The Impact of Chinese Rice Support Policies on Rice Acreages

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Abstract

Declining arable land and yield stagnation challenge food security in China. Since 2004, the Chinese government has introduced a bundle of subsidies and income support measures to stimulate production and increase national food security, including a minimum procurement price in the main rice-cultivating regions. Rice acreages have increased since 2004, but this could also be due to rising rice price levels nationally and globally. This raises the question whether the rice support policies were effective. Using a natural experiment created by the minimum procurement price policy being introduced in selected regions, we use a dynamic fixed effects model to perform a difference-in-differences analysis on the effectiveness of these rice support policies. We find that indica rice acreages respond to changes in the rice prices, and, controlling for rice prices, that China's rice support policies were effective in increasing rice acreages of both early and late indica between 2004 and 2017.

Keywords Rice acreages, policy intervention, impact assessment, China, panel data

JEL code Q15, Q18, C23

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1. Introduction

The agricultural challenges for China include maintaining farmers' incomes, achieving sustainable agricultural development and ensuring national food security (Huang and Yang, 2017). With only 6% of fresh water and 7% of arable land in the world, China has to feed nearly 20% of the world's population (Wong and Chan, 2016). Therefore, ensuring food security, especially grain security, is important for economic development and social stability (Li et al., 2013).

Rice is the main staple food for more than half of the world's population (Fukagawa and Ziska, 2019) and China consumes more rice than any other country, 155 million metric tons in 2021 (USDA, 2022). Due to increased grain yield and improved crop management practices, such as fertilization and irrigation, rice production in China has increased from 40 million metric tons in the 1960s to more than 200 metric tons in the 2010s. However, the rate of rice yield growth has slowed markedly since 2000 (Deng et al., 2019; National Development and Reform Commission [NDRC], 2021). To feed its growing population, China will need to produce around 20% more rice by 2030 compared to 2008 (Peng et al., 2009).

From 1976 to 2004 there was a declining trend in rice acreages in China (NDRC, 2017). The continuously decreasing rice acreages in combination with China's desire for national food security triggered the introduction of various policy interventions since 2004. The first set of measures include the abolition of taxes and fees and the introduction of subsidy programs since 2004. Price intervention was introduced to ensure minimum procurement prices for rice since 2004 (Huang and Yang, 2017). Subsidies for seed, machinery and aggregate inputs as well as a direct subsidy that is expected to improve farmers' income were also introduced (Yi et al., 2015).

After 2004, rice acreages stabilized and even increased by 8.3% between 2004 and 2017 (NDRC, 2017). However, in that same period, international rice prices also rose, culminating in the 2008 and 2011 price peaks (FAO, 2022). This raises the question whether the increasing rice acreage is due to the policy intervention or due to the increasing domestic rice price in line with the international rice price.

The objective of this paper is to investigate whether the minimum procurement price policy had a positive effect on rice acreages in China given the increased rice prices. In order for the rice support policies to be effective, there are two questions to be answered. First, did rice acreages respond to rice support policies via expected rice prices? If rice acreages did not respond to expected prices, we would not expect the minimum procurement price policy to be effective. Second, was there a positive impact of the policy support on rice acreages?

These two questions will be analysed with a dynamic fixed effects panel data model using acreage data and domestic prices for 3 main rice varieties (early, middle, and late indica) for 15 Chinese provinces in the period 1988-2017. We use a natural experiment created by the minimum procurement price policy by distinguishing between provinces that implemented this policy (treated) and those that did not (control). The difference-in-differences method is used to assess the impact of the policy intervention on rice acreages in the provinces that adopted the minimum procurement price policy. We focus on rice acreages instead of total production since yields per unit area are directly affected by weather, pests and diseases and other factors over which farmers have little or no control.

Some previous papers studying the effectiveness of the Chinese grain support policies focused on grain subsidy programs. Based on their survey, Huang et al. (2011) concluded that grain subsidy programs did not distort Chinese farmers' decisions in terms of grain area or input use decisions. Yi et al. (2015) and Su et al. (2021) examined the effects of the grain subsidy programs on grain-sown areas in China. A few recent papers studied the effectiveness of Chinese price support policies in a broader sense. Su et al. (2021) applied panel data regression to analyse the impacts of the minimum procurement price program for grain on agrochemical use and found that it negatively affected both chemical fertilizer and pesticides use. Li and Chavas (2018) used quantile auto-regression to investigate the effects of China’s price support policy on price enhancement and price stabilization in the Chinese rice and corn market. Their results show that the price support policy increased the price of corn and contributed to stabilizing the domestic rice market. Wang and Wei (2021) developed an aggregate structural econometric model of China’s soybean market to analyse the worldwide impacts of China’s soybean price support policies from 2008 to 2016. They showed that the soybean price support policies played an effective role in stabilizing the domestic price and the welfare distribution. Lyu and Li (2019) used a structural break regime-switching model to evaluate the effectiveness and sustainability of the grain price support policies in China. They found that there is a structural change since 2004 when the price support policies were established, and since then, Chinese grain prices have followed a regime with significantly lower volatility.

So far, the literature focuses on the effectiveness of price support policies in stabilizing domestic grain price and agrochemical use. As far as we are aware, there is not much research on evaluating the effectiveness of the minimum procurement price policy on the acreage change, which also considers the effect of rice price increases in the same period, except for Su et al. (2021). However, they did not distinguish between different rice varieties and studied acreage responses at household level. Due to aggregation effects, elasticities calculated at the macro level in general differ from those calculated at the micro level. This study contributes to the literature by investigating whether the rice support policies were effective for three rice varieties at a macro level given that rice prices increased after 2004. This study has implications for different stakeholders, especially policy makers, in China. Policy implications relate to the scientific evidence of land allocation reactions to price support policies when market prices are increasing, and taking this knowledge into consideration in the design and implementation of agricultural policies aimed at stimulating farmers´ planting behaviour in compliance with China’s grain self-sufficiency policy.

