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The impact of China's new agricultural subsidy policy on grain crop acreage

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ABSTRACT

As China is the world's largest producer, importer, and consumer of agricultural products, the new agricultural subsidy policy has significant implications for the global agricultural market. We assess the impact of the new agricultural subsidy on the grain crops acreage by applying difference-in-difference estimation to the China Rural Household Panel Survey (CRHPS) data. Results indicate that the new agricultural subsidy increases grain crop acreage. The results remain robust even after controlling for the effects from other policy measures. The study also identified the mechanism behind the subsidy's effect. Namely, the new program encourages operators to increase their grain crop acreage by renting more land and increasing the share of grain crops grown. Regarding heterogeneity of the results, the subsidy policy has a more positive impact on grain crop growers than on mixed crop growers, it does not affect large farms (>100 Mu) and its influence is greater among operators in the Northern regions of China. Our findings are relevant for understanding the effect of China's new agricultural subsidy policies and agrarian market reforms.

1. Introduction

In 2004, concerned about rural household incomes and national food self-sufficiency, the Chinese government decided to modify its long-standing policy of taxing farm households and to provide them with subsidies instead, i.e., the "*direct grain subsidy*", the "*quality seed subsidy*" and the "*aggregate input subsidy*" (Gale et al., 2005; Huang et al., 2013). However, most surveys have shown that this grain subsidy program is based on historical grain production or contracted land areas and is unrelated to farmers' current-year grain inputs or outputs (Tian and Meng, 2010; Huang et al., 2011). Moreover, in 2015 there were 185 million migrants from rural to urban areas in China, most of whom still received agriculture subsidies. However, the person who cultivates, or the operator who rents the farmland, does not receive the subsidy support (MOA, 2016a, 2016b). With this misalignment of the subsidy policy, its effect on food production was often lower than predicted by research (Gale et al., 2005; Heerink et al., 2006; Huang et al., 2011; Gale, 2013; Lin and Huang, 2021).

In 2016, the Chinese government began to reform agricultural subsidies by distributing part of them to the actual producers[1]. Since then, the three direct subsidies, *direct grain subsidy*, *quality seed subsidy*, and *aggregate input subsidy*, have been merged into one and renamed "*agricultural support and protection subsidy*" (in Chinese–*nongye zhichi baohu butie*) or aggregated subsidy. The "*agricultural support and production subsidy*" policy is designed to protect farmland quality and encourage grain production on a moderate scale (Zhan, 2017). More precisely, 80% of the stock of the "*aggregate input subsidy*" was combined with the "*direct grain subsidy*" and the "*quality seed subsidy*" to form the "*farmland quality subsidy*" (*gengdi zhiliang baohu butie*) and distributed to all farmers with land contract rights. The remaining 20% of the "*aggregate input subsidy*" and the incremental funds of the other three subsidies were merged with the pilot subsidy to large-scale farmers to form a "*moderate-scale*

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[1] Since China has the long-term goal of achieving 95 percent self-sufficiency in grains, which it sees as a strategic prerequisite to ensure the country's stable development the central government hoped the recipients would grow more grain.

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Table 1
Changes in China's agricultural subsidy policy.

	Old agriculture subsidy, i.e., *Sanxiang butie* (pre-reform)			Agricultural support and protection subsidy (post-reform)	
	Direct grain subsidy	Quality seed subsidy	Aggregate input subsidy	Farmland quality subsidy	Moderate-scale operation subsidy
Target	Encourage farmers to produce grains	Improve the coverage of high-quality seeds	Reduce the cost of growing grains	Improve the quality of land	Improve the productivity of grains
Receiver	Most farmers with contracted land	Most farmers with contracted land	Most farmers with contracted land	Farmers with contracted land	Large-scale operators who cultivate grains
Criteria	Payment is based on contracted land areas or taxable grain-sown area	Payment is based on contracted land areas or taxable grain-sown area	Payment is based on contracted land areas or taxable grain-sown area	Payment is based on contracted land areas or taxable grain-sown area or planting area	The actual cultivated area of operators
Payment method	Cash transfer	Cash transfer	Cash transfer	Cash transfer	Cash transfer is predominant, in-kind subsidy or loan interest subsidy is secondary

Source: Author's own summary.

operation subsidy" (*shidu guimojingying butie*)[2]. This subsidy was granted to operators planting grains on a large scale, especially large specialized farms, family farms, farmer cooperatives, social service organizations, and other new business entities. It is based on the principle "those who grow grain get support first" (MOF-MOA, 2015; MOF-MOA, 2016a).

Although a significant amount of public expenditure is dedicated to grain subsidy programs both in China and around the world, it is still not clear what impacts they have on grain production. On the one hand, there is evidence that subsidies can affect agricultural production through channels such as risk preference (Hennessy, 1998; Serra, Goodwin and Featherstone, 2011; Just, 2011), credit constraints (Goodwin and Mishra, 2006; Kropp and Whitaker, 2011; O'Toole and Hennessy, 2015), and labor participation (Ahearn et al., 2006; Nordin, 2014). On the other hand, several studies have shown that agricultural subsidies do not play a significant role in agrarian production (Fall and Magnac, 2004; Breen et al., 2005; Kirwan and Roberts, 2016). For example, Goodwin and Mishra (2006), Weber and Key (2012), and Moro and Sckokai (2013) found that agricultural subsidies do not really encourage an increase in production acreage because they are capitalized into higher land rental prices (Goodwin and Mishra, 2006). Accordingly, the capitalization of agricultural subsidies in China has attracted the attention of researchers and policymakers (Zhang et al., 2020; Xin and Li, 2019; Lin and Chen, 2021). Indeed, in a recent study, Zhang et al., (2020) found that a 10% increase in grain subsidy payments led to a 1% rise in rental prices for contracted farmland. In contrast, Lin and Chen (2021) found that agricultural subsidies do not affect land rental prices in China.

Existing literature has focused on the capitalization of the subsidy policy, but has neglected its potential to change cropping patterns. Tenants may respond to rising land rental costs by shifting their food crop production to cash crops (Zhang et al., 2020; Qiu et al., 2020), thus negatively affecting grain production. Up till now, no study has explicitly explored the impact of China's new agricultural subsidy policy, the "*moderate-scale operation subsidy*", on the area sown with grain crops and the associated underlying mechanisms. Moreover, since agricultural subsidization is on the rise in many developing countries (like China), it is essential to determine just how much of the subsidy is capitalized into the land rent versus its effect on grain production (acreage allocation), giving due consideration to imperfections in the farmland transfer market (Ciaian et al., 2021).

Therefore, the objective of this study is to systematically analyze the influence of China's new agricultural subsidy policy on grain production. There are at least three reasons which justify empirical research on this topic in China. First, China represents an excellent case for the systematic study of the impacts of agricultural subsidy because, unlike the US and the European Union (EU), the country has recently introduced a new agricultural subsidy program. The Chinese program encourages agricultural operators to grow grain crops on a large scale (Gale, 2013; Rada et al., 2015). Given China's enormous population, any changes in agricultural policy could have far-reaching implications for international food trade and global food security. Second, the impact of the new agricultural subsidy on grain production represents an exogenous shock that has not yet been studied in depth in the literature. Following the reforms, the agricultural subsidy was no longer granted solely to families holding land contracts but included the person cultivating or the operator farming the land. The amount of subsidy has also increased significantly. Under this scenario, the agricultural subsidy can boost grain production by relieving operators' credit restraints. On the other hand, if the subsidy was capitalized in the land rental price, it may have no impact at all on grain production. Third, a deeper understanding of the impact of new agricultural subsidy on China's grain production contributes to bridging gaps in research on the way these policy measures function in developing countries. This could be very helpful for other countries seeking to implement similar agricultural subsidy policies.

This study contributes to the literature in several ways. First, to the best of our knowledge, it is the first study focusing on China's new agricultural subsidy policy using nationally representative panel data. This analysis is important because grain production costs in China have risen in recent years (Liu et al., 2019). The central government aims to use the new agricultural subsidy to incentivize operators to grow grain crops. But, the potential capitalization of the agricultural subsidy may offset the income effect and even negatively affect the grain sown area. Second, this study adds to the current literature on the impact of the agricultural subsidy on grain production. It reveals the mechanism through which the new agricultural subsidy affects grain acreage by evaluating the factors of renting farmland or adjustments to cropping structures (crop mix). Furthermore, the heterogeneous impact of the new agricultural subsidy policy is studied, considering differences between regions and operator demographics. Third, the robustness and reliability of our results and conclusions are enhanced by applying the difference-in-difference method to analyze the effect of new agricultural subsidy and using panel data to control for time-invariant unobserved heterogeneity.

