25.2	23.7	18.7	41.5	27.5
Commodity price (yuan/kg)	2.5	0.44	2.6	0.32	2.3	0.48
Characteristics of households						
Number of household labor (person)	3	1.1	3	1.1	3.1	1.1
Gender of person in charge of scale farming (1 = male; 0 = female)	0.92	0.27	0.92	0.27	0.92	0.27
Age of person in charge of scale farming (year)	49.3	9.8	46.8	9.5	51.8	9.5
Education of person in charge of scale farming (year)	7.4	3.2	7.4	3.2	7.4	3.2
N	916		458		458	

Table 2
Changes in farm size and machinery investment in different constraint groups.

	Farming season in 2013		Liquidity constraint in 2013		Off-farm employment opportunity in 2013	
	Tight	Loose	Strong	Weak	< 50%	≥ 50%
Change in cultivated land (mu)	79	128	76	198	124	80
Change in rent-in land (mu)	79	128	76	198	124	80
Change in machinery value (10 thousand yuan)	17	39	16	70	39	15
Change in machinery power (horsepower)	88	178	88	289	170	92
N	212	246	349	109	258	200

We conducted the first round questionnaire survey in 2014. In 2019, we conducted the follow-up survey to all of the sampled villages and households to form a two-period balanced panel data. It should be pointed out that although our research focus on tenant farmers, smallholders are also included in the sampling population. We selected farmers engaged in scale farming in the year of 2013 and/or 2018 as our sample. That is, our sample includes all possible changes in the scale farming status of farmers, engaging in scale farming in both 2013 and 2018, engaging in scale farming either in 2013 or in 2018, to avoid sample selection bias. The final sample size was 458 and the number of observation was 916.

The surveys designed the block of questions on production, land transfer behavior, machine investment, farming season, financial constraint, off-farm employment opportunity. Table 1 presents the definition of the variables and the descriptive statistics. The average cultivated land which is defined as the sum of own land and rent-in land doubled from 97 mu (6.47 ha) in 2013–200 mu (13.3 ha) in 2018 and it is mainly driven by the expansion of rent-in land. This indicates that enlarging farm sizes can be achieved through the functioning of land rental markets (Chari et al., 2021; Gao et al., 2012). Our data show that the average agricultural wage increased from 141 yuan/day (20.1 US$/day) in 2013–180 yuan/day (25.7 US$/day) in 2018, with an average annual growth rate of 5%. Furthermore, changes in machinery investment are consistent with those in farm size. The total value and power of machinery owned by farmers is witnessed a significant increase from 2013 to 2018 responding to wages increase. Here, households allocated 32.5% of their labor force to off-farm employment, with the remainder allocated to agriculture in 2013. The share of off-farm labor to total labor had risen over the five years, suggesting that household labor was reallocated from agriculture to the off-farm sector (Wang et al., 2016b). The value of household asset also increased significantly from 2013 to 2018 with the evidence that the share of households owning a car doubled from 24% to 48%. The farming season measures the climatic conditions of a region and does not change in the short-term. The right planting time in the regions is about 20 days while it is more flexible in Sichuan than that in Jiangsu and Jilin.

The average land area per household was about 8.4 mu (0.56 ha) and it, remains stable over five years. That is reasonable because of the secured land right and land reallocation is restricted (Chari et al., 2021). Land rent increased slightly, from 461 yuan/mu in 2013–494 yuan/mu in 2018. The unit price of mechanization services price that used to measure the supply of machinery services, showed a downward trend. This may due to the increased supply of agricultural mechanization services in China (Qiu & Luo, 2021). The national statistics shows the number of service providers for agricultural machinery operation increased more than 20 thousand to 187.3 thousand in 2016 from 165.6 thousand in 2008, and the labor engaged in agricultural mechanization services soared almost threefold, from 0.73 million to 2.08 million (China Agricultural Machinery Industry Yearbook, 2017). In 2013, scale farming or machinery outsourcing services were subsidized in a third of the sample village. The subsidy program expanded to 48% of the villages in 2018, indicating the expanding scope of government subsidies for scale farming and agricultural machinery purchases. Simultaneously, land transfer rate increased from 23.7% in 2013 to 41.5% in 2018, which is closely related to the rapid development of urbanization and the migration. From the perspective of household characteristics, the average number of labor is three persons. Male labor are in charge of the agricultural operations in most households, with the proportion as high as 92%. On average, they are around 47-years-old and only finished primary schooling.

Table 2 shows the relationship between changes in the outcome variables and constraint variables. We divided the farming season into two groups according to the median of the right farming days. The more flexible the farming season, the more pronounced the growth trend of scale expansion and machinery investment would be. When considering the liquidity constraint, we divided farmers into two groups based on whether they owned a car in 2013. Owning a car implies that the liquidity constraint is weak, whereas a non-owner's liquidity constraint is strong. The results show that the growth rate of the machinery investment of farmers with weak liquidity constraints is higher than that of farmers with strong liquidity constraints. The smaller the probability of obtaining off-farm employment, the more likely the scale expansion and machinery investment would be. The descriptive statistics are consistent with our hypothesis.

4. Empirical strategy

This section presents the estimation strategy, and discusses identification issues. The analysis uses a two-period household-level balanced panel data of tenant farmers to examine the impact of wage increases on the farm size and machinery investment under the different farming season, liquidity, and off-farm employment opportunity constraints. In all the econometric estimations, first-differenced estimators are applied to wipe out unobserved fixed error components. The steps of empirical analysis are shown in Fig. 1.[3]

[3] We thank one of the referee for pointing it out.