2. Background information on Chinese rice policies and acreages

Rice planting practices in Chinese regions differ due to heterogeneous climatic conditions. Paddy rice planting in China distinguishes four main varieties: early, middle, and late indica rice, and japonica rice. Early indica grows primarily in southern provinces along the Yangtze River, which is planted from February to April, and harvested in July. The taste of early indica rice is inferior to other rice, and therefore, it is mainly processed. Middle indica grows primarily in the southwest and in the northern part of China and is planted from March to June, and harvested in October. Late indica is planted after the early indica harvest, and is harvested in November. Late indica needs relatively more time to ripen due to the cold weather. The other popular rice is japonica, most of which is planted in the northern part of China. Figure 1 shows the regional distribution of different kinds of rice in 2017.

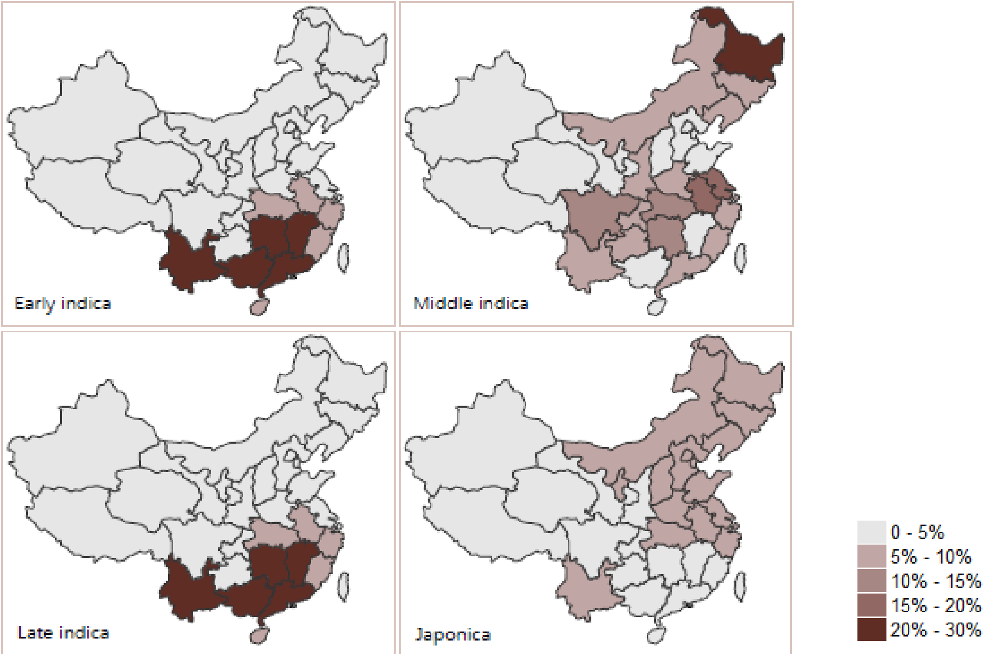


Figure 1. Distribution and planting density of four rice varieties in 2017
Data source: Authors, based on Ning and Hu (2017)
Note: The acreage data for japonica is not available. Therefore, the coloured area for japonica only indicates where it was planted in 2017.

The annual total acreage for rice was 30 million hectares in China in 2019, which is 18% of the world's rice acreage (FAOSTAT, 2020). Three-quarters of the acreage in China is planted with indica varieties, and the rest with japonica varieties. More than 40% of acreage is planted with high-quality rice due to the improvement of living standard and increasing demand for high-quality rice (Peng et al., 2009). Between 1978 and 2004, the acreages of main rice varieties in China decreased by 17.4% from 34.4 to 28.4 million hectares (NDRC, 2017).

To curb the steady decline in total rice acreage, the government initiated several policy interventions from 2004 onward. These interventions include different kinds of subsidies, starting with the "direct grain subsidy", "quality seed subsidy", and "machinery subsidy" in 2004, and extended to the "aggregate input subsidy" in 2006. As their names indicate, these direct subsidy programs subsidize planting grains and the costs of buying quality seed, machinery and inputs, such as chemical fertilizer and fuel (Huang and Yang, 2017). However, according to Huang and Yang (2017), these subsidies had a moderate impact on farmers' incomes and a negligible impact on grain production. In addition, there have been direct payments to rice producers since 2004 to motivate cultivation. The direct payments and subsidy programs target all provinces in China (Yi et al., 2015).

Other important policy interventions include the temporary storage program for maize, rapeseeds, and soybean since 2008, and the price intervention program with minimum procurement prices, which has been implemented for rice since 2004 (Gale, 2013; Huang and Yang, 2017) and for wheat in 2006 (Lyu and Li, 2019). The Chinese government set the minimum procurement price for rice to ensure that it is high enough to cover the production cost and earn a profit. Different from direct payments and subsidy programs, the minimum procurement price is only implemented in the main production provinces (Lyu and Li, 2019), and is set annually for different kinds of rice based on the production cost, market demand and supply, as well as prices at home and abroad. Those provinces include Anhui, Jiangxi, Hubei, Hunan, Jilin, Heilongjiang and Sichuan, and since 2008 also Liaoning, Jiangsu, Henan and Guangxi (Cheng, 2011; Su et al., 2021)[1]. The selection of the provinces is a top-down decision made by the Chinese government.