The rest of this study is organized as follows. Section 2 outlines the background of China's agricultural subsidy policy. Section 3 introduces the analytical framework, and Section 4 describes the data and empirical strategy. Section 5 presents results and robustness checks, while Section 6 provides mechanism tests and heterogeneity analysis. Conclusions and policy implications are put forward in the final section.

[2] This paper regards the "*moderate-scale operation subsidy*" as the evaluation target because it is the main force of transformation in this round of China's agricultural subsidy reform. We also call it new agricultural subsidy for short.

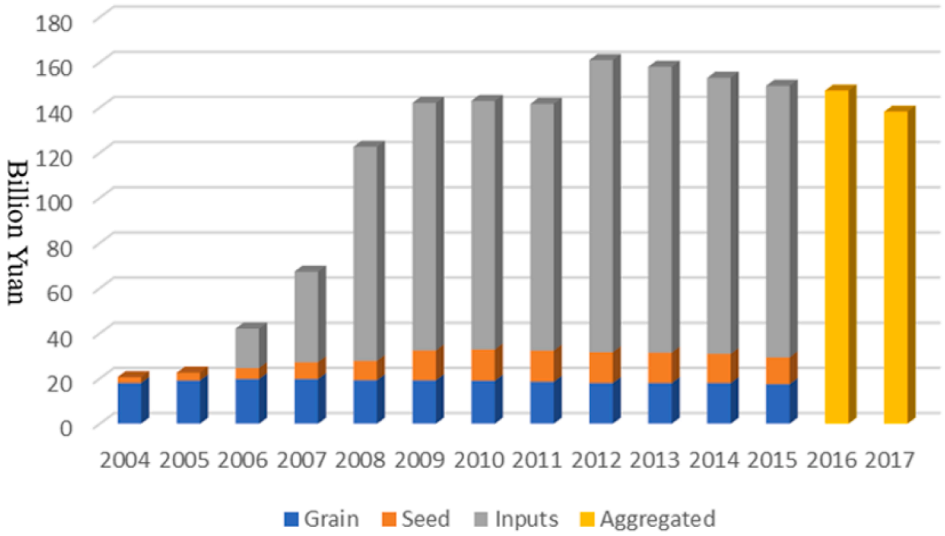

Fig. 1. Agricultural subsidies in China, 2004–2017 (billion yuan in 2017 price). Sources: China Agricultural Development Report (2005–2017), Ministry of Agriculture, China.

2. China's agricultural subsidy policy

2.1. Evolution of the agricultural subsidy policy

2004 marked the start of a new era in China's approach to its agricultural sector and support for agrarian households. The Chinese government began to subsidize farming rather than taxing it (Gale, 2005). This agricultural subsidy program included the "*direct grain subsidy*", the "*quality seed subsidy*", and the "*machinery subsidy*". The price of fertilizer and other agricultural inputs rose during the global food crisis from 2006 to 2008. It resulted in the "*aggregate input subsidy*", which was introduced in 2006 and was an element of the grain subsidy program. Since most Chinese farms are small, only a few farmers were eligible for the "*machinery subsidy*". Therefore, with the exception of the "*machinery subsidy*", the remaining three subsidies were generally regarded as agricultural subsidies (*Sanxiang butie*). Table 1 provides an overview of China's agricultural subsidy policies and shows that the "*direct grain subsidy*" was designed to encourage farmers to produce grains. The "*quality seed subsidy*" was designed to encourage grain producers to adopt better varieties of seeds. In contrast, the "*aggregate input subsidy*" aimed at offsetting high production costs caused, e.g., by fuel and fertilizer price increases (Yi, Sun and Zhou, 2015). Fig. 1 shows the composition and trends of agricultural subsidies in China. The figure reveals that, while the amount allocated to the "*direct grain subsidy*" remained more or less constant in nominal terms from 2004 to 2015, the other subsidies, i.e., the "*quality seed subsidy*" and especially the "*aggregate input subsidy,*" experienced rapid growth. The total amount of subsidies increased more than sevenfold, from about 21 billion yuan in 2004 to about 161 billion yuan in 2012 (China Agricultural Development Report (2005–2017), Ministry of Agriculture, China).

Most surveys show that China's grain subsidy program has no impact on agricultural production. One reason for this is that the subsidy payment is not based on farmers' current-year grain inputs or outputs but on contracted land areas or taxable grain-sown areas (Tian and Meng, 2010; Huang et al., 2011). The contracted land area is the most commonly used measure for allocating subsidies (Yi et al., 2015). Specifically, due to the extremely high administrative costs of monitoring grain production of more than 200 million smallholders, the agricultural subsidy programs were implemented by granting subsidies to each farm household simply based on their contracted land size that was signed in the late 1990 s and regardless whether they still cultivate or grow anything (Huang et al., 2011; 2013; Lin and Huang, 2021). Under these circumstances, the land contractors still receive the agricultural subsidies even if they have rented out their land. However, operators who rent-in land do not receive grants associated with the rental land, which weakens the effect of subsidies on agricultural production (Huang et al., 2011; MOF-MOA, 2016b; Lin and Huang, 2021). Besides, in 2012 the Chinese government took stock of the substantial financial burden, decided to cut down the total subsidy budget in 2013 (Huang and Yang, 2017 and Fig. 1), and set about planning to reform the existing agricultural subsidy policy.

In 2015, China's finance and agriculture departments jointly announced adjustments to the agricultural subsidy policy for 2016. Specifically, this round of agricultural subsidy policy reform would combine the "*direct grain subsidy*", the "*quality seed subsidy*" and the "*aggregate input subsidy*" to form the "*agricultural support and protection subsidy*" and was designed to improve the directivity, efficiency, and precision of the policies (MOF-MOA, 2015; MOF-MOA, 2016a). In contrast to the old grain subsidy program (*Sanxiang butie*), the new "*agricultural support and protection subsidy*" consists of the "*farmland quality subsidy*" and the "*moderate-scale operation subsidy*" which have the following features (cf. Table 1). First, the policy target became more central. The "*farmland quality subsidy*" aims to improve land quality, and the "*moderate-scale operation subsidy*" is intended to enhance productivity in the grain sector. Second, the receivers of the subsidy were defined more precisely. This meant that the subsidy was no longer universal but that the funds were increasingly granted to the actual operators. In addition, the criteria for granting subsidies became more explicit. For instance, the allocation of the "farmland quality subsidy" is still based mainly on the farmers' contractual rights. However, the "*moderate-scale operation subsidy*" is granted according to the actual area cultivated by the operator. Third, although the cash transaction is the primary method of subsidy payment, the local governments are encouraged to increasingly divert the subsidy funds toward establishing agricultural credit and guarantee systems in the future. Comparing these policies reveals that the target, criteria, and payment methods of the "*farmland quality subsidy*" still closely resemble the "*Sanxiang butie.*" Thus, the "*moderate-scale operation subsidy*" is the main source of changes in China's new agricultural subsidy reform. This is in line with the Central Government's plan and serves as the focus of our study.

2.2. Differentiated policy implementation

In China, a vast and diverse country, the central government only designs a general path for the new agricultural subsidy policy, while local governments develop different strategies to meet the actual conditions of each region (Huang and Kim, 2020). In practice, the distribution of the new agricultural subsidy generally follows the "top-down" principle. First, the central government sets the total amount of support for each province according to regional differences in grain production. Then, the provincial government distributes funds to the city and county levels according to each region's economic development and agricultural characteristics. Finally, the county government sets specific criteria for allocating subsidies to farmers. Thus, even in the different counties of the same province, there are still differences in the detailed management of the subsidy.