In the analysis of farm size changes and machinery investments, the following first-differenced equation is specified:

$$\Delta y_{ij(0,1)} = \alpha_1 \Delta W_{j(0,1)} + \beta \Delta Z_{j(0,1)} + \delta \Delta X_{ij(0,1)} + \Delta \mu_{ij(0,1)} \tag{1}$$

where $\Delta y_{ij(0,1)}$ is change in cultivated land or rent-in land, or change in total value of machinery or total power of machinery for household i in village j, during the period 2013–2018 while the subscripts 0 and 1 represent the year of 2013 and 2018, respectively. When the mechanization level is already high, an increase in labor costs will likely increase the use of machines with higher power rather than the use of more machines. The average value of machine stock cannot adequately measure the effects of quality of machinery (Otsuka et al., 2013). Here, the total power of machinery is use as the proxy variable for machine investment as a supplement to the value of machinery, which was generally used in the existing literature (Wang et al., 2016b). $\Delta W_{j(0,1)}$ is change in village-level agricultural wage from 2013 to 2018. $\Delta Z_{j(0,1)}$ is change in a vector of village characteristics, including the farming season constraint,[4] the liquidity constraint, land area per household, land rent, price of mechanization service, subsidy policy, land transfer rate at the village, and commodity price.[5] Loose farming seasons help tenant farmers reduce labor supervision costs, and thus has a positive effect on farm size. Both scale expansion and machinery investment demand more capital input, so liquidity constraint affects farm size and machinery investment. Land area per household measures the abundance of land. The more abundant the land resources are, the more conducive to the expansion of scale and the adoption of machinery. As factor prices rise, the demand for factors will decline, as will the demand for complementary factors. Since machinery and land are complementary (Otsuka et al., 2013), the increase in land rent may not only reduce farms scale, but also lead to reduced investment in machinery. The impact of price of mechanization service is similar to the impact of land rent. Subsidy policy should have positive effects on scale expansion and machinery investment. Land transfer rate measures the development degree of land transfer market. The more active the land transfer market is, the lower the transaction cost will be for tenant farmers, which is conducive to farm scale expansion. In addition, with the increase in land transfer rate, tenant farmers are more likely to acquire contiguous land to reduce the impact of land fragmentation on production. Contiguous land is conducive to mechanical operations (Wang et al., 2020). The increase in land transfer rate may have a positive impact on machinery investment. Theoretically, farmers will adjust scale of production according to commodity price. If the price of products increases, small-scale tenant farmers can still increase their farm size. The commodity price variable is used in the regression. $\Delta X_{ij(0,1)}$ is change in a vector of household characteristics, including number of household labor, gender, age, and education of the person in charge of scale farming.[6] Generally speaking, households with a large number of labor have advantages in large-scale farm management, and we include number of household labor in the regression. $\Delta \mu_{ij(0,1)}$is the difference in shocks.

To further examine the role of farming season, liquidity and off-farm employment opportunity constraints on the impact of wage increases on scale farming, change in agricultural wage is interacted with the initial farming season, liquidity and off-farm employment opportunity.

$$\begin{aligned}\Delta y_{ij(0,1)} = {} & \alpha_1 \Delta W_{j(0,1)} + \alpha_{21} \Delta W_{j(0,1)} S_{j0} + \alpha_{22} \Delta W_{j(0,1)} L_{ij0} + \alpha_{23} \Delta W_{j(0,1)} O_{ij0} \\ & + \beta \Delta Z_{j(0,1)} + \delta \Delta X_{ij(0,1)} + \Delta \mu_{ij(0,1)}\end{aligned} \tag{2}$$

where S_{j0} is the farming season constraint in 2013. To measure the farming season, the survey recorded how much each of the farmers thought the interval from the latest sowing time of crops in the current season (to ensure an adequate growth period) to the earliest harvest time of crop in the previous season. In this study, we use the average of farmer's response on farming season in a village. The larger the magnitude, the longer the suitable planting time and the less the farming season constraint are. L_{ij0} is a dummy variable that represents the liquidity constraint in 2013, which is proxied by whether a family owns cars. We preferred cars over income because income is endogenous and fluctuating. Moreover, the liquidity constraint mainly depends on the level of savings and wealth. Additionally, rural credit markets are highly imperfect, and the ability of a household to borrow depends on its asset endowment, which can be used as collateral or serve as a collateral substitute (Binswanger & Singh, 2018). Therefore, it is appropriate to measure liquidity constraints in terms of cars. O_{ij0} is the availability of off-farm employment opportunities in 2013, measured by the proportion of household labor participating in off-farm employment to total household labor.

Note that α_1 shows the effect of the agricultural wage on the dependent variable, and α_{21}, α_{22}, and α_{23}capture how the initial farming season, liquidity constraints for capital, and availability of off-farm employment opportunity mediate the impact of agricultural wage on the outcome variables. To test the heterogeneity of tenant farmers with different farm sizes in handling wage increases, we conduct subsample regression subject to the cultivated land based on Eqs. (1) and (2).

[4] Farming season is a natural feature does not change in a short term and its coefficient is omitted in the regression results, so this variable is not shown in the empirical results tables.

[5] Following the referee's comment, we include the commodity price in all of the estimation specifications.

[6] Gender, age, and education of the person in charge of scale farming do not change due to the follow-up survey and their coefficients are omitted in the regression results, so these three variables are not shown in the empirical results tables.

Table 3
Impact of wage increases on changes in farm size and machinery investment.

	Change in cultivated land	Change in rent-in land	Change in machinery value	Change in machinery horsepower
Change in agricultural wage	0.198	0.192	0.0358	0.174
	(0.441)	(0.429)	(0.260)	(0.324)
Change in liquidity constraint	86.71 * *	86.76 * *	1.446	25.72
	(2.374)	(2.375)	(0.209)	(0.911)
Change in land area per household	-1.760	-1.786	-0.430	-1.172
	(−0.857)	(−0.868)	(−0.734)	(−0.453)
Change in land rent	-0.138	-0.137	0.00629	-0.0145
	(−0.719)	(−0.715)	(0.0762)	(−0.0490)
Change in price of mechanization service	-0.613	-0.616	0.115	0.0933
	(−1.363)	(−1.370)	(0.762)	(0.170)
Change in subsidy policy	76.20	75.84	26.11	95.61
	(1.641)	(1.634)	(1.389)	(1.459)
Change in land transfer rate	2.020 * **	2.019 * **	0.411 * **	1.513 * *
	(3.350)	(3.346)	(2.854)	(2.498)
Change in commodity price	105.8	106.0	2.582	-24.75
	(1.218)	(1.220)	(0.236)	(−0.494)
Change in household labor	30.29	30.59	8.369	30.26
	(1.307)	(1.320)	(0.674)	(0.708)
Constant	55.32	55.74	16.68 *	71.93 *
	(1.362)	(1.373)	(1.818)	(1.912)
N	458	458	458	458
R-squared	0.066	0.067	0.025	0.023

Note. * ** , * *, and * , significant at 1%, 5%, and 10%, respectively

Table 4
Impact of wage increases on changes in farm size and machinery investment of tenant farmers with different initial farm size.