The minimum procurement price is announced in January before rice is planted. If the domestic market price falls below the minimum price set by the government, the state-owned China Grain Reserve Corporation, i.e. Sinograin, and qualified enterprises entrusted by Sinograin will purchase the rice from farmers (Su et al., 2021). Purchased rice is stored until it can be auctioned at a grain exchange at a higher price. The Chinese government subsidizes storage and operational costs (Gale, 2013). Figure 2 shows the level of the minimum procurement price for early, middle, late indica and japonica in China between 2004 and 2021. The minimum procurement price for each rice variety has been gradually increasing until 2014. It stabilized in 2015, decreased in 2016, and stabilized again since 2018 (NDRC, 2021).

[1] Consultation of experts of China's agricultural policies did not result in a consistent list of provinces that voluntarily implemented the policy and the years of implementation. We therefore prefer to use the only documented information that we are aware of, that provided by Cheng (2011).

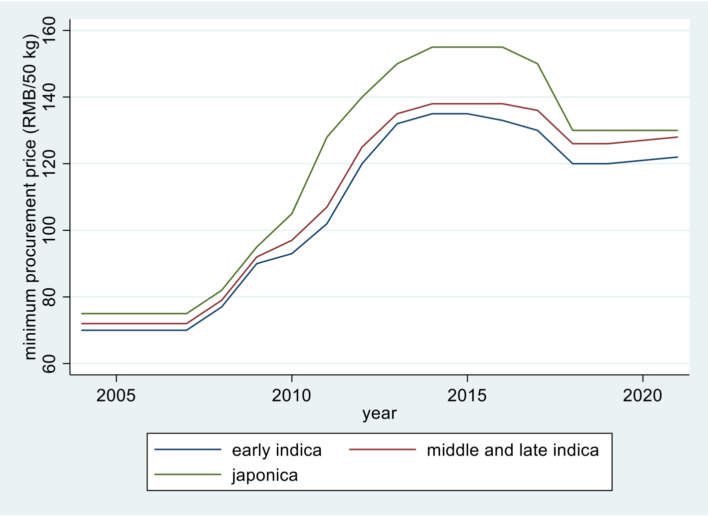


Figure 2. The minimum procurement price for early, middle, and late indica and japonica in China
Data source: Authors' calculations based on NDRC (2021)

3. Data

The data used for the analysis are yearly provincial acreages (1988-2017) from Ning and Hu (2017), and provincial market prices of early, middle and late indica (1975-2017) in 15 provinces in China (see Appendix 1) from the NDRC (2017). We only focus on early, middle and late indica because the provincial acreages for japonica are not available.

Figure 3 shows the development of provincial acreages for early, middle and late indica rice. As observed, acreages in general were decreasing before 2004, especially for early and late indica. After 2004, the acreages stabilized and in some provinces even increased. This trend is not clear for middle indica as the acreages in some provinces were increasing before 2004.

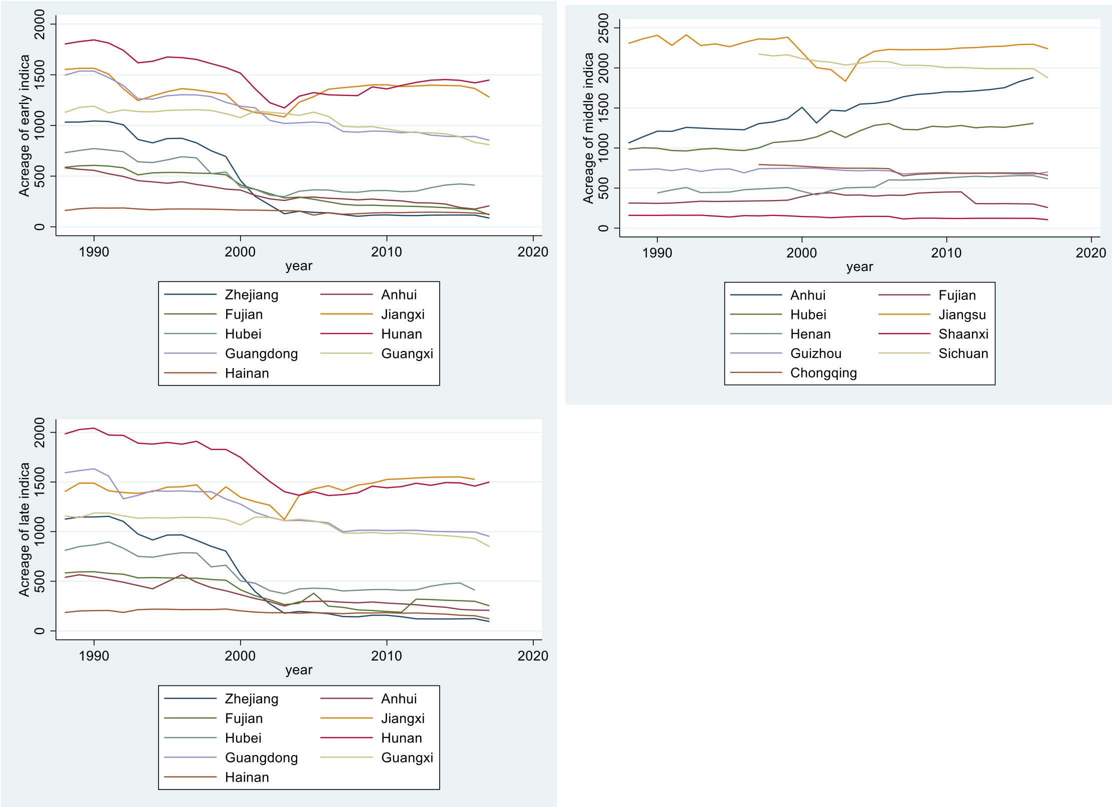
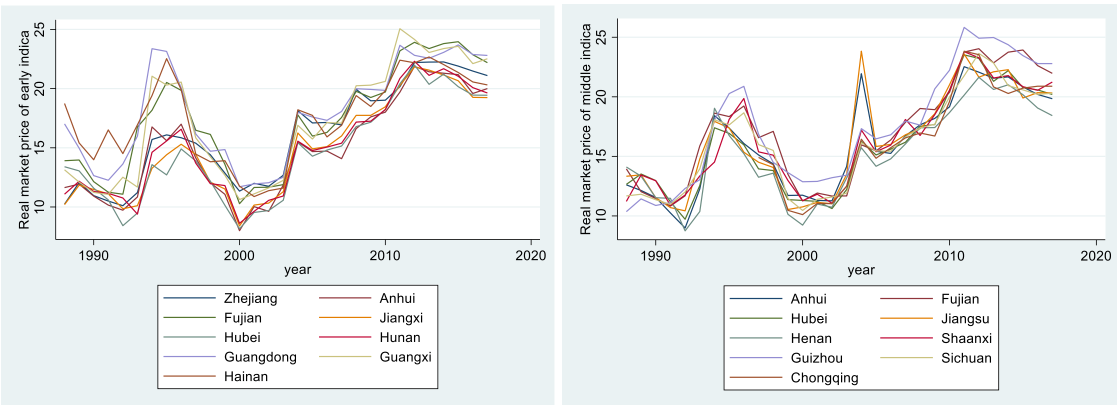


