frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 11 March 2024
DOI 10.3389/fsufs.2024.1329239

OPEN ACCESS

EDITED BY
Jianxu Liu,
Shandong University of Finance and Economics, China

REVIEWED BY
Xiaole Wan,
Ocean University of China, China
Arnab Majumdar,
Jadavpur University, India
Qing Li,
Shandong University, China

*CORRESPONDENCE
Chen Cao
✉ 1920190001@stu.nufe.edu.cn

RECEIVED 15 November 2023
ACCEPTED 26 February 2024
PUBLISHED 11 March 2024

CITATION
Cao C and Shao K (2024) Improving quality standards of purchase policy and sustainable staple food safety.
Front. Sustain. Food Syst. 8:1329239.
doi: 10.3389/fsufs.2024.1329239

Improving quality standards of purchase policy and sustainable staple food safety

Chen Cao* and Kaichao Shao

Institute of Food Economics, Nanjing University of Finance and Economics, Nanjing, China

Introduction: Food quality is closely related to food safety. Improving food quality, especially staple foods quality, is crucial to ensuring sustainable food safety. China's government is making efforts to improve the quality of staple foods and has improved quality standards of purchase policy for staple food. However, the actual effects of the new quality standards of purchase policy in implementation have not been verified.

Methods: Based on this background, applying difference-in-differences models, this paper examines whether the new quality standards of purchase policy can improve the quality of staple food supply based on the wheat market transaction data.

Results and discussion: The results show that the new quality standard of purchase policy has a significant positive impact on the quality of staple food supply. The conclusion remains robust through several alternative tests. Further research shows that the new quality standards of purchase policy significantly expand the degree of quality premiums in the market, thereby improving the staple food supply quality. Our research provides an insight for policy or standard makers to change relevant purchase quality limits following consumer demand to ensure sustainable food security.

KEYWORDS

staple food, quality standards, staple food safety, purchase policy, test weight, wheat

1 Introduction

Staple foods provide a good amount of carbohydrate which are notably rich sources of vitamin, protein and minerals. Meanwhile, staple foods play an important role in our dietary structure. Therefore, ensuring sustainable supply of staple foods is important for national security and economic stability, especially in developing countries or countries with insufficient supply. Nowadays, many countries, particularly food-importing countries, have provided strong policy purchase support for staple food (Niu et al., 2021). These policies have contributed to staple food security in terms of sufficient quantity of calories, but they are not effective in improving nutrition and health outcomes (FAO, 2022). As the residents' life quality keep growing, re-shaping food policies to deliver healthy diets continue to be of great concern. Therefore, improving the quality of staple food is important for promoting the sustainability of food security.

All this time, China's government has introduced a food security policy of ensuring absolute security of staple food (Selim, 2015). Therefore, the purchase policy with minimum support price for staple foods (i.e., rice and wheat) has been implemented in order to ensure staple food production and reduce their prices volatility since 2004. However, China's staple food purchase policies emphasize too much on the quantitative security of staple foods, leading to some negative effects. For example, Li et al. (2020) argue that China's purchase policy led to large stocks and imports, which are not conducive to the development of food security in China and are unsustainable, especially when international

prices were lower than domestic prices. In addition, China has imported a large number of high-quality rice and wheat to meet domestic demand, which have exceeded the quota limit in the past 2 years. Massive imports of staple grains obviously violate Chinese principle of staple food self-sufficiency.

A number of scholars have studied the impact of price support policies from multiple perspectives. For example, Li et al. (2021) investigated the impact of rice price support policy on consumer welfare, and the results showed that price increases would reduce consumer welfare, but a moderate level of price support could reduce the long-run average price without causing a loss of consumer welfare. Other scholars also obtained similar results in soybean policy studies (Wang and Wei, 2021). Suchato et al. (2021) analyzed the impact of sugarcane price support policy on farmers' planting behavior and found that an attractive sugarcane price guarantee policy positively affected farmers' willingness to plant sugarcane. Virgilio-León et al. (2023) study the impact of a staple food price support policy on rice production, consumption, imports, and social welfare, which, if adequately supported, would increase rice production and reduce dependence on imports. Obviously, staple food purchase policies ignore the impact of food quality on food security which will lead to unsustainable purchase. In fact, sustainable staple food security is not only reflected in quantitative security, but also in qualitative security. From an economic perspective on staple food quality, Fontanelli et al. (2021) found that replacing white rice and white bread with their whole-grain versions has the potential to improve diet quality based on the 2015 Health Survey of São Paulo. Laska et al. (2019) examined the impact of a local staple foods ordinance on the nutritional quality of grocery store products, customer purchases, and the food environment. The results indicate that the policy can significantly increase retailers' healthy food additions in both Minneapolis and St. Paul. Abate et al. (2021) based on the aspects of downstream agents' willingness to pay for quality, upstream quality premium competitiveness, cost-effective certification, and farmers' capacity to respond to certification, the conditions of third-party quality certification to promote the value chain of staple foods in Sub-Saharan Africa are studied, and found that quality premiums paid to farmers is uneven through the survey, however, where quality premiums do exist, farmers will be incentivized to improve quality. It is clear from the above literature that if the quality of staple foods does not match actual market demand, too much production will become stocks rather than being effectively consumed. In general, as residents' incomes are growing, per capita staple food consumption will drop slightly, whereas consumer preferences drive demand for quality staple food (Mottaleb et al., 2017; Bairagi et al., 2020).

Considering changes in the structure of consumption, China's government re-evaluated their purchase policy for staple food and issued the latest policy documents "*Minimum Purchase Price Implementation Plan for Wheat and Rice*" in May 2018. Compared to the previous policy documents, the most important change in the new policy is to improve the quality threshold, namely from original grade No. 5 to grade No. 3, hoping to release the policy signal of high-quality purchase and guide staple food farmers to pay more attention to planting quality to help improve sustainable production.

The policy has been in implementation for 5 years. However, limited by data, no study has explicitly explored the impact of improving quality standards of purchase policy on staple food supply quality and their underlying associated mechanisms up till now. Therefore, the objective of our study is to systematically analyze the influence of improving quality standards of purchase policy on staple food supply quality. Based on wheat market transaction data from 2016 to 2022, we examine whether improving quality standards of purchase policy alter wheat supply quality through the difference-in-differences regression estimators as well as several alternative tests. In addition, we reveal the impact mechanism of improving quality standards of purchase policy on wheat supply quality.

This study contributes to existing researches on three aspects:

(1) Our research data is derived from real transactions, covering all main production areas with a long-time span. The data is obtained with python software and is used to study for the first time in China.
(2) The conclusions of this paper strongly support that improving quality standards of purchase policy for staple food could improve the quality of staple food supply. The impact of the policy is empirically verified, and our study helps to clarify the nexus between food purchase policies and food quality.
(3) A further contribution of our paper is to try to provide an insight for finding a policy or some standards to adapt to changes in staple food consumption, especially in the countries where government have to balance food quantity and quality security.

2 Framework of analysis

2.1 Quality standards of purchase policy for staple food

Since 2004, China has implemented the minimum purchase price procurement policy for staple food (i.e., rice and wheat) and purchase a great quantity of staple food (Li et al., 2021). In most situations, staple food purchase policies are often used in combination with price support policies. When the staple food market prices are lower than the policy support price, the governments will purchase them in the market until their prices return back to the policy price level. This policy can affect staple food market supply and demand through direct purchase and price intervention.

Chinese staple food purchase policy mainly regulates the areas of the policy implementation, the price of the policy and the quality requirements for purchase. Take wheat for example, the policy has been implemented only in Anhui Province, Jiangsu Province, Shandong Province, Henan Province, Hebei Province and Hubei Province, whereas the other provinces remain unaffected. The policy price is determined by the government after taking into account a number of factors such as production cost, market situation and farmers' revenue.

These staple foods purchased by the policy need to meet minimum quality requirements, namely quality threshold. In

TABLE 1 Grades and grade requirements for wheat in China.