To examine the details of the implementation of the new agricultural subsidy policy, we randomly selected two counties each from the eastern, central, and western regions of China.[3] In reviewing the implementation processes of these counties, we came to the following conclusions. First, counties employed different methods for the subsidy program. Most counties (e.g., Pingdu in Shandong Province, Ningxiang in Hunan Province, and Pingchang County in Sichuan Province) used the cash subsidy method. In other counties (e.g., Dingyuan in Anhui Province and Lingshan in Guangxi Province), agricultural subsidies were used to build a farm credit system or disseminate agricultural technologies, and the target groups were mainly large farm operators. Therefore, most farmers did not benefit from the new agricultural subsidy. Second, counties set different criteria for the cash subsidy. For example, Dehua County in Fujian Province stipulated that farmers with more than 15 mu could receive 250 yuan per mu. Ningxiang County in Hunan Province stipulated that farmers with 20 mu or more could receive 100 yuan per mu. Finally, Pingchang County in Sichuan Province stipulated that farmers with more than 30 mu could receive 150 yuan per mu. In contrast, farmers with more than 50 mu in Pingdu County in Shandong Province could only receive 60 yuan per mu.

Third, most counties delegate the task of verifying the eligibility of subsidy recipients to village cadres because they have an informational advantage over farmers. In China, the large number of small households in rural areas can lead to extremely high administrative costs if the government intends to implement the policy directly. In practice, village cadres, as important agents for the government, are at the forefront of implementing government policies (Wang and Mou, 2021). According to our research, the implementation of China's new agricultural subsidy policy is as follows. First, village cadres are responsible for collecting information about land operation in their village and reporting it to the township government. The township governments are then responsibile for forwarding the verified information to the county government. After random verification of the information, the county government finally grants the subsidy funds to the operators through the banking system.

In summary, the variation in subsidies received by different households allows us to estimate the marginal effect of the new agricultural subsidy policy. We conduct a heterogeneity analysis to determine whether the effect of the subsidy varies by region. As shown in Fig. 1, the total sum attributed to the "*agricultural support and protection subsidy*" in 2016 amounted to about 144 billion yuan and included about 24 billion yuan from the "*moderate-scale operation subsidy*" granted to large-scale agricultural operators to encourage them to grow grain at scale.

[3] Using the rand command in Microsoft Excel, we randomly selected two counties from the eastern, central, and western regions of China: Pingdu in Shandong, Dehua in Fujian, Dingyuan in Anhui, Ningxiang in Hunan, Pingchang in Sichuan, and Lingshan in Guangxi. The details of the policy implementation come from the county government's websites.

3. Analytical framework

Profit maximization is the best-established reference framework for analyzing farmers' behavior and the impact of policy instruments (Moro and Sckokai, 2013). For rational farmers, the mechanism behind the impact of agricultural subsidies on farm production can be viewed as farmers' allocation of agricultural resources under various constraints to maximize their income. In general, the effects of agricultural subsidies on agricultural production can be divided into the income effect and the capitalization effect. The income effect can alleviate not only the liquidity constraints but also the labor constraints of farmers, so the subsidized farmers are more willing to increase their grain crop acreage than farmers who do not receive subsidies. Many farm operators in China lack productive assets due to liquidity constraints (Dong et al.2012) which limits their farm scale. Agricultural subsidies can relieve this situation. There is evidence that agricultural subsidies represent a kind of income subsidy (Guo et al., 2021; Huang et al., 2011), which can help to ease liquidity constraints and enable operators to obtain productive assets to stimulate production, farming scale, and income (Vercammen 2007; Hazarika 2003). For example, Yi et al. (2015) show that China's grain subsidy program led to an increase in the area of grain planted by liquidity-constrained farm households.

Similarly, agricultural subsidies can ease labor constraints. The booming industrialization and urbanization encouraged millions of farmers to leave their farms (Zou et al., 2018; Zhang et al., 2021; Zou et al., 2022) for better jobs in the cities. This has led to a dramatic shortage of agricultural labor in China that significantly constrains agricultural production (Liu, 2018). Agrarian subsidies can help ease labor constraints and motivate farmers to increase grain crop cultivation. There is evidence that agricultural subsidies not only encourage farming families to return to their land (Huang et al., 2020; Olper et al., 2011) but offset shortages of agricultural workers by hiring labor or purchasing agrarian services, which helps them to expand their farming operations (Mtaturu and Tumaini, 2022; Yang et al., 2013). Bojnec and Fertő (2022) found that agricultural subsidies can promote farm employment, and farm employment is positively associated with farm size.

In contrast, the potential capitalization effect of land rent payments may offset the income effect of agricultural subsidies and may even negatively affect the grain sown area. The capitalization of the subsidies is a process whereby they are factored in the rental rates, increasing the farmland prices and the value of farm assets. The higher the capitalization, the lower the efficiency of subsidies as an instrument to support the production of actual farm operators (Roberts, Kirwan and Hopkins, 2003; Gohin, 2006; Justyna et al., 2015). Moreover, tenants may respond to rising land rental costs by shifting their food crop production to cash crops (Zhang et al., 2020), thus negatively affecting grain production. Several studies in China have shown that an agricultural subsidy would positively impact the observable land rental price if the payment went to the person who cultivates the land or land operator, and they are more likely to respond by growing more non-grain crops (Xin and Li, 2019; Zhang et al., 2020; Lin and Chen, 2021).

The overall effect resulting from these two opposing forces is determined by the development of the land transfer market. The economic theory suggests that agricultural subsidies do not affect production when markets are complete since they capitalize in farmland rental rates (Goodwin et al., 2003; Ciaian et al., 2012). However, this is only partially supported by empirical evidence since land rental markets in China are informal and a larger percentage of the transactions are agreements between neighbors and relatives than in other countries. These transactions are often characterized by land rents below the average market price or even zero (Deininger and Jin, 2005; Feng et al., 2010; Wang et al., 2015). For example, agricultural subsidies have been shown not capitalize on land rents when land rental activity occurs only within the same village (Lin and Chen, 2021). Furthermore, even if part of the subsidies is capitalized into land rent, operators may not respond

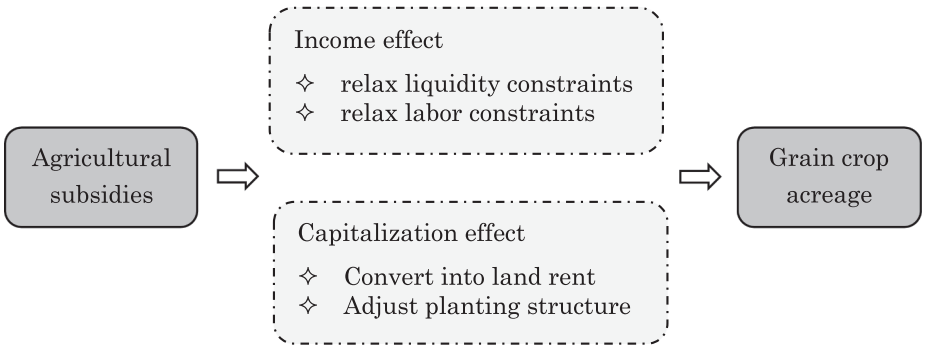

Fig. 2. Analytical framework.

by increasing their cash crop sown area. The reason is that growing cash crops involves higher market risks and requires more labor inputs than growing grain crops, and thus operators are less likely to change their farming structure (Qiu et al., 2020). Therefore, we deduce that while part of China's agricultural subsidies may leak into the land and increase the land rental rates, they can still stimulate grain crop acreage. Fig. 2 shows the mechanisms by which agricultural subsidies are expected to increase grain crop acreage. Whether the subsidy ultimately affects grain acreage remains an empirical question to be investigated using econometric methods.

4. Data and empirical framework

4.1. Data source

Our primary data source is the Chinese Family Database (CFD). This is based on surveys conducted by Zhejiang University, China and consists of four rounds of China Rural Household Panel Survey (CRHPS) data over the years 2011, 2013, 2015, and 2017. CRHPS is a nationwide survey of households in China. The sample was selected using stratified, three-stage, and probabilities proportional to size (PPS) sampling methods (Gao et al., 2021; Wu et al., 2018). The survey is stratified at three levels - community, household, and individuals. The database includes data from surveys on the levels of community economic development, the basic family structure, agricultural subsidies, crop cultivation area, and land transfer. This data allows us to examine the effect of agricultural support and protection subsidies. Since the 2015 and 2017 rounds also include detailed product information (grain crops and cash crops), we only use 2015 and 2017 data in our study (see Gao et al., 2021).