Figure 3. Provincial acreages (1000 ha) of early, middle and late indica in China from 1988 to 2017
Data source: Ning and Hu (2017)

Figure 4 shows the provincial real market prices for early, middle and late indica rice, and japonica rice. All prices are rather volatile, with a peak in the mid-1990s, then rapidly declining until early 2000, after which a gradual increase started that lasted until 2012, after which prices slightly declined again.



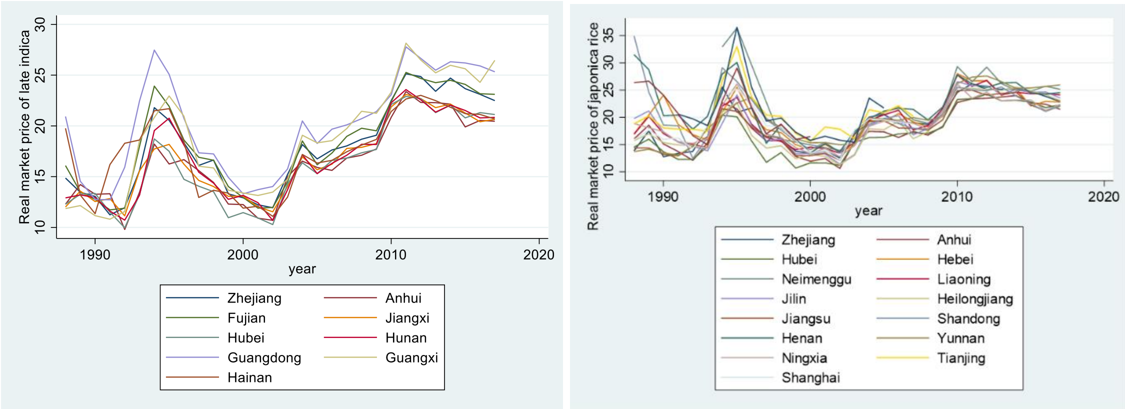


Figure 4. Provincial market prices (RMB/50 kg, base year=1978) of early, middle, late indica and japonica in China, 1988-2017
Data source: NDRC (2017)

Table 1 provides descriptive statistics of the data used in our study. Treated provinces, provinces that implemented the minimum procurement price for rice, include Anhui, Jiangxi, Hubei, Hunan, Guangxi, Jiangsu, Henan and Sichuan (see notes 4-6 below table 1 for details per rice variety). Although Liaoning, Jilin and Heilongjiang are also in the treated group, no complete price data is available. Control provinces include Zhejiang, Fujian, Guangdong, Hainan, Chongqing, Guizhou and Shaanxi. These are not all rice-growing provinces in China, but their acreage and price data are complete. Therefore, we focus our study on those provinces. We provide detailed information on provinces and rice varieties in Appendix 1. For all considered provinces, average real prices and average expected prices – based on the minimum procurement price and weighted lagged prices, see equation (4) below – for all rice varieties were higher after 2004 when the minimum procurement price policy was implemented in most treated provinces. For all considered provinces, average rice acreages of early and late indica were lower after 2004. For the middle indica in the treated provinces, average rice acreages were higher after 2004, but there was no significant difference for those in the control provinces.

Table 1. Descriptive statistics[1] of main variables, 1988-2017

	Early indica		Middle indica		Late indica	
Before 2004	Treated[4]	Control[4]	Treated[5]	Control[5]	Treated[6]	Control[6]
Real price (RMB/50 kg[2])	12.14	14.46	13.04	13.67	13.97	15.82
	(2.65)	(3.32)	(2.53)	(2.85)	(2.80)	(3.84)
Expected price[3]	12.29	13.40	12.51	10.92	12.50	13.81
	(3.11)	(5.43)	(4.17)	(6.51)	(5.75)	(7.39)
Acreage (1,000 ha)	1020.44	681.23	1370.98	457.74	1101.74	732.81
	(468.22)	(450.24)	(667.65)	(258.38)	(511.10)	(479.23)
After 2004						
Real price	18.90	20.33	19.25	20.15	20.34	21.54
	(2.81)	(2.40)	(2.63)	(3.09)	(3.07)	(3.12)
Expected price	19.41	20.51	20.04	20.31	20.79	21.75
	(2.88)	(2.56)	(2.87)	(3.28)	(3.16)	(3.20)
Acreage	870.97	350.86	1566.02	471.05	921.56	401.15
	(484.81)	(345.84)	(591.22)	(243.57)	(510.30)	(367.24)
Difference before / after 2004 (after - before)						
Real price	6.77***	5.87***	6.21***	6.48***	6.37***	5.72***
	(0.45)	(0.52)	(0.42)	(0.56)	(0.48)	(0.64)
Expected price	7.12***	7.11***	7.53***	9.39***	8.30***	7.94***
	(0.49)	(0.76)	(0.58)	(0.92)	(0.75)	(1.01)
Acreage	-149.47**	-330.37***	195.04**	13.32	-180.18**	-331.65***
	(78.40)	(72.82)	(107.71)	(47.68)	(84.23)	(77.44)