Grade	Test weight (g/L)	Unsound kernel	Foreign material (%)		Moisture (%)	Color and odor
			Total	Inorganic impurity		
No. 1	≥790	≤6.0	≤1.0	≤0.5	≤12.5	Normal
No. 2	≥770	≤6.0				
No. 3	≥750	≤8.0				
No. 4	≥730	≤8.0				
No. 5	≥710	≤10.0				
Outside	<710	/				

terms of the quality requirements for China's purchase policy, we mainly focus on quality standards for wheat. According to the wheat standard documents "*GB 1351-2008*" issued by the General Administration of Quality Supervision and Inspection and Quarantine of China and the Standardization Administration of China in 2008, the grades and grade requirements of wheat are shown in Table 1. The first row of Table 1 indicates the main quality indicators affecting the grade. The first row of Table 1 indicates the main quality indicators affecting the grade. Among them, test weight is the quality of the wheat kernel per unit volume. Unsound kernel refers to the wheat food that is damaged but still has value, including injured kernel, spotted kernel, broken kernel, sprouted kernel and moldy kernel. Foreign materials are all substances other than wheat kernels, including throughs, inorganic impurity and organic impurity. Normal color and odor represent the color, luster and odor inherent in wheat. The test weight has a significant relationship with other quality traits, such as foreign material, unsound kernel, moisture and so on. Furthermore, as can be seen from Table 1, there is no significant difference between different grades of wheat in foreign material, moisture, color and odor. And there is a very strong correlation between test weight and unsound kernel. Therefore, it can be assumed that the most important quality indicator for grade is the test weight.

Before 2018, the quality threshold was only grade No. 5, showing that quantity is more important than quality for policy purchase. Therefore, farmers are planting with more attention to yield rather than quality. As a consequence, China's supply of high-quality staple food is insufficient. To change this situation, China's government issued the latest policy documents "*Minimum Purchase Price Implementation Plan for Wheat and Rice*" in May 2018. Compared to the previous policy documents, the most important change in the new policy is to improve the quality threshold, namely from original grade No. 5 to grade No. 3. That means wheat with a test weight of <750g/L will be unqualified for policy purchases after 2018.

2.2 Mechanism analysis

Food procurement policies are a common food market intervention tool which is used by a number of countries, especially where food prices are relatively unstable (Brummer et al., 2009). Those policies are mainly aimed at staple foods, mainly rice and wheat. Cummings et al. (2006) argue that most of Asian countries apply food purchase policies to stabilize prices. Yu and Bandara (2016) state that the Indian government implements minimum support prices (MSPs) and public procurement to maintain sufficiently high domestic food supply by supporting producer's incentives. Qian et al. (2020) show that China's current purchase policies affect food output and farmers' income by mediating food supply and demand, and find that they have increased the self-sufficiency rates of rice and wheat by about 1.38 and 6.19 percentage points, respectively. Previous work has established that purchase policy for staple food is a successful policy tool to ensure staple food quantity security.

As residents' income increases, the demand for high-quality staple food is increasing. The purchase policy for staple food become unsustainable. Therefore, China's government has modified its staple purchase policy and raised the quality threshold in May 2018. Before 2018, the quality threshold for staple food policy purchase was grade No. 5, so the staple food could be sold to state-owned food enterprises commissioned by the government as long as they are grade No. 5 or above. After 2018, the staple food below grade No. 3 lost the qualification for policy purchase. Growing low-grade staple foods will also face a lot of uncertainty due to the loss of a certain policy purchase channel. For example, even when the prices of low-grade staple foods are very low, they can only be forced to be sold in the market and not purchased by the government. As a consequence, those farmer, especially small-scale farmers with a weak risk tolerance, will be more inclined to grow high-quality varieties of staple foods or to add more quality inputs. In summary, it can be seen that improving quality standards of purchase policy could form incentives for high-quality food production, thereby improving the quality of staple food supply eventually.

Obviously, improving the quality of staple food stems from varieties selection and farmers' quality inputs at planting. Although higher quality means higher price, high-quality staple food spend more costs and brings about a yield reduction effect (van der Merwe and Cloete, 2018). Therefore, for an equal or better return, quality premiums will need to offset the cost and the lower food yield. Most of scholars believe that quality premiums are a key factor of improving staple food quality and a compensation for the quality-producing farmers (Prom-u-thai and Rerkasem, 2020; Simionescu et al., 2022). Fiamohe et al. (2015) and My et al. (2018) believe

that consumers' willingness to pay more premiums for quality food, which will promote high quality production by farmers.

Nowadays, the quality premium standards for staple foods are always 0.02 yuan among adjacent grades for China's policy purchase, whereas the quality premiums are constantly fluctuating in market transaction (Drugova and Curtis, 2022). Before the new policy was implemented, it was difficult for the price of low-grade staple food (i.e., staple food below grade No. 3) to fall significantly due to policy price support. Therefore, the purchase policy decreased its price difference with high-grade staple food. After the new policy was implemented, even if the price of low-grade staple food falls significantly, it cannot get the policy support, which will increase quality premiums for higher grade staple food. It is the quality premium that raises the returns for farmers growing higher grade staple food (Anissa et al., 2021).

As shown in Figure 1, the horizontal axis represents the time and the vertical axis represents the price. The wavy lines represent market prices, the horizontal lines represent the policy prices, the high-grade staple food price is above the low-grade staple food price, and the quality premium is the high-grade staple food price minus the low-grade staple food price. The shaded areas represent the quality premiums of the staple food for all time. It can be seen that the shaded area in the right graph is significantly larger than that in the left graph by comparison, indicating that the quality premiums for high-grade staple food increases when low-grade staple food cannot be purchased by the policy. Accordingly, we propose the following hypotheses:

H1: Improving quality standards of purchase policy has a positive effect on the quality of staple food market supply.

H2: Quality premiums play a mediator role in improving quality standards of purchase policy and the quality of staple food market supply.

3 Materials and methods

3.1 Empirical model

3.1.1 DD models

According to the minimum support price policy for wheat, once the market price triggers the activation condition of the policy, the government will openly purchase wheat that meets the quality standard. In May 2018, the Chinese government raised the quality standard of the wheat price support policy from grade No. 5 to grade No. 3, whereas wheat whose grade is below No. 3 will only be purchased by the market, and the low-grade wheat loses its eligibility to be purchased by the policy. This paper uses the year of the policy change as a "quasi-natural experiment" to assess the qualitative effects of the policy adjustment by comparing the actual effects of the two groups. Policy evaluation can often be done using "counterfactual" methods, of which the difference-in-differences method is the most commonly used (Petrick and Zier, 2010), which divides samples into a treatment group and a control group according to whether they are affected by policies. Given the repetitive cross-section data, the specific econometric model is set up as follows (Kiel and McClain, 1995):

$$quality_{kit} = \beta_0 + \beta_{sd} P \times T + \lambda X + \mu_{prov} + \nu_{year} + \varepsilon_{kit} \quad (1)$$

Where $quality_{kit}$ represents the quality of a staple food transaction k in province i and year t. T is the time dummy variable which is 1 after or in 2018 and is 0 before 2018. The setting is as follows:

$$T = \begin{cases} 1 & year \geq 2018 \\ 0 & year < 2018 \end{cases}$$

P is the second dummy variable of the treatment group and the control group. When a transaction occurs in six provinces, including Anhui Province, Jiangsu Province, Shandong Province, Henan Province, Hebei Province and Hubei Province, the value is 1, otherwise, the value is 0 for other regions as the control group, which is set as follows:

$$P = \begin{cases} 1 & policy\ areas \\ 0 & non-policy\ areas \end{cases}$$

The main parameter of interest is β_{sd}, which captures the effect of improving quality standards of purchase policy on the quality of staple food supply. β_0 is a constant term. X are the control variables that represent some factors that may affect food quality except for the above dummy variables. λ are the parameters of the influence effect of the control variable to be estimated. μ_{prov} is the provincial fixed effect. ν_{year} is the year fixed effect. ε_{kit} is the random error term.

3.1.2 Event study models

Next, to provide a more detailed overview of annual treatment effects, we estimate the following model using an event study approach:

$$quality_{kit} = \beta_0 + \sum_{t=2016}^{2022} \beta_t year \times P + \lambda X + \mu_{prov} + \nu_{year} + \varepsilon_{kit} \quad (2)$$

The main parameter of interest in estimating Equation (2) is β_t, whereas all other variables remain the same as in Equation (1).