	Large-scale tenant farmers (> 48 mu)				Small-scale tenant farmers (< 48 mu)			
	Change in cultivated land	Change in rent-in land	Change in machinery value	Change in machinery horsepower	Change in cultivated land	Change in rent-in land	Change in machinery value	Change in machinery horsepower
Change in agricultural wage	2.688 * **	2.676 * **	0.327	1.851 *	-1.079 * **	-1.078 * **	-0.0625	-0.583 *
	(2.827)	(2.815)	(1.193)	(1.685)	(−3.122)	(−3.122)	(−1.052)	(−1.776)
Change in liquidity constraint	110.2 *	110.0 *	-7.921	-23.85	38.41	38.71	7.135	58.20 * *
	(1.714)	(1.711)	(−0.588)	(−0.457)	(1.521)	(1.532)	(1.175)	(2.095)
Change in land area per household	0.273	0.255	0.458	2.508	-1.113	-1.147	0.171	-0.426
	(0.0864)	(0.0806)	(0.403)	(0.559)	(−0.475)	(−0.489)	(0.359)	(−0.162)
Change in land rent	-0.139	-0.137	0.0319	0.0364	-0.266 * *	-0.266 * *	-0.0387 * *	-0.118
	(−0.372)	(−0.368)	(0.211)	(0.0673)	(−2.562)	(−2.559)	(−2.173)	(−1.120)
Change in price of mechanization service	-4.074 * *	-4.077 * *	-0.344	-2.229	0.0206	0.0193	0.0442	-0.00215
	(−2.481)	(−2.483)	(−0.704)	(−1.197)	(0.0840)	(0.0786)	(1.043)	(−0.0103)
Change in subsidy policy	105.9	105.4	34.71	133.3	-24.41	-24.56	-1.539	-15.80
	(1.272)	(1.266)	(1.183)	(1.278)	(−0.941)	(−0.946)	(−0.367)	(−0.780)
Change in land transfer rate	2.505 *	2.494 *	0.557 *	1.922	1.695 * **	1.698 * **	0.223 * **	0.843 * *
	(1.889)	(1.880)	(1.961)	(1.590)	(3.829)	(3.832)	(2.862)	(2.593)
Change in commodity price	401.5 *	401.2 *	63.09 *	208.6	76.11 *	77.02 *	8.353	23.94
	(1.827)	(1.825)	(1.936)	(1.601)	(1.744)	(1.757)	(1.134)	(0.509)
Change in household labor	76.44	77.33	26.41	87.97	15.23	15.21	-0.675	2.874
	(1.252)	(1.267)	(0.778)	(0.760)	(1.337)	(1.338)	(−0.210)	(0.197)
Constant	63.19	63.90	38.47 *	137.6 *	101.6 * **	101.8 * **	12.07 * **	74.94 * **
	(0.747)	(0.755)	(1.953)	(1.808)	(3.440)	(3.449)	(2.763)	(2.935)
N	220	220	220	220	238	238	238	238
R-squared	0.101	0.101	0.043	0.040	0.249	0.249	0.115	0.126

Note. * ** , * *, and * , significant at 1%, 5%, and 10%, respectively

Table 5
Effect of constraints on the impact of wage increases on tenant farmers.

	Change in cultivated land	Change in rent-in land	Change in machinery value	Change in machinery horsepower
Change in agricultural wage	-2.209 * **	-2.216 * **	-0.663 * *	-2.612 * *
	(−2.674)	(−2.684)	(−1.991)	(−2.266)
Change in agricultural wage × farming season constraint (2013)	0.113 * **	0.113 * **	0.0302 * *	0.125 * *
	(2.950)	(2.954)	(1.998)	(2.456)
Change in agricultural wage × liquidity constraint (2013)	2.480 * **	2.477 * **	1.086 * **	3.938 * **
	(3.102)	(3.099)	(3.756)	(3.744)
Change in agricultural wage × off-farm employment opportunity (2013)	-0.0144 *	-0.0144 *	-0.00541 * *	-0.0212 * **
	(−1.743)	(−1.738)	(−2.500)	(−2.663)
Change in liquidity constraint	127.4 * **	127.4 * **	18.15 * **	87.49 * **
	(3.512)	(3.512)	(3.159)	(3.591)
Change in land area per household	-0.841	-0.867	-0.131	-0.0195
	(−0.422)	(−0.434)	(−0.239)	(−0.00818)
Change in land rent	-0.0564	-0.0557	0.0374	0.101
	(−0.288)	(−0.285)	(0.432)	(0.328)
Change in price of mechanization service	-0.712	-0.715	0.0796	-0.0413
	(−1.536)	(−1.542)	(0.526)	(−0.0742)
Change in subsidy policy	68.68	68.32	23.17	84.62
	(1.559)	(1.551)	(1.320)	(1.380)
Change in land transfer rate	1.682 * **	1.680 * **	0.271 * *	0.998 * *
	(2.969)	(2.966)	(2.232)	(2.018)
Change in commodity price	133.4	133.6	11.26	9.605
	(1.497)	(1.499)	(0.892)	(0.180)
Change in household labor	39.15 *	39.45 *	11.80	43.04
	(1.687)	(1.700)	(0.928)	(0.994)
Constant	58.57	59.00	17.40 * *	75.03 * *
	(1.477)	(1.488)	(2.003)	(2.120)
N	458	458	458	458
R-squared	0.120	0.120	0.095	0.098

Note. * ** , * *, and * , significant at 1%, 5%, and 10%, respectively

5. Empirical results

5.1. Polarization of scale farming

This section presents the regression results of the effect of wage increase on the scale adjustment and machinery investment of tenant farmers with different farm size. We started the analysis by using the whole sample and the results are presented in Table 3. The results show that wage growth has no significant effect on farm scale adjustment and machinery investment. This motivates us to further analyze whether the impact of rising wages may have heterogeneity among different farmers. The significant variables include the changes in liquidity constraint and land transfer rate. The weaker the liquidity constraint, the more likely farmers expand their scale. The higher the proportion of the land transfer rate and the more developed the village land transfer market is, the easier it would be for tenant farmers to rent land. Additionally, as the land transfer rate increases, the degree of land fragmentation decreases, which benefits mechanization.