Source: Authors, based on Ning and Hu (2017) and NDRC (2017).
Note 1: Mean values are presented, with standard deviations in parentheses. *, **, and *** indicates statistical significance at 10%, 5%, and 1% level, respectively.
Note 2: Adjusted by the Consumer Price Index, with 1978 as the base year.
Note 3: Expected price is defined below in equation (4) as the maximum of the expected market price (derived from past prices) and the minimum procurement price.

Note 4: Treated provinces (Anhui, Jiangxi, Hubei, Hunan, and Guangxi) and control provinces (Zhejiang, Fujian, Guangdong, and Hainan)
Note 5: Treated provinces (Jiangsu, Anhui, Henan, Sichuan, and Hubei) and control provinces (Fujian, Chongqing, Guizhou, and Shaanxi). We dropped Hunan from the treated group as there exist too many consecutive missing values in price.
Note 6: Treated provinces (Anhui, Jiangxi, Hubei, Hunan, and Guangxi) and control provinces (Zhejiang, Fujian, Guangdong, and Hainan)

4. Model specification

To investigate whether the minimum price policy was effective in increasing the rice acreage, we use a dynamic fixed effects (FE) panel data model that allows for doing a difference-in-differences analysis. Difference-in-differences is a quasi-experimental method that utilizes data from treated and control groups to assess a causal effect. It is widely used to assess the impacts of policy intervention by comparing the changes in outcomes over time between a treated and control group (Card and Krueger, 1993; Tiwari et al., 2016). In our case, we use it to compare changes in rice acreage between provinces that implemented the minimum procurement price policy for rice and provinces that did not.

The parallel trend assumption ensures that the control group provides the appropriate counterfactual of the trend that the provinces in the treated group would have followed if they had not been treated. Testing this assumption requires the difference between the treated and control groups to be similar over time in the absence of treatment (Cunningham, 2021: 429). Figure A1 in Appendix 2, shows that early and late indica meet the parallel trend assumption that three leads of the treatment are not significantly different from zero while middle indica does not meet the assumption. Therefore, we cannot use the difference-in-differences method to assess the policy effectiveness for middle indica. We will test the acreage response of three rice varieties to their prices and focus on early and late indica only for assessing the impact of the rice policies.

Modelling in a dynamic way is important, because the rice acreage in the current year is highly dependent on the acreage in the previous year, accounting for momentum and inertia. Although including the lagged acreage introduces endogeneity, research has shown that when the time period covered by the data (T) is large, the within fixed effects estimator is consistent for dynamic models (Verbeek, 2017: 406).

Before estimating the dynamic FE difference-in-differences model, we first estimate a basic dynamic model to test acreage response of a variety to its lagged acreage, its expected price and a general time trend (equation 1). Next, we extend this model by including a dummy capturing the period since the policy interventions, so the combined effect of the minimum procurement price and other rice support policies in general (equation 2). Finally, equation (3) separates the treatment effect of the minimum procurement price policy from other rice support policies by performing the difference-in-differences analysis.

$$acreage_{int} = \beta_{i0} + \beta_{i1} acreage_{int-1} + \beta_{i2} p^e_{int} + \beta_{i3} t + \sum_{n=1}^{N} \gamma_n \overline{acreage}_t + \alpha_{in} + \nu_{int} \quad (1)$$

$$acreage_{int} = \beta_{i0} + \beta_{i1} acreage_{int-1} + \beta_{i2} p^e_{int} + \beta_{i3} t + \beta_{i4} d_{nt} + \sum_{n=1}^{N} \gamma_n \overline{acreage}_t + \alpha_{in} + \nu_{int} \quad (2)$$

$$acreage_{int} = \beta_{i0} + \beta_{i1} acreage_{int-1} + \beta_{i2} p^e_{int} + \beta_{i3} t + \beta_{i4} d_{nt} + \beta_{i5} did_{nt} + \sum_{n=1}^{N} \gamma_n \overline{acreage}_t + \alpha_{in} + \nu_{int} \quad (3)$$

where $acreage_{int}$ denotes the rice acreage and p^e_{int} the expected price of rice variety *i* in province *n* in year *t*. We include time *t* as a trend term in the model to control for factors that affect land use over time, such as industrialization and urbanization. Furthermore, d_{nt} is a period dummy that equals 1 after the year of announcing the minimum procurement price policy and 0 otherwise; did_{nt} is the difference-in-differences policy treatment effects, defined as the interaction between the treated provinces and the period dummy; α_{in} denotes the provincial fixed effects and v_{int} is the residual.

A major concern in lengthy macro-economic panels is cross-section dependence, which implies correlations in unobservables across provinces. Pesaran (2006), Bai (2009) and Greenaway-McGrevy et al. (2012) recommend adding common factors to the panel regression in order to deal with this problem. Therefore, we add cross-sectional average of rice acreages ($\overline{acreage}_t$) to the equations (Gaibulloev et al., 2014), each with a province specific coefficient. These can be considered as a supplement to time fixed effects, because they are weighted by the acreage of a specific year.