3.1.3 DDD models

The quality of wheat supply will not only be affected by policy implementation area and non-policy implementation area, but also by the quality grade division. The double difference estimator cannot achieve grouping for twice. However, the triple difference estimator can effectively solve the problem of grouping for twice, which is maybe more in line with our research requirements (Olden and Men, 2022). Therefore, we adopt the triple difference estimator to test the robustness of the benchmark model. Take the government's increase in policy procurement quality threshold

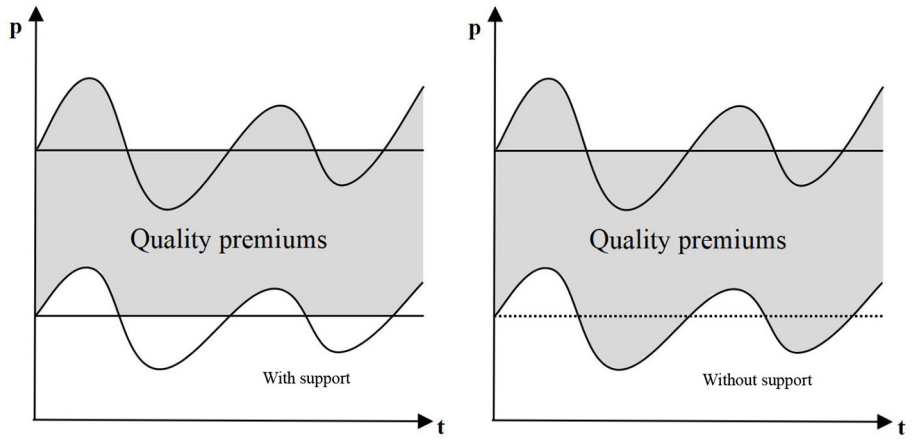

FIGURE 1
Quality premiums change.

in 2018 as a quasi-natural experiment. The specific econometric model is set as follows:

$$quality_{kit} = \beta_0 + \beta_{td}C \times P \times T + \beta_2 C \times T + \beta_3 P \times T + \beta_4 C \times P + \beta_5 C + \lambda X + \mu_{prov} + \nu_{year} + \varepsilon_{kit} \quad (3)$$

The main parameter of interest in estimating Equation (3) is β_{td}. C is the dummy variable of the grade treatment group and control group which is set as follows:

$$C = \begin{cases} 1 & Grade\ No.1, 2\ and\ 3 \\ 0 & Grade\ No.\ 4\ and\ 5 \end{cases}$$

whereas all other variables remain the same as in Equation (1).

3.1.4 Mediator effects model

In order to explore the mediator role of quality premiums between policy changes and the quality of staple food supply, we construct the following three econometric equations, i.e., Equations (4–6) according to Kuang et al. (2021).

$$premium_{kit} = \beta_0 + \beta_m P \times T + \lambda X + \mu_{prov} + \nu_{year} + \varepsilon_{kit} \quad (4)$$

$$quality_{kit} = \beta_0 + \beta_{sdm} premium_{kit} + \lambda X + \mu_{prov} + \nu_{year} + \varepsilon_{kit} \quad (5)$$

$$quality_{kit} = \beta_0 + \beta_{sdm} premium_{kit} + \beta_{sd} P \times T + \lambda X + \mu_{prov} + \nu_{year} + \varepsilon_{kit} \quad (6)$$

$premium_{kit}$ is a mediator variable. The main parameters of interest are β_m, β_{sdm} and β_{sdm}, whereas all other variables remain the same as in Equation (1). If these parameter estimates pass the significance test, it means that there is a mediator effect.

3.2 Variable selection

3.2.1 Dependent variable

Staple food quality: Since wheat is the most widely consumed staple food in the world, we use wheat quality instead of staple food quality. Currently, wheat quality is measured mainly from characteristics such as test weight, moisture, gluten, falling number, etc. In general, the quality of wheat depends on its final commercial demand, such as milling and baking. Since the evaluation standards of wheat quality for purchase policy is mainly measured on the basis of test weight. In addition, the test weight is a key indicator of how much flour can be extracted so that it is the primary and most widely test for determining quality grade (Karaman and Yavuz, 2014). Therefore, traders tend to use test weight as the only indicator of quality measurement in the actual wheat market in China. Given data availability and simplification of research, we only use test weight of wheat as the sole standard of quality measurement.

3.2.2 Independent variable

As mentioned above, the independent variables have been clarified in the section of empirical models.

3.2.3 Mediator variable

Quality premium: It is the price difference between foods of different quality grades. The quality premium, which has a positive effect on quality improvement, is measured as the price difference between different grades of the same food. Although quality can be defined from a variety of aspects (Sakolwitayanon et al., 2018; Takayama et al., 2021), in this paper, the quality is only defined from test weight, so the

price differences between different test weights are measured as quality premiums.

3.2.4 Control variables

In addition to the policy and time dummy variables, the quality of wheat supply can also be affected by many factors. Referring to previous studies (Kawasaki and Uchida, 2016; Yadav and Ellis, 2016; Pearsons et al., 2022), we choose transaction price, food consumer price, wheat import price, corn market price, indica market price, agricultural services cost, rainfall, household income as a control.

Transaction price: Staple food price is an important factor affecting its quality. Generally speaking, the quality is positively related to price in the market, which reflects the principle of selling high-quality produce at higher prices. In addition, the price is a compensation for quality payment, and can also influence farmers to choose to plant quality varieties or pay more quality inputs.

Food consumer price: Wheat market transactions occur mainly among intermediaries, traders or processing enterprises. The wheat they purchased is not used for consumption, but for better re-sale. So consumer purchases at the downstream end of the supply chain can effectively affect upstream transactions, including the quality of transactions.

Wheat import price: As China imports large quantities of wheat, the correlation between domestic and foreign markets becomes closer, so import prices can also affect domestic wheat market supply and quality.

Substitute Prices: The substitutes for wheat are mainly corn and rice. The prices of the substitutes will affect the output of wheat and its quality, so we choose corn and indica rice prices as controls.

Agricultural services cost: In general, improving the quality of staple food need farmers' quality inputs at planting, such as labor and services, thus increasing the cost of wheat production. Therefore, we use agricultural services cost as a control variable.

Rainfall: According to previous studies (Messaoudi et al., 2023), weather is an important factor affecting the quality of wheat. Because rainfall can affect the growth of wheat, thereby changing the wheat quality, we use rainfall as a control variable.

Household income: The income of the population can influence the quality of life and consumption. Individuals' income can influence their choice of product quality, including the consumption of staple foods. Therefore, we use household income as a control variable.

3.3 Data sources

Staple food quality and transaction price: To capture wheat market trading data, we joined the membership of the China food and Oil Information website which is the largest food trading information website in China. Subsequently, python software is used to collect information related to wheat-related transactions with keywords such as transaction price, test weight, transaction location and transaction time. Finally, we drop some samples with obvious errors and obtain a total of 26978 samples which is the actual information of wheat traders. Accordingly, we obtained data on wheat quality and transaction prices.

Quality premium: Firstly, we directly calculate the average prices of Grade No. 3 wheat in every province by using an arithmetic average method, and then subtract the above-mentioned average prices from the prices of other grade wheat to approximate the quality premium level in the wheat market.

Among the control variables, the data on rainfall is obtained from China National Meteorological Science Data Sharing Service Platform. The data on agricultural services cost is obtained from National Agricultural Product Cost and Benefit Data Collection for the period 2016 to 2022. The monthly wheat import average price data is derived from the monthly import and export details released by the General Administration of Customs from 2016 to 2022. The data on corn market price and indica market price is obtained from China Rural Statistical Yearbook for the period 2016 to 2022. The data on household income and food consumer price is obtained from China Statistical Yearbook for the period 2016–2022. Different data are matched according to the transaction time and transaction location, and some missing values are estimated by the difference method. A descriptive analysis of the data is shown in Table 2.

4 Analysis of empirical results

4.1 Benchmark regression

Currently, the quality of staple foods needs to be improved in order to ensure sustainable staple food safety. China is committed to maintaining sustainable staple food security. The key to whether improving quality standards of purchase policy can help promote sustainable staple food security lies in whether it can improve the quality of staple grain supply. Table 3 shows that the average impact of improving quality standards of purchase policy on the wheat supply quality. The model estimated in model (1) includes no control variables. Model (1) shows that improving quality standards of purchase policy has a significant positive impact on wheat supply quality without province and year fixed effects. The significance test is also passed. The model estimated in models (2) controls for rainfall, agricultural services cost, transaction price, wheat import price, corn market price, indica market price, food consumer price and household income. The regression result shows that improving quality standards of purchase policy has a positive impact on wheat supply quality, passing the 1% significance test. In the baseline model with control variables [model (3)], compared to wheat supply quality in non-policy areas, we find that improving quality standards of purchase policy increases wheat supply quality by about 3.839 g/L for policy areas ($p < 0.01$). In summary, all of results show that improving quality standards of purchase policy has a significant positive impact on the supply quality of wheat. So, the hypothesis 1 is verified.

TABLE 2 Variable name and descriptive statistics.