To test the heterogeneity of farmers with different farm sizes, we further divide sample farmers into two groups according to the median of cultivated land. The first four columns in Table 4 presents the regression results of large-scale tenant farmers as well as the last four columns presents those of small-scale tenant farmers.

Regression results in Table 4 indicate that, for large-scale tenant farmers, the impact of wage increases on expansion of farm size is significantly positive at the 1% test level and the impact of wage increases on machinery horsepower is significantly positive at the 10% test level. This suggests that larger farmers are more likely to continue expanding their farm size and increase larger machinery investment when wages increase. This result is consistent with previous research of other Asian countries (Foster & Rosenzweig, 2011; Liu et al., 2020; Otsuka et al., 2013; Yamauchi, 2016). Changes in liquidity constraint and land transfer rates remain significant and robust. Change in price of mechanization service has a significant negative impact on the farm size. The effects of commodity price on cultivated land, rent-in land, and machinery value are significantly positive at the 10% test level.

Regarding small-scale tenant farmers, some of our results differ from those of large-scale tenant farmers. The impact of change in wages on cultivated land and rent-in land is significantly negative at the 1% test level, suggesting that, when wages rise, small-scale tenant farmers may reduce the farm operation by reducing the farm size. These empirical results are consistent with hypothesis 1. Consequently, when we perform full sample regression analyses, we find that the coefficient of change in wages is insignificant. This is due to that small farms' advantage of efficiently using family labor declines as labor becomes more costly. Simultaneously large farms' advantage from scale economies due to machine use increases. Hence, the optimum farm size tends to increase. If farm size adjustments take place smoothly through market transactions, only efficient large farms survive (Otsuka et al., 2016). Empirical evidence from the United States also indicates that the smallest crop farms fell further behind large farms in terms of productivity. The difference in marginal cost between the smallest farms and larger farms increased in recent decades because the larger farm use the widespread

Table 6
Effect of constraints on the impact of wage increases on tenant farmers with different initial farm size.

	Large-scale tenant farmers (> 48 mu)				Small-scale tenant farmers (< 48 mu)			
	Change in cultivated land	Change in rent-in land	Change in machinery value	Change in machinery horsepower	Change in cultivated land	Change in rent-in land	Change in machinery value	Change in machinery horsepower
Change in agricultural wage	-2.172	-2.189	-1.181	-4.151	-1.088 * *	-1.088 * *	-0.0420	-0.341
	(−1.352)	(−1.363)	(−1.520)	(−1.602)	(−2.349)	(−2.349)	(−0.424)	(−0.619)
Change in agricultural wage × farming season constraint (2013)	0.168 * **	0.168 * **	0.0513	0.215 *	0.0183	0.0183	0.00217	0.00392
	(2.625)	(2.632)	(1.454)	(1.909)	(0.955)	(0.955)	(0.476)	(0.187)
Change in agricultural wage × liquidity constraint (2013)	3.308 * **	3.302 * **	1.430 * **	4.723 * **	0.623	0.620	0.314 * *	1.402 * *
	(2.722)	(2.718)	(3.426)	(2.974)	(1.313)	(1.307)	(2.586)	(2.442)
Change in agricultural wage × off-farm employment opportunity (2013)	-0.00618	-0.00618	-0.00613	-0.0211	-0.0108 * *	-0.0108 * *	-0.00288 * **	-0.0142 * **
	(−0.316)	(−0.316)	(−0.943)	(−0.906)	(−2.520)	(−2.512)	(−3.320)	(−3.145)
Change in liquidity constraint	180.3 * **	180.0 * **	21.20 * *	75.82 *	51.61 * *	51.87 * *	11.94 *	80.26 * **
	(2.916)	(2.911)	(2.063)	(1.798)	(2.010)	(2.019)	(1.946)	(2.805)
Change in land area per household	0.896	0.880	0.564	3.142	-1.512	-1.546	0.142	-0.562
	(0.303)	(0.298)	(0.483)	(0.711)	(−0.630)	(−0.644)	(0.306)	(−0.217)
Change in land rent	0.0174	0.0188	0.0941	0.260	-0.272 * *	-0.272 * *	-0.0387 * *	-0.120
	(0.0469)	(0.0508)	(0.567)	(0.445)	(−2.453)	(−2.450)	(−2.032)	(−1.073)
Change in price of mechanization service	-4.436 * **	-4.438 * **	-0.491	-2.750	0.151	0.149	0.0881 *	0.190
	(−2.648)	(−2.650)	(−0.956)	(−1.419)	(0.584)	(0.577)	(1.864)	(0.895)
Change in subsidy policy	96.80	96.33	29.97	117.7	-21.51	-21.66	-0.736	-12.03
	(1.190)	(1.185)	(1.106)	(1.207)	(−0.834)	(−0.839)	(−0.183)	(−0.614)
Change in land transfer rate	2.976 * *	2.965 * *	0.720 * *	2.554 * *	1.528 * **	1.532 * **	0.158 * *	0.561 *
	(2.225)	(2.217)	(2.393)	(2.087)	(3.437)	(3.440)	(2.216)	(1.671)
Change in commodity price	368.8 *	368.5 *	49.54	159.8	78.32 *	79.24 *	8.010	21.45
	(1.689)	(1.688)	(1.613)	(1.277)	(1.793)	(1.806)	(1.093)	(0.457)
Change in household labor	98.84 *	99.74 *	35.06	120.2	14.56	14.54	-0.482	3.590
	(1.659)	(1.675)	(0.965)	(0.982)	(1.219)	(1.220)	(−0.146)	(0.240)
Constant	22.06	22.80	21.31	77.02	103.4 * **	103.6 * **	12.59 * **	76.93 * **
	(0.272)	(0.281)	(1.093)	(1.029)	(3.540)	(3.549)	(2.934)	(3.049)
N	220	220	220	220	238	238	238	238
R-squared	0.156	0.156	0.116	0.112	0.266	0.267	0.171	0.178

Note. * ** , * *, and * , significant at 1%, 5%, and 10%, respectively

technological advances (such as large combine harvesters) and the technology adoption rates is lower for the smallest farms (Key, 2019). The effects of land rent on cultivated land, rent-in land, and machinery value are significantly negative at the 5% test level. The effects of changes in land transfer rate and commodity price remain significant positive and robust.