We assume that farmers in southern and central China cannot easily switch between paddy rice and other crops. The main alternative to growing indica rice in these regions is land abandonment, which is a major problem in particular in the hilly areas in these regions (Xu et al., 2019). Therefore, we do not include prices of other crops in the model. However, for middle indica we also estimated a model with the relative expected price between middle indica and japonica rice to capture possible substitution effects because there are some overlapping provinces cultivating both rice varieties. No substitution effect is found (Table A1 in Appendix 2) and therefore, only the expected price of rice p^e_{nt} is included in the model. Nerlove (1958) argues that farmers react not to last year's price, but rather to the expected price. Shonkwiler and Maddala (1985) argue that the presence of the price intervention program should directly affect farmers' expectations. Therefore, expectations should be conditioned by both market conditions and the intervention. Nerlove (1958) argues that although in theory all past prices are supposed to be included, we can ignore prices in the very distant past.

In this study, we assume that expected prices depend on prices from the past five years. The expected price can be defined as a weighted function of past prices with declining weights. We define the weights using an exponential format, $\gamma_j = \varphi^j,\ j = 1, 2, 3, 4, 5$ (Richardson et al., 1998; Bollen, 2015). Since the weights should sum up to 1, we calculate $\varphi \approx 0.51$. Besides the weighted lagged prices, the expected price is also based on the announced minimum procurement price. Combining both elements, the expected price is expressed in equation (4), which indicates that the expected market price equals either the announced minimum procurement price, or the expected market price in case this exceeds the minimum price. For the period before 2004 when there was no minimum procurement price, the expected price equals the weighted lagged price.

$$p_t^e = \max\left\{ p_t^{\min},\ p_{t-1}\sum_{j=1}^{5}\varphi^j\left(\frac{p_{t-j+1}-p_{t-j}}{p_{t-j}}+1\right)\right\} \tag{4}$$

For equation (1) we are interested in particular in parameter β_{i2}, indicating whether the expected price has a significant positive impact on the acreage response. Price responsiveness is a precondition for the minimum procurement price policy to be effective, i.e. in affecting the rice acreage. If farmers do not respond in their acreage decisions to changes in expected prices, a minimum procurement price policy is not expected to work. However, if farmers do respond to changes in expected prices, we cannot conclude that the policy is necessarily effective. Besides, we are also interested in the coefficient β_{i4} in equation (2), which captures the combination effect between minimum procurement policy and other rice support policies. β_{i5} in equation (3) indicates whether the minimum procurement policy was effective, because adding in the interaction term did_{nt} disaggregates the effect of minimum procurement policy from other rice support policies indicated by d_{nt}.

5. Results and discussion

We estimate equations (1) - (3) for main rice-producing provinces in China between 1988 and 2017. Acreage, lagged acreage and expected price are in natural logarithms. Table 2 shows parameter estimates and test statistics of acreage response and effectiveness of policy support.

For all rice varieties, the lagged acreage has a significant impact on the current acreage as expected showing the sluggishness of acreage adjustments. Expected prices have a statistically significant positive effect on acreages in equation (1) for all rice varieties, which is consistent with the literature (Haile et al., 2015). This is an important prerequisite for the rice price subsidy to be effective, since it shows that acreages do respond to rice price changes. The estimated price elasticities are low though. A 1% increase in rice prices, only leads to acreage increases of 0.04% to 0.09% in the short run and to increases of 0.09% to 0.25% in the long run. Our price elasticity of supply for rice is similar to that in Haile et al. (2015), which equals 0.024 for the short run. Adding the period dummy in equation (2) makes the coefficient of the expected price of late indica insignificant. This may be because acreage response was more heavily influenced by various kinds of rice support policies after 2004. These estimated aggregate responses are considerably lower than the household-level price elasticities of 0.94 (short run) and 1.27 (long run) estimated for rice acreages by Su et al. (2021). This difference might be due to the use of microdata in Su et al. (2021). Since there were many farm exits during the examined period in China, the remaining farmers often increased their scale of production. In a time of increasing prices, this overestimates the price responsiveness at micro level. Moreover, farmers leaving agriculture were replaced by other farmers in the panel dataset used by Su et al. (2021), which provides another source of overestimation of the price responsiveness. Since our study uses total acreages at provincial level, these sources of bias are not present.

The time trend has a statistically significant negative impact on the acreages for middle indica, but not for early and late indica. This may be because the time effect is also largely captured by the common factors capturing cross-sectional dependence. The effect for middle indica is small though, each year the general decline in middle indica area is only 0.4%. The results for equation (2) show that for early and late indica, there is a statistically significant positive change in acreage response after 2004 of 5% to 6%, which can be interpreted as the joint effect from both the minimum procurement policy and other rice support policies.

Equation (3) shows that the minimum procurement price policy increased the acreage of early indica by 6%, which is statistically significant at 10% significance level. The treatment effect is not significant for late indica. However, an F-test rejects at 5% significance level the null hypothesis that the coefficients of the period dummy and treatment are jointly equal to zero. This means that there was a general policy effect after 2004, but the effect from the minimum procurement price policy cannot be separated from the general policy effect. The common factors are significant in controlling unobserved components that ultimately become part of the error term, common shocks and spatial dependence.

The use of the fixed effects estimation approach is justified by the outcome of the F-tests on the province-specific effects. The null hypothesis that these effects are all similar (absence of constant regional differences) is rejected for early and late indica, but not for middle indica. Therefore, for middle indica, we use an OLS regression as robustness check, which shows the same sign and significance, and similar magnitudes for all coefficients (table A2 in Appendix 4). Another robustness check is to use the lagged real price as expected price, and this also yields similar results (table A3 in Appendix 5).