Agricultural production is aggregated into two categories: grain crops and cash crops. We calculate the area sown with grain and its share. Grain crops include rice, wheat, and maize; cash crops refer to peanuts, rapeseed, cotton, and other species. As mentioned above, China's new agricultural subsidy includes both monetary and in-kind subsidies, whereby the latter involves seeds, pesticides, fertilizers, etc., converted into monetary equivalents based on market prices of the input in that year. Following previous studies (Goodwin and Mishra, 2006; Huang et al., 2011; Yi, Sun, and Zhou, 2015) we include a series of control variables. The agricultural production information consists of the machinery services, the price[4] and production cost of grain and cash crops and whether the household hires farm labor. To avoid potential reverse causality, we use prices and costs for grain and cash crops on the province level derived from the National Compilation of Agricultural Products Cost-benefit Data (Lin and Huang, 2021). Similarly, we use the mean values of the expenditures for agricultural machinery services by other households in the same village and the mean value of whether other households in the village have hired agricultural labor to measure the development of agricultural machinery services and agricultural labor markets, respectively (Wang et al., 2016; Liu et al., 2022). The land information covers the contracted land area, whether the household received the new land certificate[5], whether the family transferred out or transferred in the land and the village's land rental price. The village's land transfer price was measured by the average price paid by other households in the same village.[6] For the village with no other households participating in the land rental market, we used the data collected from the village cadre during the survey.[7] In addition, the characteristics of the head of the household and the family as well as information on personal income and off-farm employment, are included as essential control variables. Note that we deflated all 2017 income and price variables to the 2015 level using the consumer price index of rural residents in each province.

The data covered 520 villages in 2015 and expanded to 608 villages in 2017, all located in 29 provinces (cities and districts). The samples are all random. Their distribution in each province is highly correlated with that in the official data released by the National Bureau of Statistics, which means the sample distribution is consistent with the geographic distribution of the whole population in China (see Gao et al., 2021).

By matching the 2015 and 2017 datasets and dropping the missing and invalid values[8], we obtained a final sample of 9,156 observations from 4,578 households covering 29 provinces, municipalities, and autonomous regions. Since the new agricultural subsidy was introduced in 2016, we set 2015 as the pre-treatment period and 2017 as the post-treatment period. The treatment group (farms that did not receive the new subsidy in 2015 but obtained it in 2017) consisted of 2,314 observations from 1,157 households, and the control group (farms that did not receive the new subsidy in 2015 and 2017) consisted of 6,842

[4] In 2016, China announced the implementation of the temporary corn storage policy reform, which may affect the grain price. The inclusion of grain price as a control variables should effectively control for the influence of the above policy reform.

[5] The new round of land certification programs started in 2009, and was implemented on a national level in 2013. It aims to provide farmers with well-defined and secure property land rights (Gao et al., 2021; Zhang et al., 2022; Deininger and Jin,2009).

[6] Rent that is paid in kind (e.g., with grain) was converted into cash using the market price at that time.

[7] Note that the land transfer price reported by the village cadre does not accurately reflect the free rental of land among relatives and friends a characteristic of the informal land rental market mentioned before (Wang et al., 2015; Liu et al., 2022).

[8] Unlike other variables, we only drop an observation if the sown area (grain crops and cash crops) is zero in both 2015 and 2017. This means that observations with zero sown area in 2017 (because they rented out their land) are also included. The invalid data is those not complying with the given conditions. For example, if the value of the in-kind subsidy is more than 20,000 yuan, the investigator probably mixed up the agricultural machinery subsidy; however, the machinery subsidy is no longer our concern, so we have to regard it as an invalid value.

Table 2
Variable descriptions and summary statistics (2015 and 2017).

Variable	All periods					Treatment group					Control group				
	Treatment group		Control group		Diff.	2015		2017		Diff.	2015		2017		Diff.
	Mean	SD	Mean	SD		Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Grain, sown area (mu)	28.09	0.48	9.92	0.76	−18.17***	10.13	1.12	46.06	2.71	35.93***	10.53	0.83	9.32	0.56	−1.21
Age of decision-maker (years)	56.16	0.11	56.72	0.12	0.56	55.63	0.18	56.70	0.17	1.07***	55.93	0.16	57.52	0.16	1.59***
Education of decision-maker (years)	7.33	0.03	7.36	0.03	0.03	7.28	0.05	7.38	0.04	0.10	7.36	0.04	7.36	0.04	0.00
Number of residents	4.36	0.08	4.26	0.01	0.10	4.35	0.16	4.37	0.16	0.02	4.22	0.02	4.30	0.07	0.08
Share of farm labor in family	0.60	0.02	0.58	0.03	−0.02	0.59	0.00	0.61	0.00	0.02	0.55	0.00	0.60	0.00	0.05
Machinery services (1,000 yuan/mu)	0.12	0.13	0.10	0.09	−0.02***	0.10	0.09	0.13	0.15	0.03***	0.10	0.09	0.10	0.10	0.01
Hired labor (1 = Y, 0 = N)	0.11	0.00	0.11	0.00	0.00	0.09	0.00	0.13	0.00	0.04	0.10	0.00	0.12	0.00	0.02*
Grain crops cost (1,000 yuan/mu)	0.96	0.01	0.95	0.01	−0.01	0.94	0.02	0.97	0.02	0.03**	0.94	0.01	0.96	0.02	0.02**
Grain crops price (1,000 yuan/50 kg)	0.12	0.02	0.11	0.01	−0.01	0.13	0.01	0.11	0.00	−0.02**	0.12	0.02	0.11	0.04	−0.01**
Cash crops cost (1,000 yuan/mu)	0.90	0.01	0.90	0.01	0.00	0.91	0.02	0.90	0.02	−0.01	0.90	0.01	0.90	0.01	0.00
Cash crops price (1,000yuan/50 kg)	0.27	0.03	0.27	0.01	0.00	0.28	0.01	0.27	0.04	−0.01	0.28	0.01	0.27	0.05	−0.01
Contracted land area (mu)	9.45	0.29	8.40	0.27	−1.05	9.25	0.38	9.65	0.43	0.40	8.42	0.39	8.39	0.35	−0.03
Land certification (1 = Y, 0 = N)	0.58	0.00	0.56	0.00	−0.02	0.46	0.00	0.69	0.00	0.23***	0.47	0.00	0.66	0.01	0.19***
Land renting-in (1 = Y, 0 = N)	0.30	0.10	0.20	0.03	−0.10**	0.22	0.07	0.37	0.12	0.15***	0.20	0.04	0.19	0.03	−0.01
Land renting-out (1 = Y, 0 = N)	0.11	0.01	0.15	0.02	0.04*	0.11	0.02	0.12	0.01	0.01	0.12	0.01	0.17	0.02	0.05**
Land rent of the village (1,000 yuan/mu)	0.41	0.02	0.32	0.02	−0.09	0.34	0.02	0.48	0.06	0.14**	0.32	0.02	0.32	0.02	0.00
Off-farm employment	0.15	0.01	0.15	0.01	0.00	0.15	0.03	0.15	0.03	0.01	0.15	0.02	0.15	0.02	0.00
Personal income (1,000 yuan)	4.42	0.12	4.43	0.01	0.01	4.26	0.34	4.58	0.32	0.32	4.26	0.53	4.60	0.51	0.34**
Number of observations	2,314		6,842			1,157		1,157			3,421		3,421		
Number of households	4,578					1,157					3,421				

Source: Authors' own calculations.

observations from 3,421 households. Table 2 presents summary statistics of the main variables used in this study separately for the treatment and control group and the two observation periods. Some interesting findings can be noted. The first one concerns the variable of grain acreage. The grain acreage in the treatment group was 28.09 mu, while in the control group it was 9.92 mu (1 mu = 1/15 ha). The mean difference between the two groups is 18.17 mu, statistically significant at the 1%-level. As for different years, the average grain area in 2015 and 2017 is not significantly different in the control group, while in the treatment group, the average grain acreage in 2017 was significantly larger than in 2015 (+35.93 mu). This suggests that subsidy recipients may have increased their grain acreage under the new agricultural subsidy policy compared to non-subsidy recipients.