Variable	Variable name and unit	Mean	Std. dev.	Min	Max	*N*
Quality	Test weight (g/l)	774.232	14.874	674.000	875.000	26,978
Price	Transaction price (yuan/catty)	1.225	0.109	1.000	1.900	26,978
Rain	Rainfall (mm)	761.593	303.577	208.200	1,665.600	26,978
Sumprice	Food consumer price index (2015 year = 100)	101.845	1.916	99.000	109.091	26,978
Income	Per capita disposable income (yuan)	25,447.590	5,656.516	14,670.300	51,606.200	26,978
Service	Material and service cost (yuan/mu)	457.815	33.562	333.380	518.930	26,978
Impotprice	Average wheat import price (yuan/catty)	0.905	0.138	0.701	1.485	26,978
Cornprice	Corn market price (yuan/catty)	1.067	0.148	0.925	1.470	26,978
Indicaprice	Indica market price (yuan/catty)	1.407	0.031	1.365	1.500	26,978
Premium	Quality premium(yuan)	0.018	0.065	−0.470	0.856	26,978

As shown in model (3) of Table 2, from the perspective of control variables, wheat transaction price has a positive impact on wheat market quality, which indicates that China's wheat market has certain characteristics of superior food and superior price. The price of corn has a positive impact on the quality of wheat supply, and the price of indica rice has a negative impact on the quality of wheat supply mainly due to the substitution relationship between corn and low-quality wheat in feed demand and between indica rice and high-quality wheat for residents' consumption. From the perspective of production substitution, when the price of corn is high, farmers will produce more corn, thus reducing the planting of low-grade wheat, thereby increasing the output proportion of high-grade wheat. Similarly, when the price of indica rice is high, farmers tend to produce more indica rice, thus reducing the supply of high-grade wheat, thereby reducing the output proportion of high-grade wheat. Therefore, the quality of wheat supply was statistically positively correlated with corn prices, while negatively correlated with indica prices. In addition, the household income and agricultural services cost have a positive impact on the quality of wheat supply, but the food consumer price has a negative impact on the quality of wheat supply, and the rainfall and wheat import price have no significant impact on the quality of wheat supply.

4.2 Parallel trends test

The key for the differences-in-differences analysis is that the trends in the control group provide an estimate of the trends that would have occurred in the treatment group in the absence of improving quality standards of purchase policy. Figure 2 shows that the trends in wheat quality are almost identical for policy areas and non-policy areas before 2018, whereas a clear boost is observable immediately after quality standards of purchase policy changes. In the first year of policy adjustment, namely in 2018, improving quality standards of purchase policy do not have a significant impact on the wheat supply quality, because the policy was issued in May 2018. Although the wheat had not yet been harvested at this time, both spring wheat and winter wheat had been sown so that farmers could not make effective quality input in time. Therefore, the impact of the policy adjustment on the quality of wheat output in that year was negligible. Therefore, the policy effect starts to be brought into play from the second year after the policy adjustment.

4.3 Event study results

Figure 3 provides annual treatment effects on wheat supply quality. It shows that there are no differential pre-2019 trends in wheat supply quality between policy areas and non-policy areas. Although I find no statistically significant differences in wheat supply quality between the two groups in the years up to 2019, all annual treatment effects between 2019 and 2022 following the policy purchase quality threshold change are large and statistically significant ($p < 0.01$). Consistent with the findings of the parallel trends test, a clear boost is again observable immediately in 2019,

TABLE 3 Benchmark regression.

	(1) Quality	(2) Quality	(3) Quality
P×T	7.890*** (0.962)	7.542*** (0.948)	3.839*** (0.940)
Price		21.700*** (1.321)	49.40*** (2.778)
Rain		0.002*** (0.000)	0.001 (0.001)
Sumprice		1.923*** (0.089)	−1.041*** (0.191)
Income		−0.001*** (0.000)	0.001*** (0.000)
Service		0.132*** (0.004)	0.107*** (0.009)
Impotprice		6.987*** (0.958)	1.081 (1.056)
Cornprice		9.172*** (0.855)	38.870*** (3.088)
Indicaprice		−52.350*** (4.542)	−29.090*** (6.416)
Province FE	No	No	Yes
Year FE	No	No	Yes
_cons	769.008*** (0.775)	560.817*** (7.487)	758.964*** (20.296)
N	26,978	26,978	26,978
Adj. R-sq	0.1067	0.2362	0.2993

Robust standard errors are in parentheses. ***Indicate significant at the 1% level.

the next year after the policy adjustment, due to lagging policy effects.

4.4 DDD results

The regression results of the triple difference are shown in Table 4. Model (1) shows improving quality standards of purchase policy has a significant positive impact on the quality of the grade No. 3 and above wheat supply without any control variables. The significance test is also passed. Model (2) is the regression result with the above control variables, showing that the improvement of quality standards of purchase policy has a positive impact on the quality of the grade No. 3 and above wheat supply, passing the 1% significance test. At the same time, it can be seen from the coefficient values in models (1) and (2) that the two are almost equal, which indicates that the addition of control variables has no influence on the regression results. Subsequently, to evaluate the effects of raising quality standards of purchase policy on different quality wheat samples, we divided the samples into two groups, one consisting of grade No. 1 and grade No. 2 wheat, the other including grade No.4 and grade No. 5 wheat. In the high-grade wheat samples, the results indicate that quality standards adjustment of purchase policy improves the test weight of grade No. 3 above wheat by about 9.42 g/L as shown in model (3) of Table 4. However, the effect of the policy change on low-grade of wheat supply quality is negative without a significance test passing as shown in model (4) of Table 4, indicating that the increasing quality threshold had no significant effect on the low-grade wheat supply quality. A possible explanation for this is that low-grade wheat is often used for forage so that the policy changes have less impact on such farmers. In summary, the results that DD and DDD estimates are similar in terms of direction and statistical significance could further support the robustness of the main results.

4.5 Placebo test

Since the above regression results may be caused by some placebos. In other words, the improvement in the quality of wheat in the market may come from other unobservable factors, not from the improvement of quality standards of purchase policy for China's wheat purchase policy. In order to exclude the placebo effect, 6 provinces were randomly selected as the new treatment group and the other provinces were used as the control group (Chetty et al., 2009). Similarly, the difference-in-differences method was used to regress for 500 times. All of the influence coefficients of improving quality standards of purchase policy on the wheat quality are calculated. All of the *t*-values obtained by the placebo test are most likely concentrated around 0, as shown in Figure 4. The hypothesis that the regression coefficient is equal to 0 cannot be rejected, which indicates that the wheat quality improvement is not caused by placebo. In summary, the placebo test results suggest that the conclusions of the benchmark regression are robust.

4.6 Robustness test

4.6.1 Change sample

The above-mentioned study is mainly based on data from wheat market transactions. To make the results more reliable, we use the data of *the survey report on the quality of newly harvested wheat* released by the National Food and Strategic Reserves Administration, mainly involving Hebei, Jiangsu, Anhui, Shandong, Henan, Hubei, Shanxi, Sichuan and Shaanxi province, where the total wheat production is about 120 million tons, representing about 89% of total China's wheat production. Those sample data can effectively reflect the wheat quality in the year. According to the evaluation index system including test weight, unsound kernel wheat rate and other indicators, all of the samples are divided into six grades. The smaller is the grade value, the higher is the wheat quality. Based on the above-mentioned reports data, the *t*-test is used for the mean of two independent samples.

Firstly, these samples are divided into policy area samples and non-policy area samples, and then continue to be divided into two groups according to the time of the policy adjustment, assuming that the samples follow a normal distribution and are independent of each other, but the variance of the samples is different.

Null Hypothesis: $u_1 = u_2$. That is, the population means of the two samples are equal.

Alternative hypothesis: $u_1 \neq u_2$. That is, the population means of the two samples are not equal.

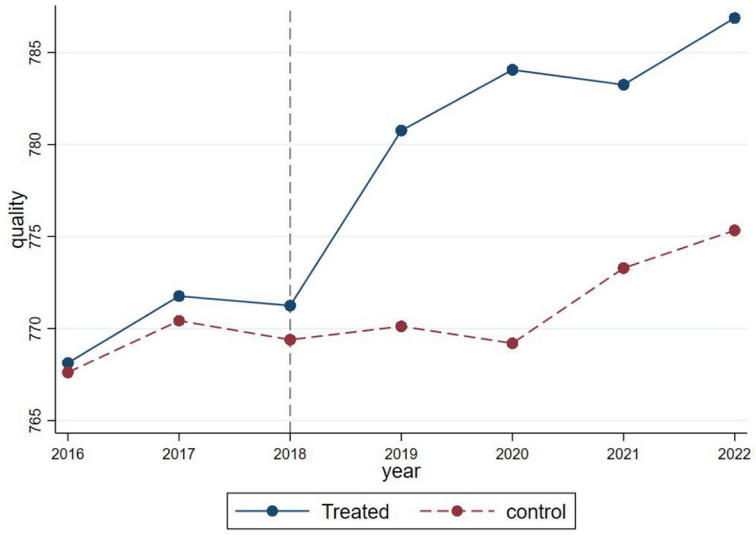

FIGURE 2
Wheat supply quality for treatment and control group.