Table 2. Factors explaining the natural logarithm of rice acreage (dependent variable), 1988-2017.

Variables	Dynamic panel model (early indica)			Dynamic panel model (middle indica)		Dynamic panel model (late indica)		
	(1)	(2)	(3)	(1)	(2)	(1)	(2)	(3)
Lagged acreage	0.561***	0.584***	0.557***	0.809***	0.814***	0.486***	0.518***	0.505***
	(0.036)	(0.037)	(0.039)	(0.046)	(0.047)	(0.045)	(0.046)	(0.047)
Expected price	0.094***	0.063**	0.055**	0.042**	0.047**	0.081***	0.047	0.045
	(0.024)	(0.027)	(0.028)	(0.021)	(0.022)	(0.028)	(0.031)	(0.031)
Trend	-0.003	-0.003	-0.003	-0.004***	-0.003***	-0.002	-0.003	-0.003
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
Period dummy		0.046**	0.016		-0.009		0.061***	0.038
		(0.020)	(0.025)		(0.016)		(0.022)	(0.028)
Treatment effect			0.057*					0.043
			(0.029)					(0.032)
Common factor	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-0.069	-0.308	-0.312	-0.505	-0.637	-0.042	-0.343	-0.323
	(0.376)	(0.386)	(0.383)	(0.530)	(0.583)	(0.415)	(0.424)	(0.423)
F-test joint significance	779.23***	733.78***	690.08***	70.99***	65.34***	390.29***	371.18***	346.15***
F-test unit-specific effects	19.48***	17.24***	17.68***	1.13	1.05	14.99***	13.87***	13.98***
Adj. R-squared	0.973	0.974	0.974	0.781	0.780	0.950	0.952	0.952
N	257	257	257	234	234	245	245	245

Note 1: Standard errors are reported in parentheses. *, **, and *** indicates statistical significance at 10%, 5%, and 1% level, respectively.

Note 2: (Lagged) acreage and expected price are in natural logarithms.

Note 3: The difference-in-differences method (equation (3)) is not applied to middle indica as it does not meet the parallel trend assumption.

Note 4: For late indica in equation (3), a joint F-test testing coefficients of period dummy and treatment effect are jointly equal to zero is rejected (p=0.010).

6. Conclusions and policy implications

In order to halt and reverse a trend of declining rice acreages, China introduced in 2004 a set of policies including input subsidies and minimum procurement prices. However, at that time also global rice prices started to increase. This raises the question whether the rice support policies have had a positive effect on rice acreages in China, or whether the observed growth in rice acreages is simply due to the increasing market prices after 2004.

A precondition for the effectiveness of the minimum procurement price policy is that acreages do respond to rice price changes. Our results show that this is the case. Having observed this important precondition, we continued to analyse the impact of the minimum procurement price. Based on a natural experiment generated by the minimum procurement price policy that was introduced in selected provinces, we distinguish between treated and control provinces and adopt the difference-in-differences method for impact assessment. The results indicate that the minimum procurement price policy was effective in increasing rice acreages for early indica by 6%, given that rice prices increased after 2004. Although the combined effect was effective for late indica, we cannot separate the effect of minimum procurement price policy from the general rice support policies after 2004. Impact assessment based on the difference-in-differences method is not valid for middle indica, because it does not meet the parallel trend assumption.

Our results have some important implications for China's food self-sufficiency policy. Price support policies such as the minimum procurement price policy can be effective even when market prices are increasing. They reduce price uncertainty and stabilize volatile markets, which in turn positively influences farmers' price expectations, stimulating their planting behaviour in compliance with policy incentives. In China, the policies stimulate the cultivation of staple food, mitigated land abandonment and the decreasing trend of rice acreage in the past decades, and continue to strengthen cereals production. Although the magnitude of the effect is not large (e.g., 6% larger acreage for early indica), we need to take into consideration that the total acreage in China is large (i.e., up to 5.6 million hectares for early indica in 2004). Therefore, effective policy design and implementation has an impact on increasing the absolute size of rice cultivation, as well as further affecting land rental price according to Lin and Huang (2021).

A combination of increasing acreage and market price between 2004 and 2017 increased total income of rice farmers in China. However, it is important to take into account that a policy may have heterogeneous impacts which are not examined in this study. Further research is needed to investigate treatment heterogeneity regarding different varieties and regions, as well as distributional impacts for different quantiles of farmers based on micro level data.

References

Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *The Review of Economic Studies 58*(2): 277-297.

Bai, J. (2009). Panel data models with interactive fixed effects. *Econometrica 77*(4): 1229-1279.

Bollen, B. (2015). What should the value of lambda be in the exponentially weighted moving average volatility model? *Applied Economics 47*(8): 853-860.

Card, D., & Krueger, A. B. (1993). Minimum wages and employment: A case study of the fast food industry in New Jersey and Pennsylvania. *American Economic Review 84*(4): 772-793.

Cheng, G. (2011). G. *China's Agricultural Subsidies* (1st ed.). China Development Press. [In Chinese]

Cunningham, S. (2021). *Providing Evidence for Parallel Trends Through Event Studies and Parallel Leads*. In Causal Inference: The Mixtape (pp. 425-433). New Haven: Yale University Press. https://doi.org/10.12987/9780300255881-040

Deng, N., Grassini, P., Yang, H., Huang, J., Cassman, K. G., & Peng, S. (2019). Closing yield gaps for rice self-sufficiency in China. *Nature Communications 10*(1): 1-9.