The second result concerns the variables of land renting in and land renting out.[9] The average probability of renting in land was significantly higher in the treatment group in 2017 than in 2015, while there was no significant difference between these two years in the control group. As regards the probability of renting out land, it was significantly higher in the control group in 2017 than in 2015, while there was no significant difference between these two years in the treatment group. This suggests that farmers receiving the new agricultural subsidy tend to rent in land, while farmers without subsidy prefer to rent out their land. In addition, Appendix A shows the difference in grain crop acreage based on whether the subsidized operators rent-in land or not. It can be observed that the subsidized operators increased their grain crop acreage by renting more land or increasing their share of grain crop production (without renting in land).

In addition, Table 2 shows that the average land rent of the village in 2017 is significantly higher in the treatment group than in 2015, while there is no statistically significant difference between the two years in the control group. This reflects the capitalization effect of China's new agricultural subsidy policy, namely that part of the subsidy has been capitalized into the land rent. Finally, in both the treatment and control groups, the production cost of grain crops per mu was significantly higher in 2017 than in 2015, while the market price decreased substantially from 2015 to 2017. This may reflect China's new strategy of "separating subsidies from support price policies," which aims to let the price be determined by market supply and demand by gradually eliminating the minimum purchase price for grain (FCA, 2016).

Note that these are only potential findings. In order to identify the causal relationship between the new subsidy program and grain acreage, an econometric model must be established and relevant control variables need to be considered. In addition, apart from machinery services and the area of rented-in and rented-out land, most control variables had no significant differences, meaning there was no systematic difference between the treatment and control groups. Hence, the characteristics of the two groups are very similar, which means that the problem of sample selection bias is probably not severe and the parallel trends assumption is more likely to hold. Nevertheless, we further investigate these issues below.

[9] It is also important to emphasize that the average probability of renting in land refers to the share of households renting in land, not the percentage of land rented. In other words, even if the share of households renting land is not very large, the corresponding land area is not small. The reason for this difference is that the transfer of farmland in China is becoming more and more concentrated, i.e., more and more farmland has been transferred to a limited number of large-scale operators, such as large-scale farmers, family farms, cooperatives, etc. (Rogers et al., 2021; Ye, 2015; Zhan, 2017).

Table 3
Impact of agricultural subsidy on area sown with grain crops (difference-in-difference estimation).

	Dependent variable: grain-sown area (*Mu*)					
	(1)	(2)	(3)	(4)	(5)	(6)
$D_i \times Time_t$	0.092***	0.091***	0.068***	0.055***	0.054***	0.053***
	(0.022)	(0.022)	(0.019)	(0.021)	(0.020)	(0.020)
Age of decision-maker		−0.000	−0.000	−0.001	−0.001	−0.001
		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Education of decision-maker		−0.001	−0.000	−0.001	−0.001	−0.000
		(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Number of residents		0.015*	0.018**	0.012	0.012	0.013
		(0.008)	(0.008)	(0.008)	(0.008)	(0.009)
Share of farm labor in family		0.052**	0.025	0.020	0.011	0.019
		(0.022)	(0.017)	(0.018)	(0.015)	(0.020)
Machinery services			0.015**	0.013**	0.010**	0.014**
			(0.007)	(0.006)	(0.005)	(0.007)
Hired labor			0.050	0.030	0.033	0.042
			(0.034)	(0.034)	(0.034)	(0.035)
Grain crops cost			−0.001	−0.001	−0.001	
			(0.001)	(0.001)	(0.001)	
Grain crops price			0.005**	0.005**	0.004**	
			(0.002)	(0.002)	(0.002)	
Cash crops cost			0.000	0.000	0.001	
			(0.000)	(0.000)	(0.001)	
Cash crops price			−0.001	−0.001	−0.001	
			(0.001)	(0.000)	(0.001)	
Contracted land area				0.002**	0.002**	0.002**
				(0.001)	(0.001)	(0.001)
Land certification				0.038**	0.030**	0.033**
				(0.019)	(0.015)	(0.016)
Land rent of the village				−0.012	−0.010	−0.013
				(0.010)	(0.010)	(0.012)
Off-farm employment					0.066	0.064
					(0.061)	(0.059)
Personal income					−0.000	−0.001
					(0.000)	(0.000)
Individual fixed effect	YES	YES	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES	YES	YES
Province fixed effect						YES
Constant	1.802***	1.743***	2.361***	2.063***	2.107***	2.218***
	(0.006)	(0.096)	(0.392)	(0.415)	(0.413)	(0.312)
Number of observations	9,156	9,156	9,156	9,156	9,156	9,156
Number of households	4,578	4,578	4,578	4,578	4,578	4,578
within_R2	0.213	0.220	0.224	0.245	0.247	0.240

Notes: The dependent variable is measured in natural logarithm form. Standard errors are reported in parentheses. *, **,*** Significant at the 10%, 5%, 1%-level.

4.2. Empirical model specification and identification strategy

The effects of the new agricultural subsidy policy implemented nationally in 2016 to encourage grain production were evaluated by applying difference-in-difference with fixed effects regression to the two time periods, 2015 and 2017. The difference-in-difference technique is an established identification strategy in applied economics (Meyer 1995; Heckman et al., 1999; Lechner 2010).[10] The method is typically used to estimate the effect of a specific intervention or treatment (such as the enactment of a policy). Specifically, the difference-in-difference method compares the changes in outcomes over time between a population enrolled in a program (the intervention group) and a population unaffected (the control group). This estimator allows controlling for unobservable, linear, and time-invariant effects (Heckman et al., 1999, Smith and Todd, 2005). We estimate the following model:

$Y_{it} = \beta_0 + \beta_1 D_i * time_t + \sum_j \theta_j X_{it}^j + f_i + f_t + \varepsilon_{it}$ (1) where Y_{it} represents the outcome variable grain-sown area of household i in year t, D_i is a dummy variable for the treated group, i.e., whether the operator was granted the new agricultural subsidy. $time_t$ is a dummy variable with a value of 1 for the period after the policy intervention, i.e., 2017 and a value of 0 for the pre-treatment period 2015. β_0 is the constant term and β_1 captures the impact of the agricultural subsidy on the outcome variable Y_{it}. Since omitted variables may affect the validity of the model, we added a series of control variables X_{it}^j, including information on the household, its farmland, and agricultural input and output. Since the omission of individual-change or time-variant factors may trigger an endogeneity problem, we control for the individual (f_i) and time effects (f_t).

5. Estimation results

5.1. Main results

Based on equation (1), this study uses the stepwise regression method to empirically analyze the new agricultural subsidy's effect on grain acreage. The results are presented in Table 3.

The first column shows the regression results conditional on controlling for individual and time effects without other control variables. The second column presents the result when additional household control variables are added to the model. In the third column, variables related to agricultural production are added as control variables. In the fourth column, information on land, especially land transfer, is added. The fifth column shows the full model after the inclusion of additional control variables related to village information. Since crop costs and prices are based on provincial aggregates, in the sixth column we

[10] The DID framework is a quasi-experimental approach to measure the causal effect of any policy intervention -in our case China's new agricultural subsidy (e.g., Butsic et al., 2017).

Table 4
Test for the random selection assumption.

	Dependent variable: farmer is in the treatment group (1 = Y, 0 = N) (year = 2015)
Grain, sown area	0.002
	(0.005)
Other controls	YES
Constant	1.085
	(0.902)
Number of observations	4,578
Number of households	4,578
R^2	0.102

Notes: Standard errors are reported in parentheses. Other controls are identical to column (4) of Table 3. *, **,*** Significant at the 10%, 5%, 1%-level.

Table 5
Test of the parallel trend assumption.

	Dependent variable: grain-sown area (*Mu*) (year = 2015)
Treatment group	0.654
	(0.701)
Other controls	YES
Constant	1.641
	(2.503)
Number of observations	4,578
Number of households	4,578
R^2	0.298

Notes: Standard errors are reported in parentheses. Other controls are identical to column (4) of Table 3. *, **,*** Significant at the 10%, 5%, 1%-level.

replaced these variables with province-fixed effects. The estimated coefficient of the agricultural subsidy and the value of within_R2 decrease in the sixth column compared to the fifth column. Therefore, the fifth column (Table 3) is treated as the main result of this paper and used for comparison with previous studies (Huang et al., 2011; Yi, Sun, and Zhou, 2015).