5.2. *Constraints of scale farming*

This section shows the constraints faced by tenant farmers with different farm sizes in response to rising wages. The regression results in Table 5 focus on the whole samples. The interaction terms are intended to capture the degree to which these constraints differentiate the wage growth effects. The results show that the interaction terms of the farming season and liquidity constraints are significantly positive at the 5% and 1% level, respectively. This indicates that the decrease of farming season and liquidity constraints weakens the negative impact of wage increases on farm size and machinery investment. The interaction term between off-farm employment and change in wage is significantly negative regardless of whether the outcome variable is farm size or machinery investment. This suggests that increased availability of off-farm employment intensifies the negative impact of wage increases on farm size and machinery investment. This remains consistent with Yamauchi's (2016) conclusions. Additionally, changes in liquidity constraint and land transfer rate remain significant positive at the 1% and 5% test level, respectively. Moreover, households with more labor are more likely to expand their farm size.

Subsequently, we examine the constraints faced by tenant farmers with different sizes. The first four columns in Table 6 show the regression results of large-scale tenant farmers. When we add the interaction terms into the model, the independent term of change in wages becomes insignificant. The interaction term of change in wage and farming season as well as the interaction term of change in wage and liquidity is significantly positive. This indicates that the scale expansion and machinery investment of large-scale tenant farmers is strongly constrained by the farming season and liquidity. These empirical results support hypothesis 2 and hypothesis 3. The

Table 7
Impact of wage increases on changes in farm size and machinery investment of tenant farmers with different initial farm size.

	Large-scale tenant farmers (> 48 mu)				Small-scale tenant farmers (< 48 mu)			
	Change in cultivated land	Change in rent-in land	Change in machinery value	Change in machinery horsepower	Change in cultivated land	Change in rent-in land	Change in machinery value	Change in machinery horsepower
Change in nonagricultural wage	1.388 * *	1.385 * *	0.525 *	1.779 *	-0.653 * **	-0.654 * **	-0.0739 * *	-0.525 * **
	(2.096)	(2.092)	(1.860)	(1.880)	(−3.634)	(−3.638)	(−2.009)	(−2.721)
Change in liquidity constraint	70.20	70.05	56.79	198.3	5.365	6.165	0.381	15.24
(measured by urban housing)	(0.585)	(0.584)	(0.938)	(0.989)	(0.163)	(0.186)	(0.0625)	(0.416)
Change in land area per household	1.620	1.595	0.356	2.557	-0.918	-0.956	0.198	-0.503
	(0.546)	(0.537)	(0.322)	(0.592)	(−0.356)	(−0.370)	(0.405)	(−0.183)
Change in land rent	-0.0618	-0.0609	0.0245	0.0547	-0.357 * **	-0.357 * **	-0.0490 * **	-0.206 *
	(−0.169)	(−0.166)	(0.163)	(0.102)	(−3.420)	(−3.419)	(−2.647)	(−1.876)
Change in price of mechanization service	-3.479 * *	-3.487 * *	-0.314	-1.837	-0.00545	-0.00636	0.0481	0.0317
	(−2.129)	(−2.134)	(−0.607)	(−0.967)	(−0.0235)	(−0.0274)	(1.198)	(0.149)
Change in subsidy policy	62.31	61.99	31.71	113.7	-21.84	-22.07	-2.643	-20.96
	(0.724)	(0.720)	(1.246)	(1.213)	(−0.977)	(−0.986)	(−0.616)	(−0.991)
Change in land transfer rate	2.509 *	2.500 *	0.795 *	2.481	1.746 * **	1.748 * **	0.224 * **	0.880 * **
	(1.827)	(1.821)	(1.946)	(1.641)	(3.897)	(3.899)	(2.923)	(2.743)
Change in commodity price	460.5 *	460.1 *	69.41 *	224.4	78.74 *	79.66 *	10.03	34.97
	(1.963)	(1.962)	(1.927)	(1.601)	(1.922)	(1.937)	(1.387)	(0.736)
Change in household labor	71.04	71.92	22.24	75.95	17.66	17.63	0.157	7.491
	(1.232)	(1.248)	(0.749)	(0.742)	(1.496)	(1.496)	(0.0550)	(0.564)
Constant	134.6	134.8	9.672	73.50	103.9 * **	104.3 * **	16.17 * **	98.73 * **
	(1.232)	(1.234)	(0.323)	(0.692)	(4.617)	(4.633)	(3.488)	(3.901)
N	220	220	220	220	238	238	238	238
R-squared	0.092	0.092	0.080	0.070	0.250	0.250	0.115	0.113

Note. * ** , * *, and * , significant at 1%, 5%, and 10%, respectively

interaction between change in wage and off-farm employment is insignificant, suggesting that the availability of off-farm employment does not have significant constraint effect on large-scale tenant farmers. We duplicated the regression for the small-scale tenant farmers and reported the results in the last four columns of Table 6. When interaction terms are included, the interaction term of change in wage and off-farm employment opportunity is significant negative, and this is noticeably different from the previous regression results concerning large-scale tenant farmers. This indicates that when small-scale tenant farmers face wage increases and once off-farm employment opportunities become available, small-scale tenant farmers often choose to lower their rent-in land and make room for large-scale tenant farmers to expend farm size. These empirical results confirm hypothesis 4. Under the background of the structural transformation of rural economies and the entire economy, farm size expands smoothly paralleled with the large exodus of rural population migrate to large cities and industrial areas. Otherwise, farm area cannot increase. The massive creation of nonfarm jobs to absorb rural population by offering lucrative wages is necessary to realize significant farm size expansion (Otsuka et al., 2016). The effects of liquidity constraint, land transfer rate and commodity price remain significant positive while the effects of land rent remain significant negative.

5.3. *Robustness test*

To test the robustness of the regression results, we changed the measure of the key explanatory variables.[7] Specifically, wage increase is measured by the nonagricultural wage, liquidity constraint is measured by whether the household has urban housing,[8] and off-farm employment opportunity is measured by the proportion of off-farm income. Subsequently, we re-estimate the impact of wage increases on farm size adjustment and machinery investment of tenant farmers with different farm sizes, as well as the constraints they face in responding to wage increases. The regression results are shown in Table 7 and Table 8.