FAO (2022). FAO Rice price update. Available at: https://www.fao.org/markets-and-trade/commodities/rice/fao-rice-price-update/en/#:~:text=The%20FAO%20All%20Rice%20Price,below%20its%20year%2Dearlier%20value (accessed on April 6th, 2022)

FAOSTAT (2020). FAO Statistical databases. Food and Agriculture Organization (FAO) of the United Nations, Rome. www.fao.org.

Fukagawa, N. K., & Ziska, L. H. (2019). Rice: Importance for global nutrition. *Journal of Nutritional Science and Vitaminology 65*(Supplement): S2-S3.

Gaibulloev, K., Sandler, T., & Sul, D. (2014). Dynamic panel analysis under cross-sectional dependence. *Political Analysis 22*(2): 258-273.

Gale, F. (2013). *Growth and Evolution in China's Agricultural Support Policies*. Economic Research Report Number 153. Washington, D.C.: USDA - Economic Research Service.

Greenaway-McGrevy, R., Han, C., & Sul, D. (2012). Asymptotic distribution of factor augmented estimators for panel regression. *Journal of Econometrics 169*(1): 48-53.

Haile, M. G., Kalkuhl, M. and von Braun, J. (2015). Worldwide acreage and yield response to international price change and volatility: A dynamic panel data analysis for wheat, rice, corn, and soybeans. *American Journal of Agricultural Economics 98*(1): 172-190.

Huang, J., Wang, X., Zhi, H., Huang, Z. and Rozelle, S. (2011). Subsidies and distortions in China's agriculture: Evidence from producer-level data. *Agricultural and Resource Economics 55*: 53-71.

Huang, J. and Yang, G. (2017). Understanding recent challenges and new food policy in China. *Global Food Security 12*(2017): 119-126.

Li, J., Chavas, J. P., & Li, C. (2021). The dynamic effects of price support policy on price volatility: The case of the rice market in China. *Agricultural Economics* 53(2): 307-320.

Li, Y., Zhang, W., Ma, L., Wu, L., Shen, J., Davies, W. J., Oenema, O., Zhang, F. and Dou, Z. (2013). An analysis of China's grain production: Looking back and looking forward. *Food and Energy Security 3*(1): 19-32.

Lin, W. and Huang, J. (2021). Impacts of agricultural incentive policies on land rental prices: New evidence from China. *Food Policy 104*: 102125.

Lyu, J. and Li, X. (2019). Effectiveness and sustainability of grain price support policies in China. *Sustainability 2019 11*: 2478.

National Development and Reform Commission (NDRC) (2017). *Compilation of Costs and Benefits of National Agricultural Products*. China Statistics Press. [In Chinese]

National Development and Reform Commission (NDRC) (2021). The minimum procurement price of rice in 2021. Available at: https://www.ndrc.gov.cn/fzggw/jgsj/jgs/sjdt/202102/t20210226_1268259_ext.html#:~:text=2021%E5%B9%B4%E5%9B%BD%E5%AE%B6%E7%BB%A7%E7%BB%AD%E5%9C%A8,128%E5%85%83%E5%92%8C130%E5%85%83%E3%80%82 (accessed on December 17th, 2021) [In Chinese]

Ning, Q. and Hu, L. (2017). *China Agricultural Statistical Yearbook*, China Agriculture Press. [In Chinese]

Nerlove M. 1958. Adaptive expectations and cobweb phenomena. *The Quarterly Journal of Economics 72*(2): 227–40.

Peng, S., Tang, Q. and Zou, Y. (2009). Current status and challenges of rice production in China. *Plant Production Science 12*(1): 3-8.

Pesaran, M. H. (2006). Estimation and inference in large heterogeneous panels with a multifactor error structure. *Econometrica 74*(4): 967-1012.

Richardson, M.P. and Boudoukh, J. and Whitelaw, R.F. (1998). The best of both worlds: A hybrid approach to calculating value at risk. Available at: https://ssrn.com/abstract=51420 (accessed on February 1st, 2020)

Shonkwiler, J. S., & Maddala, G. S. (1985). Modeling expectations of bounded prices: An application to the market for corn. *The Review of Economics and Statistics* 67(4): 697-702.

Su, M., Heerink, N., Oosterveer, P., Tan, T., & Feng, S. (2021). Impacts of China's minimum grain procurement price program on agrochemical use: A household-level analysis. *Agriculture 11*(10): 910.

Tiwari, S., Daidone, S., Ruvalcaba, M. A., Prifti, E., Handa, S., Davis, B., Niang, Q., Pellerano, L., van Ufford, P. and Seidenfeld, D. (2016). Impact of cash transfer programs on food security and nutrition in sub-Saharan Africa: A cross-country analysis. *Global Food Security 11*: 72-83.

United States Department of Agriculture (USDA) (2022). Grain and Feed Annual. Available at: https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Grain%20and%20Feed%20Update_Beijing_China%20-%20People%27s%20Republic%20of_01-20-2022.pdf (accessed on March 18th, 2022)

Verbeek, M. (2017). *A Guide to Modern Econometrics*. John Wiley & Sons.

Wang, W., & Wei, L. (2021). Impacts of agricultural price support policy on price variability and welfare: Evidence from China's soybean market. *Agricultural Economics 52*(1): 3-17.

Wong, A.Y. and Chan A.W. (2016). Genetically modified foods in China and the United States: a primer of regulation and intellectual property protection. *Food Science and Human Wellness 5*: 124-140.

Xu, D., Deng, X., Guo, S. & Liu, S. (2019). Labor migration and farmland abandonment in rural China: Empirical results and policy implications. *Journal of Environmental Management 232*: 328-350.

Yi, F., Sun, D., & Zhou, Y. (2015). Grain subsidy, liquidity constraints and food security—Impact of the grain subsidy program on the grain-sown areas in China. *Food Policy 50*: 114-124.