As the primary focus of this study, China's new agricultural subsidy has a significant positive impact on the acreage under grain, which is consistent with our expectations. The coefficient is statistically significant at the 1%-level in all cases after controlling for individual and time effects and continuously adding other control variables. Note that we measure the dependent variable *grain-sown area* by its natural logarithm[11]. Therefore, the results in Column (5) of Table 3 reveal that the average treatment effect of the new agricultural policy is a 5.5% increase in land allocated to grain production. Our finding is consistent with Yi, Sun, and Zhou (2015), who argue that the agricultural subsidy -a form of cash transfer- relaxes the liquidity constraints of farm households when credit markets are not complete. As a result, the subsidies support farmers in adjusting their cropping patterns to increase the grain sown area. However, the findings of Yi, Sun, and Zhou (2015) differ from Huang et al. (2011), who concluded that grain subsidies did not influence the land demand for grain production. Interestingly, in this study, the capitalization effect of the agricultural subsidy has been partially confirmed[12], but it does not seem to completely offset the income effect of the support on agricultural production. One explanation for this finding is that most land transactions in our sample remain between acquaintances in the same village (with low or even zero rents), weakening the agricultural subsidy capitalization process (Lin and Chen, 2021). Note that the new Chinese agricultural subsidy program investigated in our study grants grain subsidies to the operator/cultivator of the land, who can be the tenant or the original contracted landowner. Thus, our results show that China's new agricultural subsidies that target payments to the operator of the farmland (cultivator) rather than to the contracted landowner effectively increased grain crop acreage and, it follows, the country's grain production. Thus, China's food security prospects may well have benefited from the new *agricultural support and protection subsidy*.

Table 6
Impact channels of the agricultural subsidy on area sown with grain crops (difference-in-difference estimation).

	(1) Land renting-in	(2) Land renting-out	(3) Share of grain crops	(4) Share of cash crops
$D_i \times Time_t$	0.036***	−0.004**	0.018**	−0.007**
	(0.013)	(0.002)	(0.008)	(0.003)
Age of household decision-maker	−0.001*	0.001**	−0.001	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Education of household decision-maker	0.002	−0.000	−0.000	0.004**
	(0.002)	(0.001)	(0.002)	(0.002)
Number of residents	−0.000	0.002	0.001	−0.000
	(0.004)	(0.002)	(0.003)	(0.001)
Share of farm labor in family	0.007**	−0.007	0.027	0.001
	(0.003)	(0.008)	(0.020)	(0.000)
Machinery services	0.027***	−0.006**	0.004**	0.002
	(0.010)	(0.003)	(0.002)	(0.012)
Hired labor	0.032**	−0.004	0.016	0.015**
	(0.015)	(0.011)	(0.013)	(0.007)
Grain crops cost	0.000	0.000	−0.001**	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Grain crops price	0.008**	−0.001	0.002**	−0.002
	(0.004)	(0.000)	(0.001)	(0.002)
Cash crops cost	0.000	0.000	0.001	−0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Cash crops price	0.000	0.001	0.000	0.005**
	(0.000)	(0.000)	(0.000)	(0.002)
Contracted land area	−0.000	0.000	0.001	0.000
	(0.000)	(0.000)	(0.001)	(0.000)
Land certification	0.023**	0.015**	0.010	0.007*
	(0.011)	(0.007)	(0.008)	(0.004)
Land rent of the village	−0.011**	0.017**	−0.011	0.021
	(0.005)	(0.008)	(0.008)	(0.015)
Off-farm employment	0.017	0.029**	0.031	0.015*
	(0.032)	(0.013)	(0.025)	(0.008)
Personal income	−0.000	0.000	−0.001	0.000
	(0.000)	(0.000)	(0.001)	(0.000)
Individual fixed effect	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES
Constant	0.068	−0.011	0.192	−0.047
	(0.208)	(0.121)	(0.163)	(0.059)
Number of observations	9,008	9,052	8,454	6,264
Number of households	4,504	4,526	4,227	4,227
within_R^2	0.246	0.172	0.196	0.151

Notes: The households with both land renting-in and renting-out have been removed. Standard errors are reported in parentheses.*, **,*** Significant at the 10%, 5%, 1%-level.

Several control variables in Table 3 (column 5) also have a significant relationship with the grain acreage. First, the coefficient on agricultural machinery services is positive and significant indicating that an additional 1,000 yuan/mu in machinery services is related to an increase of about 1% in grain acreage. Since grain production is more easily mechanized in rural China (Luo, 2018), agricultural machinery services can help operators to expand their grain crop acreage (Qiu et al., 2020).

The coefficient of the grain price is positive and significant while grain production costs are not significantly related to the grain crop acreage, which is also consistent with the findings of Yi, Sun, and Zhou (2015). In turn, the cash crop price and its production costs are not related to the acreage under grain. A possible explanation is that most farm operators mainly grow grain crops and are insensitive to the price of cash crops. As Qiu et al. (2020) suggest, growing cash crops involves higher market risks and requires more labor inputs than growing grain

[11] Since some of the values are 0, 0.001 is added to all values before taking the logarithm to avoid the loss of observations (Qian et al., 2022).

[12] As shown in Table 2, the average land transfer price has risen in the village of the operator who received the new subsidy.

Table 7
Grower type heterogeneity analysis for mixed crop and grain crop growers (difference-in-difference estimation).

	Dependent variable: grain-sown area (*Mu*)	
	(1) Grain crop growers	(2) Mixed crop growers
$D_i \times Time_t$	0.066**	0.023**
	(0.028)	(0.010)
Age of decision-maker	−0.000	−0.000
	(0.001)	(0.004)
Education of decision-maker	−0.000	0.006
	(0.005)	(0.013)
Number of residents	0.008	0.031
	(0.009)	(0.030)
Share of farm labor in family	0.032	0.010
	(0.020)	(0.007)
Machinery services	0.025***	0.005
	(0.008)	(0.008)
Hired labor	0.021	0.089
	(0.037)	(0.084)
Grain crops cost	−0.000	−0.001
	(0.000)	(0.001)
Grain crops price	0.008**	0.010**
	(0.004)	(0.005)
Cash crops cost	0.000	0.002**
	(0.000)	(0.001)
Cash crops price	−0.001	−0.004**
	(0.001)	(0.002)
Contracted land area	0.002**	0.006***
	(0.001)	(0.002)
Land certification	0.041**	0.019
	(0.020)	(0.067)
Land rent of the village	−0.012	−0.047***
	(0.010)	(0.016)
Off-farm employment	0.075	0.050
	(0.066)	(0.170)
Personal income	−0.000	−0.000
	(0.000)	(0.000)
Individual fixed effect	YES	YES
Time fixed effect	YES	YES
Constant	1.948***	4.393**
	(0.434)	(1.758)
Number of observations	6,102	902
Number of households	3,051	451
within_R^2	0.235	0.174

Notes: The dependent variable is measured in natural logarithm form. Standard errors are reported in parentheses. *, **,*** Significant at the 10%, 5%, 1%-level.

crops, so operators would not readily change their cropping structure. The contracted land area coefficient is positive and statistically significant at the 5% level of significance, which is in line with the findings of Huang et al. (2011), indicating that households with relatively large contract acreage are more likely to grow grain crops (Sheng et al., 2019).

Results in Table 3, column 5 also show that farm families with land certificates from the government[13] are more likely to expand their grain acreage. The results indicate that farm families holding land certification increase their grain crop acreage by 3%. A plausible explanation is that land certification enables farm families to apply for credit from commercial and cooperative banks. Thus, land certification can help relax liquidity constraints and result in increased quantity and quality of inputs and the hiring of farmworkers[14] (Xu and Du, 2022). Contrary to expectations, the average rental price of land in villages is not significantly related to the grain crop acreage.

5.2. Robustness checks and assumptions tests

In this section, we conduct a robustness test for the baseline results and test the underlying assumptions of random sample grouping and parallel trends. First, we test the exogeneity of the difference-in-difference method. We ensure that the sample grouping is random by using a logit model to examine the data for 2015, i.e., prior to the implementation of China's new agricultural subsidy policy. In this model, the binary dependent variable measures 'whether the farmer is in the treatment group', while the key explanatory variable is 'farmers' grain crop sown area.' As shown in Table 4, before introducing the subsidy policy, the relationship between the area sown with grain crops and farmers' group affiliation was insignificant, indicating that the acreage under grain crops does not determine the sample grouping. Therefore, the difference-in-difference model is valid under the random selection hypothesis.