Table 7 and Table 8 show the impact of wage increases on the farm size and machinery investment of large-scale and small-scale tenant farmers without and with constraints, respectively. These regression results demonstrate the robustness of main findings. The regression results in Table 7 indicate that wage increases have diametrically opposite effects on tenant farmers with different farm sizes. It promotes large-scale tenant farmers to further expand their farm size and invest in machinery, while make small-scale tenant

[7] We thank for the referee for the comment.

[8] This is justified as on one hand, whether owning an apartment in cities is a key component of the household's wealth; on the other hand, the mortgage of the apartment in cities could also partially be a solution of the financial constraint.

Table 8
Effect of constraints on the impact of wage increases on tenant farmers with different initial farm size.

	Large-scale tenant farmers (> 48 mu)				Small-scale tenant farmers (< 48 mu)			
	Change in cultivated land	Change in rent-in land	Change in machinery value	Change in machinery horsepower	Change in cultivated land	Change in rent-in land	Change in machinery value	Change in machinery horsepower
Change in nonagricultural wage	-1.298 (−1.349)	-1.308 (−1.361)	-0.540 (−1.110)	-2.365 (−1.590)	-0.858 * ** (−3.372)	-0.859 * ** (−3.375)	-0.0558 (−0.927)	-0.417 (−1.233)
Change in nonagricultural wage × farming season constraint (2013)	0.0851 * (1.782)	0.0853 * (1.788)	0.0443 (1.465)	0.156 * (1.672)	0.0156 (1.480)	0.0156 (1.477)	0.000799 (0.377)	0.00541 (0.486)
Change in nonagricultural wage × liquidity constraint (2013) (measured by urban housing)	3.493 * (1.731)	3.508 * (1.739)	0.289 (0.757)	1.485 (0.843)	-0.158 (−0.764)	-0.159 (−0.768)	-0.0213 (−0.704)	-0.0654 (−0.386)
Change in nonagricultural wage × off-farm employment opportunity (2013) (measured by proportion of off-farm income)	0.00746 (0.720)	0.00747 (0.721)	-0.00251 (−0.500)	0.00311 (0.178)	-0.00142 * (−1.784)	-0.00141 * (−1.766)	-0.000506 * ** (−3.093)	-0.00331 * ** (−2.986)
Change in liquidity constraint	79.99	79.92	57.16	188.3	6.538	7.323	0.527	16.77
(measured by urban housing)	(0.673)	(0.673)	(0.937)	(0.927)	(0.194)	(0.217)	(0.0859)	(0.456)
Change in land area per household	1.993 (0.645)	1.968 (0.635)	0.746 (0.602)	4.282 (0.932)	-0.864 (−0.330)	-0.902 (−0.344)	0.216 (0.442)	-0.393 (−0.144)
Change in land rent	-0.0596 (−0.169)	-0.0586 (−0.166)	0.0465 (0.283)	0.101 (0.176)	-0.362 * ** (−3.413)	-0.363 * ** (−3.411)	-0.0513 * ** (−2.702)	-0.220 * (−1.953)
Change in price of mechanization service	-2.917 * (−1.726)	-2.922 * (−1.729)	-0.239 (−0.469)	-1.476 (−0.797)	0.0198 (0.0836)	0.0187 (0.0790)	0.0491 (1.205)	0.0446 (0.210)
Change in subsidy policy	49.88 (0.621)	49.52 (0.616)	28.95 (1.172)	99.78 (1.108)	-23.07 (−1.016)	-23.29 (−1.025)	-2.710 (−0.623)	-21.43 (−0.997)
Change in land transfer rate	2.543 * (1.913)	2.534 * (1.906)	0.818 * * (2.077)	2.643 * (1.850)	1.694 * ** (3.793)	1.696 * ** (3.795)	0.226 * ** (2.923)	0.890 * ** (2.634)
Change in commodity price	385.6 (1.627)	384.9 (1.624)	53.41 (1.644)	149.5 (1.178)	86.53 * * (2.084)	87.43 * * (2.097)	11.29 (1.555)	42.46 (0.898)
Change in household labor	76.17 (1.221)	77.05 (1.237)	27.87 (0.854)	92.26 (0.817)	17.56 (1.476)	17.54 (1.477)	-0.0380 (−0.0131)	6.195 (0.458)
Constant	121.4 (1.104)	121.6 (1.106)	8.319 (0.287)	66.88 (0.643)	107.4 * ** (4.729)	107.8 * ** (4.745)	16.38 * ** (3.489)	100.0 * ** (3.874)
N	220	220	220	220	238	238	238	238
R-squared	0.154	0.155	0.116	0.109	0.255	0.256	0.123	0.126

Note. * ** , * *, and * , significant at 1%, 5%, and 10%, respectively

farmers reduce their farm size and investment in machinery. The regression results in Table 8 show that large-scale tenant farmers are mainly constrained by farming season and liquidity constraint when wage increases. Wage increase has a greater positive impact on the farm size and machinery investment of large-scale tenant farmers when farming season is loose and liquidity constraint is weak. Small-scale tenant farmers are mainly constrained by off-farm employment opportunity when coping with wage increases. Wage increase has a greater negative impact on the farm size and machinery investment of small-scale tenant farmers when off-farm employment opportunity is available.

In addition, we also changed the criteria for grouping large and small scale tenant farmers to test the robustness of the results. The regression results are shown in the Appendix Table A1 and Table A2. We divide tenant farmers into three groups according to tertiles of cultivated land. We focus on comparing the regression results of the minimum and maximum size groups. Although the magnitudes of the coefficients and significance levels differ slightly from the results in Table 4 and Table 6, the results are consistent. Again, for large-scale tenant farmers, the main choice is to handle the wage increases by expanding farm size. However, this is affected by the constraints of farming season and liquidity. It is a popular choice for small-scale tenant farmers to exit from scale farming in response to wage increases. Our conclusion is also supported by a research on the relationship between real wage growth and change in the WTP to rent in land conducted by Wang et al. (2020). Their research shows that an increase in wage induces relatively large farmers to be more willing to rent in to increase their farm size，relatively small farmers tend to be less willing to rent in and decrease their farm size.