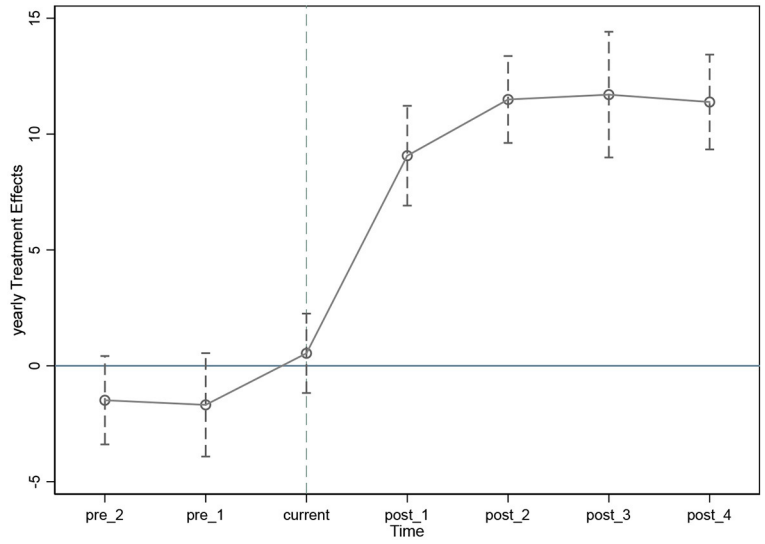

FIGURE 3
Event study results.

Secondly, the Satterthwaite approximation method is adopted, and the formula for calculating the value of the statistic T is Equation (7):

$$T = (\overline{X}_1 - \overline{X}_2)/\sqrt{S_1^2/n_1 + S_2^2/n_2} \tag{7}$$

The degrees of freedom are calculated as Equation (8)

$$v = (S_{\overline{x}_1}^2 + S_{\overline{x}_2}^2)^2/[S_{\overline{x}_1}^4/(n_1 - 1) + S_{\overline{x}_2}^4/(n_2 - 1)] \tag{8}$$

Where $\overline{X}_1$ and $\overline{X}_2$ represent the mean of the sample of both groups, n_1 and n_2 represent the sample size of both groups, S_1^2 and S_2^2 represent the sample variance of both groups, $S_{\overline{x}_1}$ and $S_{\overline{x}_2}$ represent the standard error of the sample mean of both groups.

Finally, the p-value is used for a significance testing, and it means $u_1 > u_2$ if $t > 0$ and $p < 0.05$; it means $u_1 < u_2$ if $t < 0$ and $p < 0.05$.

The results are shown in Table 5. From the sample of the policy area, the average wheat test weight before and after the policy adjustment has a statistically significant difference where the null hypothesis is rejected and the T-value is negative. The proportion of grade No. 1, grade No. 2 above, and grade No. 3 above wheat before the policy adjustment are significantly less than after the policy adjustment, which indicates that improving quality standards of purchase policy significantly promote the supply of high-quality wheat. However, from the samples of non-policy areas, there are no significant difference in wheat quality before and after the policy adjustment. In summary, improving quality standards

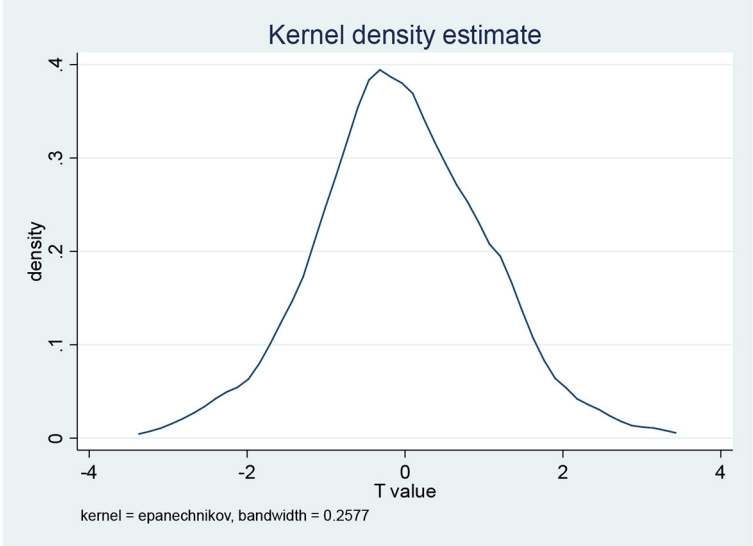

FIGURE 4
Distribution of T-value for 500 times.

of purchase policy can enhance the quality awareness of wheat planting by farmers.

4.6.2 Regional robustness

Although the minimum purchase price policy has been implemented in major wheat production areas, there are differences in wheat production and climate types among different provinces, which lead to variations in wheat varieties. In addition, there are differences in dietary habits between residents in the northern and southern regions. All these factors result in regional heterogeneity in the quality of wheat supply in the market. To address this issue, the wheat policy implementation regions are divided into southern and northern regions based on their relative geographical positions. The southern region includes Hubei Province, Anhui Province, and Jiangsu Province, while the northern region includes Henan Province, Hebei Province, and Shandong Province. The differences in dietary habits and wheat varieties between these regions lead to variations in the quality effects of policy adjustments. Column (1) and (2) in Table 6 represent the impact of quality threshold improvements of purchase policy on wheat supply quality in the southern and northern regions, respectively. The results show that policy adjustments have a positive influence on the wheat supply quality in both regions, and the results are significant at the 1% level. Comparing the coefficient values and significance of the regression results, we observe that the impact of policy adjustments on wheat market supply quality is similar in both regions. Furthermore, there are no significant differences between the two regions and the benchmark regression results in terms of coefficients and significance, indicating that the benchmark regression results are robust.

4.6.3 Policy implementation robustness

The implementation of the purchase policy only takes place from June to September each year, which may result in certain heterogeneity in the quality of wheat supply during different periods. Therefore, we divide the year into two periods: the policy implementation period and the non-policy implementation period. The policy implementation period refers to June to September, while the remaining time is considered the non-policy implementation period. According to the regression results shown in columns (3) and (4) of Table 6, it is evident that there is a positive impact of the policy adjustments on improving the quality of wheat supply during both the policy implementation and non-policy implementation periods. The results also pass a significance test at the 1% level. Furthermore, based on the coefficient values, the effect of the policy during the policy implementation period is slightly smaller than that during the non-policy implementation period. The main reason for this result is that the policy implementation period is also the period of wheat harvesting. During this period, a considerable number of state-owned enterprises, flour processing companies, food companies, and various wheat traders enter the market for acquisition. Due to the policy support, farmers do not have difficulties in selling their grain. As a result, they tend to sell lower quality wheat during this period, while higher quality wheat is sold later. This strategy leads to phenomenon of reluctance to sell, which results in a slightly lower impact of policy adjustments on wheat market quality during the policy implementation period compared to the non-policy implementation period. However, it is worth noting that the results do not differ significantly in terms of sign and significance from the benchmark regression results, indicating the robustness of the baseline regression.

TABLE 4 The DDD results of the policy effect.

	(1) Quality	(2) Quality	(3) Quality	(4) Quality
C × P × T	28.431*** (6.568)	27.436*** (6.453)		
P × T	−21.125*** (6.510)	−20.952*** (6.403)	9.068*** (0.858)	−3.192 (7.314)
C × T	−9.251 (6.366)	−6.974 (6.212)		
C × P	−17.501*** (1.802)	−15.965*** (1.836)		
C	46.575*** (1.766)	42.931*** (1.808)		
Price		31.484*** (1.791)	11.644*** (1.443)	−14.269*** (3.797)
Rain		0.001 (0.001)	−0.001 (0.001)	0.022** (0.009)
Sumprice		−0.899*** (0.170)	−0.961*** (0.165)	−2.830* (1.493)
Income		0.001*** (0.000)	0.000 (0.000)	−0.002 (0.002)
Service		0.071*** (0.008)	0.057*** (0.007)	0.059 (0.043)
Impotprice		0.120 (0.947)	2.386*** (0.860)	−2.952 (5.911)
Cornprice		26.626*** (2.486)	23.354*** (2.237)	−38.603*** (10.431)
Indicaprice		−10.861* (5.587)	−6.246 (4.943)	−14.276 (33.007)
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
_cons	744.834*** (3.078)	734.755*** (18.016)	834.173*** (16.523)	1,072.219*** (166.662)
N	26,978	26,978	19,181	1,206
Adj. R-sq	0.4349	0.4555	0.1859	0.2796

Robust standard errors are in parentheses. *, ** and ***Indicate significant at the 10%, 5% and 1% level, respectively.