Second, we test the parallel trend assumption since one of the essential preconditions of the difference-in-difference method is that it conforms to the parallel trend assumption (Abadie, 2005). In other words, without the agricultural subsidy reform, the trend in the acreage under grain crops would have been the same in both the treatment and control groups. Due to the lack of data, we cannot follow previous studies that use historical data to examine the above rules. Like Hu et al. (2021), we use the area the farmer allocated to grain crops in 2015 as the dependent variable and whether the farmer belonged to the treatment group in 2017 (1 = Yes, 0 = No) as the key explanatory variable. The results are presented in Table 5. Before implementing the new agricultural policy, there were no significant differences between the areas farmers had under grain crops in the treatment group and their counterparts. As a result, even without the policy, the same trends relating to grain crop acreages applied to both the experimental and control groups. Thus, we can conclude that the difference-in-difference estimator is valid according to the parallel trends' assumption.

6. Potential mechanisms and heterogeneity analysis

6.1. Potential mechanisms

The evidence presented in Section 5 suggests that the implementation of China's new agricultural subsidy policy increased the acreage under grain crops. This section indicates potential channels, from the perspectives of land transfer participation and crop restructuring by households, to explain how the farm subsidy increases the area planted with grain crops. Instead of using the grain acreage as the dependent variable in the difference-in-difference regressions, we replaced it with land renting-in (renting-out) and the share of grain crops (cash crops) to identify the mechanism by which the agricultural subsidy influences the grain crop acreage.[15]

The results of the mechanism tests are reported in Table 6. The coefficient of the agricultural subsidy does not only reveal a positive relationship between the subsidy and rented-in land of operators but also with their share of grain crops. In contrast, the coefficient of the

[13] Note that in China farmers do not legally own land (Kung, 2002). However, it is important that their legitimate land tenure rights are officially acknowledged. In 2003, the Chinese government started land certification that entitled farmers to out-transfer land use rights. In 2009, Anhui province started the first pilot scheme for rural land certification in China. The 2009 reform continued till 2013, known as as "Phase I" of the 2009 land reform. Afterwards, "Phase II" of the reform began in 2014, with the central government officially announcing that the land reform was extended to all 31 provinces nationwide. By the end of 2016, a total of 22 provinces issued guidelines for the implementation of the 2009 land reform (Xu and Du, 2022).

[14] Xu and Du, 2022 note that the 2009 land certification program increased both renting-in and renting-out farmland. Furthermore, farming families with land certification increased expenditure on inputs and the household income rose.

[15] As with the logarithm of the grain acreage, 0.001 is added to the value of the share of grain crops (cash crops) before taking the logarithm to avoid loss of observations where the operator does not grow anything (Qian et al., 2022).

Table 8
Scale heterogeneity analysis for different operational farm sizes of growers (difference-in-difference estimation).

	Dependent variable: grain-sown area (*Mu*)			
	(1)Operational scale (Mu≦30)	(2)Operational scale (30 < Mu≦50)	(3)Operational scale (50 < Mu≦100)	(4)Operational scale (Mu > 100)
$D_i \times Time_t$	0.056**	0.039***	0.023**	0.024
	(0.025)	(0.014)	(0.011)	(0.154)
Age of decision-maker	−0.001	0.002	0.067	−0.011
	(0.001)	(0.005)	(0.046)	(0.009)
Education of decision-maker	−0.002	0.092	0.091	−0.090**
	(0.004)	(0.082)	(0.091)	(0.043)
Number of residents	0.009	0.012	0.576**	0.161
	(0.008)	(0.017)	(0.242)	(0.104)
Share of farm labor in family	0.049	0.053	0.747	0.135
	(0.037)	(0.105)	(0.579)	(0.201)
Machinery services	0.016**	0.021**	0.025**	0.028**
	(0.008)	(0.010)	(0.011)	(0.013)
Hired labor	−0.014	0.138	0.315	0.018
	(0.033)	(0.349)	(0.512)	(0.203)
Grain crops cost	−0.000	−0.008	0.003	−0.011***
	(0.000)	(0.005)	(0.023)	(0.002)
Grain crops price	0.007**	0.012***	0.016**	0.021**
	(0.003)	(0.004)	(0.008)	(0.010)
Cash crops cost	0.000	0.004	−0.002	0.001
	(0.000)	(0.003)	(0.018)	(0.001)
Cash crops price	−0.002**	−0.017*	−0.015*	−0.011
	(0.001)	(0.010)	(0.009)	(0.017)
Contracted land area	0.015**	0.004**	0.001	0.002
	(0.006)	(0.002)	(0.009)	(0.002)
Land certification	0.015*	0.022**	0.022***	0.039**
	(0.009)	(0.009)	(0.007)	(0.016)
Land rent of the village	−0.002	−0.018***	−0.021***	−0.041
	(0.003)	(0.006)	(0.008)	(0.026)
Off-farm employment	0.042	0.012**	0.011**	0.023*
	(0.063)	(0.006)	(0.005)	(0.013)
Personal income	−0.000	−0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Individual fixed effect	YES	YES	YES	YES
Time fixed effect	YES	YES	YES	YES
Constant	1.568***	2.546	2.236	2.963
	(0.441)	(2.037)	(3.712)	(3.877)
Number of observations	7,498	896	574	188
Number of households	3,749	448	287	94
within R^2	0.247	0.569	0.405	0.787

Notes: The dependent variable is measured in natural logarithm form. Standard errors are reported in parentheses. *, **,*** Significant at the 10%, 5%, 1%-level.

agricultural subsidy indicates a negative relationship between the subsidy and rented-out land of operators and their share of cash crops. These findings suggest that China's new agricultural subsidy policy promotes the area sown with grain crops by encouraging operators to rent land and increase their share of grain crops. Our finding is consistent with Xu and Du (2022) and Yi, Sun and Zhou (2015). Yi, Sun and Zhou (2015) argue that grain subsidies had a non-negligible effect on areas planted with grain under the existence of the land rental market. Our finding also suggests that the policymakers have achieved their objective of encouraging operators to grow grain crops on a large scale. In addition, the land rent of the village is negatively related to land renting-in, while it is positively related to land renting-out. An explanation is that higher village land rents inhibit the renting-in behavior of operators who received the subsidy and encourage the renting-out behavior of operators who have not received the subsidy. Consistent with Qian et al. (2022), we also find that higher purchase of agricultural machinery services by operators leads to a higher probability of land renting-in and a lower probability of renting-out.

6.2. Heterogeneity analysis

Up to now, the analysis assumes that the agricultural subsidy's effect on the area under grain crops is identical across all farmers and regions. However, China is a large country with farmers and regions exhibiting tremendous differences. Particularly, the land transfer market in China is becoming increasingly heterogeneous[16], transforming from traditional relationship-based transactions between acquaintances to price-based transactions with market participants such as cooperatives and agribusinesses (Zhan,2017; Rogers et al., 2021; Qiu et al., 2020). This implies that the effect of the agricultural subsidy might vary widely due to these heterogeneous characteristics. We test for variations in the agricultural subsidy's effect on the area under grain crops by estimating it for subsamples of various types of operators (types of cultivation and size of operation) and different regions. We use the same model as our base specification in Table 3.

First, we divided the sample into mixed crop growers who cultivate both grain and cash crops and grain crop growers according to their sowing status in 2015. Results are reported in Table 7 and indicate that the new agricultural subsidy policy has a positive and significant effect on grain crop acreage for both grain and mixed crop growers. However, the effect of the subsidy is stronger for grain crop growers than for mixed crop growers. Our finding is consistent with Yi, Sun, and Zhou (2015). It may be that mixed crop growers have higher asset specificity (e.g., years of experience growing cash crops or considerable fixed asset investments), which makes them hesitant to change farming structures (Hao et al. 2018). In addition, mixed growers differ from grain growers

[16] As described in chapter 3, the capitalization of agricultural subsidies and their impact on the grain sown area is strongly influenced by the development of land transfer markets.