Table A1
Impact of wage increases on changes in farm size and machinery investment of tenant farmers with different initial farm size.

	Large-scale tenant farmers (> 95 mu)				Small-scale tenant farmers (< 20 mu)			
	Change in cultivated land	Change in rent-in land	Change in machinery value	Change in machinery horsepower	Change in cultivated land	Change in rent-in land	Change in machinery value	Change in machinery horsepower
Change in agricultural wage	2.635 * *	2.630 * *	0.125	1.363	-1.073 * **	-1.070 * **	-0.115 * *	-0.745 * *
	(1.995)	(1.991)	(0.326)	(0.936)	(−3.342)	(−3.334)	(−2.097)	(−2.058)
Change in liquidity constraint	152.1 *	152.1 *	-9.577	-24.97	42.32 * *	42.57 * *	3.710	24.44
	(1.727)	(1.728)	(−0.506)	(−0.347)	(2.346)	(2.356)	(1.285)	(1.416)
Change in land area per household	1.273	1.230	0.641	2.729	2.133	2.115	0.396	0.951
	(0.195)	(0.188)	(0.282)	(0.303)	(1.336)	(1.323)	(1.412)	(0.483)
Change in land rent	-0.0960	-0.0949	0.0907	0.306	-0.105	-0.107	-0.00312	0.00666
	(−0.175)	(−0.173)	(0.418)	(0.386)	(−1.176)	(−1.191)	(−0.221)	(0.0691)
Change in price of mechanization service	-6.772 * **	-6.760 * **	-0.729	-4.343	-0.100	-0.102	0.0153	0.0201
	(−2.850)	(−2.843)	(−0.955)	(−1.465)	(−0.575)	(−0.586)	(0.596)	(0.114)
Change in subsidy policy	14.01	14.11	11.77	16.59	-16.60	-16.82	-2.831	-19.41
	(0.134)	(0.135)	(0.366)	(0.143)	(−0.913)	(−0.922)	(−0.951)	(−1.049)
Change in land transfer rate	1.330	1.328	0.177	0.429	0.825 * **	0.827 * **	0.0886 *	0.459
	(0.817)	(0.816)	(0.487)	(0.279)	(2.862)	(2.863)	(1.934)	(1.519)
Change in commodity price	766.1 * *	764.7 * *	122.4 * *	454.1 * *	155.6 * *	155.9 * *	20.56 *	86.27
	(2.265)	(2.259)	(2.204)	(2.049)	(2.361)	(2.369)	(1.843)	(1.267)
Change in household labor	120.0	120.0	40.41	136.1	20.27 *	20.18 *	2.535	15.26 *
	(1.295)	(1.295)	(0.776)	(0.772)	(1.740)	(1.737)	(1.565)	(1.726)
Constant	235.6	235.3	88.49 * *	326.5 * *	100.9 * **	101.0 * **	13.52 * **	81.07 * *
	(1.511)	(1.508)	(2.429)	(2.432)	(3.431)	(3.436)	(2.630)	(2.470)
N	148	148	148	148	157	157	157	157
R-squared	0.152	0.151	0.046	0.046	0.331	0.332	0.186	0.142

Note. * ** , * *, and * , significant at 1%, 5%, and 10%, respectively

6. Conclusion

In the past two decades, most countries in Asia are experiencing wage increase, which raise production costs and weaken the commodities competitiveness. An important characteristic of agriculture, especially grain production, is that production is seasonal and agricultural labor demand is also seasonal. That the difficulty in employing labor becomes more prominent creates challenges to scale farming which is more likely to hire labor. Although machinery investment and scale adjustment are important choices when wages increase, not all tenant farmers engaged in scale farming have the advantage of factor substitution and scale expansion. In theory, the adaptive behavior will vary owing to different farm sizes. Scale farming development will show a trend of polarization under the impact of wage increases. More importantly, tenant farmers will face various constraints in the process of factor substitution and scale expansion. It is crucial to clarify how different tenant farmers respond to rising wages and adopt policy measures to alleviate the constraints they face in adopting adaptive behaviors. This is of great significance for small-peasant economy countries in Asia to realize agricultural modernization and enhance their comparative advantages in agriculture under the scenario of wage increases.

Existing studies on other labor-intensive farming countries in Asian focused on discussing how initial farm size affected farmers' responses to changes in real wage. Yamauchi (2016) finds that an increase in real agricultural wages in Indonesia induces the expansion of farm size and the use of machines and the magnitude of the coefficient is larger among relatively large farmers. Foster and Rosenzweig's research on India shows that farmers with small landholdings lease out to farmers with larger landholdings, suggesting land consolidation as a way of expanding farm size through the functioning of land rental markets (Foster & Rosenzweig, 2011). Liu et al. (2020) provide an evolution of rural labor market and how it functions given the structural transformation of rural Vietnam. They find that machinery investment has been steadily increasing over time and increasing fastest among the larger farms. Otsuka et al. (2013) use a country-level panel data obtained from FAO's data source to examine the effects of real wage increase on Asian agriculture. The empirical evidences also support that an increase in real wages has been inducing the substitution of labor by machines in agriculture and this process is more successful in the countries with large farm size. Their conclusions were generally consistent that farm size expansion and introduction of large-scale mechanization is more successful for large-scale farmers given the growth of real wages. However, all of the above studies missed the stylized facts that some of small-scale farmers may reduce their farm size and machinery investment in the context of the Asian counties. Additionally, these studies do not investigate the constraints that farmers face when farm size and machinery in production change simultaneously. Our study contributes to the existing literature in three ways and draws several interesting conclusions.

First, our study goes further to test the responses of heterogeneous tenant farmers responding to the increase of wage. The results show that large-scale tenant farmers expand their farm size and increase investment in agricultural machinery to adapt to wage

Table A2
Effect of constraints on the impact of wage increases on tenant farmers with different initial farm size.