4.7 Mediator effect test

The differences-in-differences method is used to test the impact of the new purchase policy on quality premiums. The results are shown in Table 7 (1). It is not difficult to find that the policy adjustment can help increase the quality premiums in the wheat market. Table 7 (2) reports the impact of wheat quality premiums on wheat supply quality, and the regression coefficient is significantly positive, indicating that the degree of quality premiums helps to improve the quality of wheat supply. Table 7 (3) reports that the co-impact of the new purchase policy and the quality premium on the quality of wheat supply, passing the significance test. In conclusion, the new purchase policy can not only directly improve the quality of wheat supply, but also indirectly improve the wheat supply quality by widening the price difference among different grades wheat. So, the hypothesis 2 is verified.

5 Discuss

Our study advances understanding of staple food policy purchase. Our research perspective differs from that of previous scholars. Most scholars have studied the key factors affecting staple food quality from the perspective of natural sciences (Randhe et al., 2009), such as breeding science (Hu et al., 2022), sowing methods (Pearsons et al., 2022; Zhu et al., 2022), production and inputs (Randhe et al., 2009; Ali and Akmal, 2022), growth environment (Kim and Kim, 2021; Zahra et al., 2023) and processing (Peng et al., 2022). Nevertheless, it is not enough to study staple food quality only from the physical and chemical properties. The study of staple food quality is also an important topic in economics.

Some scholars suggest that China's government can increase subsidies for high-quality rice and wheat (Qian et al., 2018; Han et al., 2021). Those suggestions are also not feasible, because subsidy policies belong to the amber box policies which are subject to minimal supports according to WTO rules. The current total aggregate measurement of support for rice and wheat in China has exceeded the threshold level when China's government negotiated to join the WTO (Ahn and Orden, 2021). China must adapt itself to the WTO rules. Li et al. (2020) and Yang and Li (2020) believe that China's government can carry out market-based procurement to help improve the quality of staple food supply. However, if this were done, China's staple food production would be severely reduced (Li et al., 2020). In addition, Yu et al. (2019) claim that China can import a large number of high-quality rice and wheat to solve supply structural problems. However, it cannot be ignored that China is a major food producer and consumer country. Relying on imports to ensure staple food security is unsustainable and will further exacerbate the imbalance between global staple food supply and demand (Fan et al., 2023). At the same time, international food cooperation is facing many uncertainties, which will also lead to more challenges for China's food security.

Although previous research has helped to improve the quality safety of staple foods, the conclusion is unsustainable. Our findings suggest a positive impact of improving quality standards of purchase policy on the supply quality in the staple food market. No scholars have previously explored the relationship between policy purchase and the quality of staple food market supply, possibly due to the lack of quality-related data. However, many studies have confirmed the quality premium as the main incentive for quality improvement (Shin and Kim, 2010; Ryan et al., 2014), as is the staple food. Therefore, we use the quality premium as a mediator variable between policy purchase quality threshold change and staple food supply quality.

Meanwhile, numerous literatures believe that food purchase policies can change market supply and demand, and the empirical study in this paper confirms that food purchase quality policies can indeed change the supply and demand of different quality foods, thus affecting the overall level of supply and demand quality in the market. Although the government can promote farmers to actively participate in wheat production through the minimum purchase price policy, it may also hinder the production of high-quality

TABLE 5 Comparison of the quality before and after the policy adjustment.

Area	Indicators and units	Before	After	Diff	*T*−value	*P*−value
Policy area	Grade 1 proportion	39.672%	58.829%	−19.157%***	−3.014	0.004
	Grade 2 above proportion	69.397%	83.554%	−14.157%**	−2.641	0.012
	Grade 3 above proportion	87.572%	94.292%	−6.719%**	−1.982	0.048
	Test weight (g/l)	778.333	790.525	−12.192***	−2.694	0.010
Non-policy area	Grade 1 proportion	27.944%	40.975%	−13.031%	−1.412	0.174
	Grade 2 above proportion	55.200%	67.021%	−11.821%	−1.173	0.255
	Grade 3 above proportion	81.011%	82.683%	−1.672%	−0.245	0.809
	Test weight (g/l)	771.556	777.750	−6.194	−0.855	0.403

** and *** indicate significant at the 5%, and 1% level, respectively.

wheat by favoring ordinary wheat plant. When continuing to implement the minimum purchase price policy, it is advisable to set a reasonable policy pricing based on market conditions and costs. This approach can ensure fairness and protect the interests of farmers while taking into account market supply and demand, thus encouraging farmers to improve the quality and quantity of high-quality wheat. In addition, our findings are also indirectly supported by other scholars. For example, Maertens and Velde (2017) find that order purchase can contribute to the quality of staple foods due to the emphasis on quality. In the most common bidding markets, buyers tend to set flexible quality thresholds according to their actual needs which help to meet minimum quality requirements and maximize value (Yao and Tanaka, 2020). Berning et al. (2013) argue that governments should establish a nutritional quality threshold for children's foods, which would reduce advertising that does not meet any current and proposed self-regulatory nutrition guidelines. The findings of these studies are similar to ours, except for the different study subjects.

Our research is essentially about re-shaping staple food support policies. Our findings suggest that staple food procurement policies can indeed create production effects effectively. Thus, not only can the purchase or price support policies be used to achieve quantitative support for food security, but also quality-related rules can be modified to improve malnutrition. This could provide some references for addressing the current global malnutrition problem. In terms of staple food consumption, people are now more conscious of quality characteristics of nutrition and health, such as pesticide residues, organic, green, essential micronutrients, etc. In re-shaping staple food procurement standards, the government can add these above-mentioned quality characteristics to guide healthy diets and consumption, which will reduce environmental damage and contribute to sustainable production. Therefore, transform food systems must also be accompanied by shifts in consumption. However, it is regrettable that due to the lack of data support, we do not have the conditions to conduct extensive mechanism analysis. After the policy adjustment, the increase in the quality threshold for wheat policy procurement will inevitably lead to an increase in quality measurement equipment. Therefore, we believe that the quality measurement equipment will play an important positive moderating role. From the perspective of high-quality wheat planting bases, the improvement in wheat quality will definitely be influenced by the number of high-quality wheat planting bases, which will also play an important positive moderating role. From the perspective of staple grain source control, the increase in the procurement quality threshold will reduce the total amount of wheat policy procurement, which will inevitably reduce the government's control over grain sources and make wheat procurement more market-oriented. Although we can only analyze that mechanisms theoretically and not through empirical analysis due to relatively limited data, we will further empirically study these mechanisms in the future.

6 Conclusion

In order to evaluate the effects of improving quality standards of purchase policy for staple food in 2018, we use some difference-in-differences models to explore whether the new staple food purchase policy can achieve the expected market quality outcomes based on wheat market transaction data. In addition, we discuss the various threats to identification and introduces several alternative tests that aim to support the hypothesis that improving quality standards of purchase policy has a significant positive impact on the quality of staple food supply. Finally, we make an empirical test the mediator mechanism of the quality premiums and come to the following conclusions:

Firstly, improving quality standards of purchase policy has a significant positive impact on the staple food supply quality. The conclusion remains robust through several alternative tests. Furthermore, the quality premium plays a mediator role in policy adjustment and the quality of staple food market supply, which shows that improving quality standards of purchase policy could widen the price difference between high-grade and low-grade staple food in a market, thereby helping to strengthen farmers' tendency to plant high-quality varieties or increase quality inputs.

This paper provides a new insight for addressing malnutrition and contributes to the avoidance of excessive support for food quantity security. For example, the government should evaluate the trend of consumer demand and the importance of staple food quality traits, then adjust some standards

TABLE 6 Robustness test results.