Table 9
Regional heterogeneity analysis for Northern and Southern region (difference-in-difference estimation).

	Dependent variable: grain-sown area (*Mu*)	
	(1) Northern	(2) Southern
$D_i \times Time_t$	0.059***	0.047***
	(0.021)	(0.018)
Age of decision-maker	−0.000	−0.000
	(0.001)	(0.004)
Education of decision-maker	0.001	−0.002
	(0.003)	(0.003)
Number of residents	0.015	0.011
	(0.012)	(0.020)
Share of farm labor in family	0.021	0.010
	(0.017)	(0.009)
Machinery services	0.015***	0.009
	(0.005)	(0.011)
Hired labor	0.036	0.041
	(0.037)	(0.034)
Grain crops cost	−0.000	−0.001
	(0.000)	(0.001)
Grain crops price	0.006**	0.002**
	(0.003)	(0.001)
Cash crops cost	0.000	0.001
	(0.000)	(0.001)
Cash crops price	−0.001	−0.002**
	(0.001)	(0.001)
Contracted land area	0.004**	0.002
	(0.002)	(0.002)
Land certification	0.036**	0.029**
	(0.015)	(0.014)
Land rent of the village	−0.012	−0.018**
	(0.010)	(0.009)
Off-farm employment	0.056	0.064
	(0.085)	(0.070)
Personal income	−0.000	−0.000
	(0.000)	(0.000)
Individual fixed effect	YES	YES
Time fixed effect	YES	YES
Constant	2.095***	1.289***
	(0.139)	(0.151)
Number of observations	4,930	4,226
Number of households	2,465	2,113
within_R^2	0.236	0.201

Notes: The dependent variable is measured in natural logarithm form. Standard errors are reported in parentheses. *, **,*** Significant at the 10%, 5%, 1%-level.

in that they are sensitive to the price and production costs of cash crops. At the same time, the average rental price of land in villages is negatively related to the area sown with grain crops of mixed growers who have a stronger resistance to market risk (Asfaw et al., 2019).

Second, we use 30 mu (2.00 ha), 50 mu (3.33 ha), and 100 mu (6.66 ha) as thresholds for the different farm sizes.[17] As shown in Table 8, the new agricultural subsidy policy is positively related to the grain sown area for operators with farm sizes less than 100 mu (columns 1, 2, and 3). However, the marginal effect of the subsidy decreases with increasing farm size and for operators with more than 100 mu (column 4), the effect of the subsidy is no longer significant. Operators with different farm sizes not only have different production capacities, risk resistance, and resource endowments, but also face an unequal land transfer market (He et al., 2022). Recall that the capitalization effect of agricultural subsidies increases with the land transfer market changing from a relationship-orientation to a price-orientation, eventually completely offsetting the income effect of the subsidy on grain acreage. At the same time, land rent of the village has a negative effect on grain sown area in columns 2 (30 < Mu≦50) and 3 (50 < Mu≦100), while the effect is not significant in columns 1 (Mu≦30) and 4 (100 < Mu). An explanation is that the land rental market for small farmers (Mu≦30) is still relationship-oriented, so the land rent does not affect their cropping decisions (Wang et al., 2015; Lin and Chen, 2021). In contrast, large-scale operators (greater than100 Mu) must grow grain due to their severe labor constraints, which could reduce the potential negative impact of rent on grain acreage (Qiu et al., 2020).

Third, we conducted a regional heterogeneity analysis on the effects of the agricultural subsidy on the acreage under grains. We divided the sample into two regions, Northern and Southern, and estimated the effect of the subsidy on the acreage under grain crops for these two regions seperately. Table 9 shows that agricultural support from the new subsidy significantly affects grain-growing areas in the Northern and Southern regions. However, the effect of the subsidy is stronger in the Northern region than in the Southern region. This may be due to the fact that the north is China's main grain production region, where farmers are more sensitive to the agricultural subsidies (Wang et al., 2018). At the same time, the negative effect of land rent on grain sown area is significant in the Southern region, but not significant in the Northern region. According to our previous analyses, the land transfer market is less developed in the Northern region than in the Southern region, so land rent has a smaller impact on agricultural production decisions.

7. Conclusions and policy implications

China's agricultural subsidy policy has undergone significant changes in recent years. The migration of over 185 million farmers from rural to urban areas and flourishing land rental markets revealed the problems arising from a mismatch in China's agriculture subsidies policy which denied subsidies to the actual operators on the land. Concerns about national food self-sufficiency and policy misalignment led China to change its agricultural subsidy policy in 2016. The new policy, designed to support the actual operators, has been implemented nationwide.

In this paper, we adopt the difference-in-difference method to verify the impact of the new agricultural subsidy on grain production. Its mechanism and heterogeneity effects are investigated using a unique panel dataset. First, our empirical results show that China's new agricultural subsidy policy significantly and positively affects the acreage under grain crops. The results are robust after controlling for potential interference from other policy measures.

Mechanism analysis reveals that the agricultural subsidy policy encourages operators to increase their grain crop acreages by renting more land and increasing their share of grain crops. Moreover, heterogeneity analysis shows that the impact of the subsidy on the grain crop acreage is heterogeneous due to differences between the operators and regions. We find that the subsidy effect is larger for grain growers than for mixed crop growers. For operators with land less than 100 mu, the marginal effect of the subsidy policy continuously decreases with increasing land size and becomes insignificant for farmers ith land greater than 100 mu. Finally, we find that the impact of the subsidy is more pronounced in the Northern area than for the Southern region.

Our findings also have policy implications. With its growing economic power, China has continued to stimulate agricultural production through price support and agricultural subsidies, which has sparked complaints from WTO members, including the United States. We note that a case brought by the U.S. against the price support China provided to grain producers was approved by the WTO in 2019 (WTO dispute settlement DS511). In this situation, restructuring agricultural support policy, i.e., abandoning price support for wheat and rice and shifting to the producer subsidy program, can be seen as a plausible alternative policy design. In the long run, however, the incentive effect of agricultural subsidies will inevitably decline as the land rental market develops.

[17] Since the central government does not set nationwide thresholds for farm size, many provinces set their standards according to local economic and social development levels, production technology conditions, and labor migration (Li et al., 2021). Referring to the existing studies (Rogers et al., 2021; Sheng et al., 2019; Zheng et al., 2022), we use 30 mu, 50 mu, and 100 mu as the threshold.

Table A1
The difference in grain sown area by land renting-in in the treatment group.

Variable	Land renting-in group					Without land renting-in group				
	2015		2017		Diff.	2015		2017		Diff.
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Grain, sown area (mu)	10.25	0.82	56.92	6.25	46.67***	10.02	0.75	34.21	1.15	24.19**
Number of observations	429			429		728		728		
Number of households	429					728				

Source: Authors' own calculations.

In particular, subsidizing large farms will drive up the price of farmland and increase the burden on agricultural production. On the positive side, more and more local governments are using their agricultural subsidy funds to develop a farm credit system or to extend green agriculture techniques. China's new agricultural subsidy appears to be moving in a "green" and "decoupling" direction, which could benefit U.S. agriculture and other competitive suppliers. Furthermore, the high land rent threatens grain production in the Southern region. Therefore, China should strive to improve the grain self-sufficiency of the Southern region.

This research could be extended to explore various other aspects. Due to data limitations, we could only examine the agricultural subsidy's influence on grain crop acreages and its impact on grain yields still remains unclear. Therefore, the effect of agricultural subsidies on agricultural production must be analyzed in depth to identify their impact on global grain markets and trade. Moreover, data limitations also restricted our investigation to the short-term impact one year after the reform. Further research into its long-term effects requires better data and other, more advanced approaches.

CRediT authorship contribution statement

Pengfei Fan: Conceptualization, Data curation, Formal analysis, Writing – original draft. **Ashok K. Mishra:** Conceptualization, Methodology, Project administration, Writing – review & editing. **Shuyi Feng:** Conceptualization, Methodology, Project administration, Writing – review & editing. **Min Su:** Conceptualization, Methodology, Project administration, Writing – review & editing. **Stefan Hirsch:** Conceptualization, Methodology, Project administration, Writing – review & editing.

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.

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Appendix A

See Table A1.

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