	Large-scale tenant farmers (> 95 mu)				Small-scale tenant farmers (< 20 mu)			
	Change in cultivated land	Change in rent-in land	Change in machinery value	Change in machinery horsepower	Change in cultivated land	Change in rent-in land	Change in machinery value	Change in machinery horsepower
Change in agricultural wage	-1.931	-1.937	-1.381	-4.534	-1.144 * **	-1.140 * **	-0.0817	-0.518
	(−0.976)	(−0.979)	(−1.492)	(−1.477)	(−2.917)	(−2.907)	(−0.843)	(−0.755)
Change in agricultural wage × farming season constraint (2013)	0.148 * *	0.148 * *	0.0483	0.202	0.00607	0.00605	-0.000552	-0.00624
	(2.162)	(2.162)	(1.252)	(1.623)	(0.563)	(0.561)	(−0.212)	(−0.349)
Change in agricultural wage × liquidity constraint (2013)	3.803 * *	3.800 * *	1.725 * **	5.526 * *	0.602	0.598	0.211 * *	1.445 * *
	(2.494)	(2.491)	(2.986)	(2.596)	(1.529)	(1.516)	(2.457)	(2.110)
Change in agricultural wage × off-farm employment opportunity (2013)	-0.0124	-0.0123	-0.00987	-0.0330	-0.00234	-0.00231	-0.00107 *	-0.00632
	(−0.491)	(−0.489)	(−1.100)	(−1.065)	(−0.999)	(−0.984)	(−1.680)	(−1.423)
Change in liquidity constraint	237.8 * **	237.8 * **	27.70 *	98.60	48.98 * *	49.18 * *	5.837 *	37.82 * *
	(2.762)	(2.762)	(1.813)	(1.640)	(2.550)	(2.558)	(1.956)	(2.090)
Change in land area per household	2.741	2.695	1.335	5.239	1.998	1.982	0.349	0.741
	(0.420)	(0.413)	(0.513)	(0.538)	(1.257)	(1.245)	(1.306)	(0.390)
Change in land rent	0.0721	0.0731	0.166	0.564	-0.101	-0.102	-0.00302	0.00874
	(0.135)	(0.137)	(0.705)	(0.673)	(−1.086)	(−1.101)	(−0.207)	(0.0849)
Change in price of mechanization service	-7.263 * **	-7.251 * **	-0.990	-5.156	-0.0389	-0.0411	0.0368	0.161
	(−2.917)	(−2.910)	(−1.204)	(−1.626)	(−0.241)	(−0.255)	(1.386)	(0.903)
Change in subsidy policy	1.568	1.711	3.375	-8.770	-16.44	-16.67	-2.597	-18.22
	(0.0149)	(0.0162)	(0.113)	(−0.0796)	(−0.920)	(−0.928)	(−0.888)	(−1.018)
Change in land transfer rate	1.871	1.869	0.386	1.183	0.725 * *	0.727 * *	0.0587	0.264
	(1.153)	(1.152)	(1.053)	(0.774)	(2.428)	(2.431)	(1.255)	(0.809)
Change in commodity price	727.8 * *	726.4 * *	109.8 *	404.2 *	151.7 * *	152.0 * *	18.75	73.73
	(2.127)	(2.121)	(1.942)	(1.793)	(2.231)	(2.239)	(1.635)	(1.038)
Change in household labor	149.0 *	149.0 *	52.12	177.6	20.80 *	20.72 *	2.612 *	16.19 *
	(1.673)	(1.673)	(0.957)	(0.970)	(1.814)	(1.811)	(1.699)	(1.827)
Constant	182.9	182.6	66.40 *	250.8 *	100.8 * **	100.9 * **	13.40 * *	80.31 * *
	(1.211)	(1.209)	(1.920)	(1.956)	(3.408)	(3.412)	(2.608)	(2.452)
N	148	148	148	148	157	157	157	157
R-squared	0.206	0.205	0.124	0.120	0.338	0.339	0.224	0.187

Note. * ** , * *, and * , significant at 1%, 5%, and 10%, respectively

increases. Small-scale tenant farmers tend to shrink farm size and machinery investment in response to rising wages. Therefore, in the context of increasing wages, tenant farmers will gradually divide toward polarization. That is large-scale tenant farmers further expend their farm size and small-scale tenant farmers reduce their farm size.

Second, in the presence of the potentially complex roles played by agroclimatic factors in agriculture, we reveal the farming season, a non-economic constraint, that farmers with different farm sizes face in the process of scale adjustment and substitution of labor by machines through machinery investment. The empirical results show that the impact of wage increases on large-scale tenant farmers is significantly influenced by the constraint of the farming season. Wage increases have a larger positive effect on farm size expansion and machinery investment of large-scale tenant farmers in regions with the flexible farming seasons.

Third, we simultaneously consider an array of important economic constraints, including liquidity constraint and off-farm employment opportunities constraint. The results show that the impact of wage increases on large-scale tenant farmers is significantly influenced by the liquidity, while the impact on small-scale tenant farmers is significantly influenced by off-farm employment opportunities. Large-scale tenant farmers with lower liquidity constraints are more likely to respond to wage increases by increasing farm size and machinery investment. Small-scale tenant farmers with higher availability of off-farm employment opportunities are more likely to respond to wage increases by decreasing farm size and machinery investment.

These findings have important policy implications not only for the Chinese government but also for other small-peasant economy countries in Asia to create favorable environments and conditions for the development of scale farming.

First, it is necessary to consistently improve the imperfect credit market and optimize product design and policies specific to large-scale tenant farmers to help ease liquidity constraints. Second, more public resources should be devoted to the innovation and application of technologies to alleviate farming season constraints. Specific technologies include varieties with a short growth period and suitable for mechanical operation, intelligent and efficient agricultural machinery technology. Meanwhile, the promotion of scale farming should be adapted to local conditions. For example, in areas with relatively tight farming seasons, it is inappropriate to encourage excessively large-scale farming. Third, since individual land ownership rights are absent in China, farm size expansion may not take place sufficiently fast. India faces the same problem that the average farm size is declining and land markets do not seem to function well due to land reform regulations. Therefore, the government should strength the land ownership rights and promote the land rental transactions. Finally, the issue of farm size expansion is not simply an 'agricultural issue'. In order to expand farm size, farm population must be reduced by rural-to-urban migration. The massive creation of off-farm employment for rural population is necessary to realize significant farm size expansion. The government should continue to create conditions for small-scale tenant farmers to exit from scale farming and turn to off-farm employment.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Data will be made available on request.

Appendix

See Tables A1 and A2 here.

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