	(1) Quality	(2) Quality	(3) Quality	(4) Quality
	Southern regions	Northern regions	Policy period	Non-policy period
P × T	7.026*** (2.091)	7.252*** (0.995)	4.305*** (1.634)	5.810*** (1.226)
Price	51.167*** (6.765)	52.154*** (2.519)	64.894*** (9.145)	71.422*** (3.906)
Rain	0.002 (0.004)	0.017*** (0.002)	0.004** (0.002)	−0.002 (0.002)
Sumprice	−0.784 (0.491)	−0.025 (0.252)	−0.204 (0.274)	−1.567*** (0.277)
Income	0.000 (0.000)	−0.001*** (0.000)	0.001*** (0.000)	0.002*** (0.000)
Service	0.162*** (0.031)	0.046*** (0.010)	0.140*** (0.015)	0.034*** (0.012)
Impotprice	6.392** (2.9)	−0.511 (1.113)	−0.358 (2.887)	−1.929* (1.137)
Cornprice	91.712*** (7.893)	30.709*** (3.145)	−5.149 (8.677)	−4.917 (3.62)
Indicaprice	−49.681*** (15.211)	−31.318*** (6.861)	23.532 (19.349)	47.360*** (8.52)
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
_cons	696.844*** (61.267)	754.344*** (23.222)	634.484*** (43.293)	739.616*** (28.437)
N	6,015	22,273	12,960	14,018
Adj. R-sq	0.332	0.2365	0.3488	0.3412

*, ** and *** indicate significant at the 10%, 5% and 1% level, respectively.

TABLE 7 Mediator effect test results.

	(1) Premium	(2) Quality	(3) Quality
P × T	0.072*** (0.002)		3.740*** (1.059)
Premium		21.397*** (5.423)	12.537** (5.894)
Price	0.994*** (0.002)	26.920*** (5.703)	36.297*** (6.372)
Rain	0.000*** (0.000)	−0.000 (0.001)	0.000 (0.001)
Sumprice	−0.009*** (0.000)	−1.001*** (0.198)	−0.928*** (0.199)
Income	−0.000*** (0.000)	0.001*** (0.000)	0.001*** (0.000)
Service	−0.001*** (0.000)	0.120*** (0.009)	0.113*** (0.009)
Impotprice	−0.001 (0.001)	1.174 (1.058)	1.180 (1.057)
Cornprice	−0.003 (0.003)	37.390*** (3.103)	37.750*** (3.123)
Indicaprice	0.009 (0.007)	−27.702*** (6.439)	−27.910*** (6.449)
Province FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
_cons	0.151*** (0.037)	768.339*** (20.283)	756.901*** (20.381)
N	26,841	26,841	26,841
Adj. R-sq	0.9544	0.2983	0.2987

Robust standard errors are in parentheses. ** and *** indicate significant at the 5% and 1% level, respectively.

or regulations accordingly, which can balance food security and nutrition better. As staple foods consumption tends to diversify, especially green, organic and pollution-free, our future researches will gradually shift to the consumer taste value so as to better reflect the actual needs of residents and provide right market information for the breeding, cultivation, trade and processing.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

CC: Writing—original draft, Writing—review & editing, Investigation, Methodology. KS: Conceptualization, Data curation, Investigation, Methodology, Project administration, Resources, Writing—review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This research was supported by Special Project for National Special Doctoral Serving Needs (BSZX2021-17).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Abate, G. T., Bernard, T., de Janvry, A., Sadoulet, E., and Trachtman, C. (2021). Introducing quality certification in staple food markets in Sub-Saharan Africa: four conditions for successful implementation. *Food Policy.* 105, 102173. doi: 10.1016/j.foodpol.2021.102173

Ahn, D., and Orden, D. (2021). China – domestic support for agricultural producers: one policy, multiple parameters imply modest discipline. *World Trade Rev.* 20, 389–404. doi: 10.1017/S1474745621000100

Ali, N., and Akmal, M. (2022). Wheat growth, yield, and quality under water deficit and reduced nitrogen supply. A review. *Gesunde Pflanzen.* 74, 371–383. doi: 10.1007/s10343-021-00615-w

Anissa, B. P., Abate, G., Bernard, T., and Bulte, E. (2021). Is the local wheat market a 'market for lemons'? Certifying the supply of individual wheat farmers in Ethiopia. *Eur. Rev. Agricult. Econ.* 48, 1162–1186. doi: 10.1093/erae/jbab018

Bairagi, S., Demont, M., Custodio, M. C., and Ynion. (2020). What drives consumer demand for rice fragrance? Evidence from South and Southeast Asia. *Br. Food J.* 122, 3473–3498. doi: 10.1108/BFJ-01-2019-0025

Berning, J. P., Huang, R., and Rabinowitz, A. (2013). An evaluation of government and industry proposed restrictions on television advertising of breakfast cereals to children. *J. Consum. Policy.* 37, 507–525. doi: 10.1007/s10603-013-9233-1

Brummer, B., von Cramon-Taubadel, S., and Zorya, S. (2009). The impact of market and policy instability on price transmission between wheat and flour in Ukraine. *Eur. Rev. Agricult. Econ.* 36, 203–230. doi: 10.1093/erae/jbp021

Chetty, R., Looney, A., and Kroft, K. (2009). Salience and Taxation: Theory and Evidence. *American Economic Rev.* 99. doi: 10.1257/aer.99.4.1145

Cummings, R., Rashid, S., and Gulati, S. (2006). Grain price stabilization experiences in Asia: What have we learned? *Food Policy.* 31, 302–312. doi: 10.1016/j.foodpol.2006.03.006

Drugova, T., and Curtis, K. R. (2022). Why can't the supply chain keep up with organic bakery product demand? Understanding miller, distributor, and baker organic wheat quality perceptions and needs. *Int. Food Agribusi. Manage. Rev.* 25, 601–617. doi: 10.22434/IFAMR2021.0138

Fan, P., Mishra, A. K., Feng, S., Su, M., and Hirsch, S. (2023). The impact of China's new agricultural subsidy policy on grain crop acreage. *Food Policy.* 118, 102472. doi: 10.1016/j.foodpol.2023.102472

FAO (2022). *The State of Food Security and Nutrition in the World 2022.* Available online at: https://www.who.int/publications/m/item/the-state-of-food-security-and-nutrition-in-the-world-2022 (accessed July 6, 2022).

Fiamohe, R., Nakelse, T., Diagne, A., and Seck, P. A. (2015). Assessing the effect of consumer purchasing criteria for types of rice in Togo: a choice modeling approach. *Agribusiness.* 31, 433–452. doi: 10.1002/agr.21406

Fontanelli, M. D., Arroyo, A. M., Sales, C. H., Seal, C. J., and Fisberg, R. M. (2021). Opportunities for diet quality improvement: the potential role of staple grain foods. *Public Health Nutr.* 24, 6145–6156. doi: 10.1017/S1368980021001531

Han, X., Xue, P., and Zhang, N. (2021). Impact of grain subsidy reform on the land use of smallholder farms: evidence from huang-huai-hai plain in China. *Land.* 10, 9. doi: 10.3390/land10090929

Hu, N. Y., Du, C. H., Zhang, W. Q., Liu, Y., Zhang, Y. H., Zhao, Z. G., et al. (2022). Did wheat breeding simultaneously improve grain yield and quality of wheat cultivars releasing over the past 20 years in China? *Agronomy-Basel.* 12, 9. doi: 10.3390/agronomy12092109

Karaman, S., and Yavuz, F. (2014). Hedonic price analysis of the quality characteristics of the Anatolian Hard Red Wheat. *Agricult. Econ.* 10, 469–478. doi: 10.17221/37/2014-AGRICECON

Kawasaki, K., and Uchida, S. (2016). Quality matters more than quantity: asymmetric temperature effects on crop yield and quality grade. *Am. J. Agric. Econ.* 98, 1195–1209. doi: 10.1093/ajae/aaw036

Kiel, K. A., and McClain, K. T. (1995). House prices during siting decision stages: the case of an incinerator from rumor through operation. *J. Environ. Econ. Manage.* 28, 241–255. doi: 10.1006/jeem.1995.1016

Kim, K. H., and Kim, J. Y. (2021). Understanding wheat starch metabolism in properties, environmental stress condition, and molecular approaches for value-added utilization. *Plants-Basel.* 10, 11. doi: 10.3390/plants10112282

Kuang, Y., Yang, J., and Abate, M. (2021). Farmland transfer and agricultural economic growth nexus in China: agricultural TFP intermediary effect perspective. *China Agricult. Econ. Rev.* 14, 184–201. doi: 10.1108/CAER-05-2020-0076

Laska, M. N., Caspi, C. E., Lenk, K., Moe, S. G., Pelletier, J. E., Harnack, L. J., et al. (2019). Evaluation of the first US staple foods ordinance: impact on nutritional quality of food store offerings, customer purchases and home food environments. *Int. J. Behav. Nutr. Phys. Acti.* 16, 1. doi: 10.1186/s12966-019-0818-1

Li, J., Chavas, J. P., and Li, C. (2021). The dynamic effects of price support policy on price volatility: the case of the rice market in China. *Agricult. Econ.* 2, 307–320. doi: 10.1111/agec.12681

Li, J., Liu, W., and Song, Z. (2020). Sustainability of the adjustment schemes in china's grain price support policy—an empirical analysis based on the partial equilibrium model of wheat. *Sustainability.* 12, 16. doi: 10.3390/su12166447

Maertens, M., and Velde, K. V. (2017). Contract-farming in staple food chains: the case of rice in Benin. *World Dev.* 95, 73–87. doi: 10.1016/j.worlddev.2017.02.011

Messaoudi, A., Labdelli, F., Rebouh, N. Y., Djerbaoui, M., Kucher, D. E., Hadjout, S., et al. (2023). Investigating the Potassium Fertilization Effect on Morphological and Agrophysiological Indicators of Durum Wheat under Mediterranean Rain-Fed Conditions. *Agriculture* 13, 6. doi: 10.3390/agriculture13061142

Mottaleb, K. A., Rahut, D. B., and Mishra, A. (2017). Modeling rice grain-type preferences in Bangladesh. *Br. Food J.* 119, 2049–2061. doi: 10.1108/BFJ-10-2016-0485

My, N. H. D., Van Loo, E. J., Rutsaert, P., Tuan, T., and Verbeke, W. (2018). Consumer valuation of quality rice attributes in a developing economy. *Br. Food J.* 120, 1059–1072. doi: 10.1108/BFJ-05-2017-0277

Niu, Y., Xie, G., Xiao, Y., Liu, J., Zou H, Qin, K., et al. (2021). The story of grain self-sufficiency: China's food security and food for thought. *Food Energy Secur.* 11, 1. doi: 10.1002/fes3.344

Olden, A., and Men, J. (2022). The triple difference estimator[Semiparametric difference-in-differences estimators]. *Econom. J.* 25, 10. doi: 10.1093/ectj/utac010

Pearsons, K. A., Omondi, E. C., Heins, B. J., Zinati, G., Smith, A., and Rui, Y. (2022). Reducing tillage affects long-term yields but not grain quality of maize, soybeans, oats, and wheat produced in three contrasting farming systems. *Sustainability.* 14, 631. doi: 10.3390/su14020631

Peng, Y. C., Zhao, Y., Yu, Z. T., Zeng, J. B., Xu, D. G., Dong, J., et al. (2022). Wheat quality formation and its regulatory mechanism. *Front. Plant Sci.* 13, 834654. doi: 10.3389/fpls.2022.834654

Petrick, M., and Zier, P. (2010). Regional employment impacts of Common Agricultural Policy measures in Eastern Germany: a difference-in-differences approach. *Agricult. Econ.* 42, 183–193. doi: 10.1111/j.1574-0862.2010.00509.x

Prom-u-thai, C., and Rerkasem, B. (2020). Rice quality improvement. A review. *Agron. Sustain. Dev.* 40, 4. doi: 10.1007/s13593-020-00633-4

Qian, J., Ito, S., Mu, Y., Zhao, Z., and Wang, X. (2018). The role of subsidy policies in achieving grain self-sufficiency in China: a partial equilibrium approach. *Agricult. Econ. (Zemědělská ekonomika).* 64, 23–35. doi: 10.17221/167/2016-AGRICECON

Qian, J., Ito, S., and Zhao, Z. (2020). The effect of price support policies on food security and farmers' income in China. *Aust. J. Agricult. Res. Econ.* 64, 1328–1349. doi: 10.1111/1467-8489.12398

Randhe, M. V., Jadhao, S. D., and Mane, S. S. (2009). Effect of organic and inorganic fertilization on yield and quality of wheat. *J. Rural Stud.* 32, 320–330.

Ryan, A., Sutton, M., and Doran, T. (2014). Does winning a pay-for-performance bonus improve subsequent quality performance? Evidence from the Hospital Quality Incentive Demonstration. *Health Serv Res.* 49, 568–587. doi: 10.1111/1475-6773.12097

Sakolwitayanon, H., Soni, P., and Damien, J. (2018). Attributes determining consumer preference for organic rice in Bangkok, Thailand. *Br. Food J.* 120, 2017–2032. doi: 10.1108/BFJ-12-2017-0667

Selim, S. (2015). The impact of grain self-sufficiency regime on regional welfare and agricultural productivity in China. *Agricult. Econ.* 46, 595–601. doi: 10.1111/agec.12156

Shin, I., and Kim, H. (2010). The effect of subsidy policies on the product quality improvement. *Econ. Model.* 27, 687–696. doi: 10.1016/j.econmod.2010.01.008

Simionescu, C. S., Plenovici, C. P., Augustin, C. L., Rahoveanu, M. M. T., Rahoveanu, A. T., and Zugravu, G. A. (2022). Fuzzy quality certification of wheat. *Agriculture-Basel.* 12, 10. doi: 10.3390/agriculture12101640

Suchato, R., Patoomnakul, A., and Photchanaprasert, N. (2021). Alternative cropping adoption in Thailand: a case study of rice and sugarcane production. *Heliyon.* 7, 12. doi: 10.1016/j.heliyon.2021.e08629

Takayama, T., Norito, T., Nakatani, T., and Ito, R. (2021). Do geographical indications preserve farming in rural areas? Evidence from a natural experiment in Japan. *Food Policy.* 102, 102101. doi: 10.1016/j.foodpol.2021.102101

van der Merwe, J. D., and Cloete, P. C. (2018). Financial impact of wheat quality standards on South African wheat producers: a dynamic linear programming (DLP) approach. *Dev. South. Afr.* 35, 53–69. doi: 10.1080/0376835X.2017.1412296

Virgilio-León, J., García-Salazar, J. A., Mora-Flores, J. S., García-Mata, R., and Ramírez-Jaspeado, R. (2023). Effects of the price supports policy on the rice market in mexico. *Revista Fitotecnia Mexicana.* 46, 195–202. doi: 10.35196/rfm.2023.2.195

Wang, W. T., and Wei, L. B. (2021). Impacts of agricultural price support policy on price variability and welfare: evidence from China's soybean market. *Agricult. Econ.* 52, 3–17. doi: 10.1111/agec.12603

Yadav, G., and Ellis, R. H. (2016). Effects of rain shelter or simulated rain during grain filling and maturation on subsequent wheat grain quality in the UK. *J. Agricult. Sci.* 155, 300–316. doi: 10.1017/S0021859616000411

Yang, W., and Li, B. (2020). Prediction of grain supply and demand structural balance in China based on grey models. *Grey Syst.: Theory Appl.* 11, 253–264. doi: 10.1108/GS-09-2019-0039

Yao, Y., and Tanaka, M. (2020). Price-quality trade-off in procurement auctions with an uncertain quality threshold. *J. Econ. Behav. Organ.* 177, 56–70. doi: 10.1016/j.jebo.2020.06.005

Yu, B., Yu, H., Yang Q, Li, K., Ji, L., Zhang, R., et al. (2019). Postcombustion capture of CO2 by diamines containing one primary and one tertiary amino group: reaction rate and mechanism. *Energy & Fuels.* 33, 7500–7508. doi: 10.1021/acs.energyfuels.9b00961

Yu, W., and Bandara, J. (2016). India's grain security policy in the era of high food prices: a computable general equilibrium analysis. *World Econ.* 40, 1547–1568. doi: 10.1111/twec.12383

Zahra, N., Hafeez, M. B., Wahid, A., Al Masruri, M. H., Ullah, A., Siddique, K. H. M., et al. (2023). Impact of climate change on wheat grain composition and quality. *J. Sci. Food Agric.* 103, 2745–2751. doi: 10.1002/jsfa.12289

Zhu, Y. A., He, J. Y., Yu, Z. Y., Zhou, D., Li, H. Y., Wu, X. Y., et al. (2022). Wheat and Faba bean intercropping together with nitrogen modulation is a good option for balancing the trade-off relationship between grain yield and quality in the Southwest of China. *Agron.-Basel.* 12, 2984. doi: 10.3390/agronomy12122984