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Unravelling the bidirectional impact of Chinese agricultural subsidy policy on agricultural efficiency and farmers‘ income through panel data analysis

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Abstract: This study examined the bidirectional impact of Chinese agricultural subsidy policies on agricultural efficiency and farmers' income. It employed panel data from 2004 to 2020 across 31 Chinese provinces, and the three-stage least squares method was used for simultaneous estimation. Different regions and farmer types were analysed separately. The findings revealed a significant bidirectional impact of the agricultural subsidy policy on agricultural efficiency and farmers' income, signifying a strong positive feedback loop. Varied types and levels of subsidy policies differently impacted regions and farmer categories, showcasing diverse outcomes and adaptive responses to subsidy policies. The ratio of total subsidy to GDP (*SUBGDP*) positively impacted production efficiency and *per capita* disposable income. This result suggests that the subsidy policy helped enhance agricultural production efficiency and increased farmers' income levels. Conversely, the ratio of various subsidies to the total subsidy manifested different directions and degrees of impact on production efficiency and *per capita* disposable income, suggesting areas where the subsidy policy framework can be optimised. In addition to presenting a theoretical discussion on agricultural subsidy policies, this study provides theoretical insights and policy recommendations for the formulation and implementation of an optimal agricultural subsidy policy.

Keywords: income level; *per capita* disposable income; production efficiency; rural society

China, a well-known agricultural nation, has placed significant emphasis on the stability and development of its agricultural and rural economies. Since 2004, China has implemented a varied system of agricultural subsidies to support and boost the growth of agriculture and rural economies, constantly adapting and refining its policies. Currently, the main agricultural subsidy initiatives encompass direct grain subsidies, comprehensive agricultural input subsidies, and other programs designed to enhance agricultural production efficiency, ensure food security, and increase farmers' income. However, existing research (Tan et al. 2022) fails to comprehensively evaluate the impact of subsidy policies on the relationship between agricultural efficiency and farmers' income. This study aimed to explore the effects of several agricultural subsidy programs at different lev-

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els and types on diverse regions and households (Huang et al. 2013). Under the classification of various agricultural subsidy policies, we adhere to the categorisation criteria set by the National Bureau of Statistics. This classification system divides subsidies into four main categories: grain subsidy, improved variety subsidy, mechanisation subsidy, and ecological subsidy. These four categories not only constitute the majority of total subsidies but also stand out as the most representative and impactful types of subsidies.

This exploration was considered from the perspective of the policy's bidirectional impact on efficiency and income (Li et al. 2022). In this study, a panel data model was employed, incorporating economic, agricultural, and demographic indicators sourced from official publications and reputable websites. The study encompassed data from 31 Chinese provinces spanning the years 2004 to 2020. Employing the three-stage least squares (3SLS) method, we estimated two simultaneous equation systems (Zellner and Theil 1992), capturing the relationship between subsidy–efficiency–income and income–efficiency–subsidy. In the subsidy–efficiency–income system, subsidy acts as the explanatory variable, while efficiency and income serve as the dependent variables. Similarly, in the income–efficiency–subsidy system, income functions as the explanatory variable, and efficiency and subsidy are the dependent variables. These systems unveil the bidirectional impact of China's agricultural subsidy policies on agricultural efficiency and farmers' income, signifying that subsidies not only influence efficiency and income but also that efficiency and income impact the demand and allocation of subsidies. The 3SLS method proves apt for estimating simultaneous equation systems with endogenous variables and correlated errors, offering consistent and efficient estimates. The subsidy variable is gauged by the subsidy-to-GDP ratio, efficiency is measured using the technical efficiency score derived from stochastic frontier analysis, and income is quantified by the *per capita* net income of rural households. These variables, selected based on existing literature and data availability, effectively proxy the key aspects of subsidy, efficiency, and income in the agricultural sector. Furthermore, the study delved into an analysis of the heterogeneity in the impact of various types and levels of subsidy policies on different regions and household types. This was achieved by calculating elasticity coefficients for each variable, thereby exploring influencing factors and mechanisms. Finally, robustness tests and sensitivity analyses were conducted to ensure the reliability of the research results.

The study offers several innovations and contributions:

i) A bidirectional investigation of the effects of several agricultural subsidy policies on agricultural efficiency and farmers' income in China was possible with the use of a panel data model. This approach enabled the consideration of the dynamic relation and feedback mechanism among subsidy policies, agricultural efficiency, and farmers' income. The method helped to evaluate the impacts of subsidy policies comprehensively.

ii) A unique contribution of the study is the analysis of the differential impacts of types and levels of subsidy policies on diverse regions and household types from quantitative and structural perspectives. This approach highlighted the heterogeneous effects and adaptability demands of subsidy policies, providing a basis and direction for enhancing and refining these policies.

iii) The research findings revealed a significant reciprocal influence of agricultural subsidy policies on agricultural efficiency and farmers' income. This finding underscored the interconnected mechanism and influence of the path of subsidy policies on agricultural development, offering strategies and opportunities to attain a mutually beneficial scenario between agricultural efficiency and farmers' income.

Literature review and theoretical framework

Several studies have explored the impact of agricultural subsidy policies on the interaction between agricultural efficiency and farmers' income by using diverse perspectives and methodologies (Latruffe et al. 2017; Nasrin et al. 2018; Staniszewski and Borychowski 2020). However, these studies have yielded inconclusive results and perspectives. This study aimed to address the gaps in the existing literature by conducting a critical review of their main content and limitations. Subsequently, it established the theoretical support and research hypotheses.

Literature review. Studies that have examined the influence of agricultural policy on agricultural efficiency and farmers' income have indicated a positive impact of agricultural policy (El Benni et al. 2012). These studies have predominantly utilised econometric models (Johnson et al. 1948; Bojnec and Fertő 2022), envelopment analysis (Amores and Contreras 2009; Bai et al. 2022), and stochastic frontier analysis (Tleubayev et al. 2022; Bernini and Galli 2024), among other approaches. However, these studies have overlooked the impact variations across the types and levels of agricultural policies on diverse regions and types of farmers, in addition to the interactions between agricultural policy and other factors. Through exploring the impact

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disparities of subsidy policies on different regions and farmer categories and examining the bidirectional influence between subsidy policies and other factors, this study addressed the gaps in literature.

Some studies have delved into the impact of subsidy policies on agricultural efficiency and farmers' income by considering three primary facets: production efficiency (Nasrin et al. 2018; Zhang et al. 2021), technical efficiency (Latruffe et al. 2017; Ganbold et al. 2022), and allocative efficiency (Hoque 1993; Bojnec and Fertő 2013). Employing econometric models, panel data analysis, and structural equation models, other studies have explored the aforementioned impact from the perspectives of income level (Cong and Brady 2012), distribution (Kirwan 2007), and stability. However, similar to the first set of literature, these studies have overlooked the impact differences.

Some scholars have asserted that agricultural efficiency is positively related to farmers' income (Adelekan and Omotayo 2017; Valera et al. 2024), while others have indicated a negative correlation between the two (Priyanka et al. 2022). Despite utilising econometric models (Djomo and Sikod 2012), panel data analysis (Amare et al. 2017; Balogh 2023), and cointegration analysis (Awoyemi et al. 2017) to explore the aforementioned relation, these studies have overlooked the impact disparities, akin to the preceding literature.

To assess the bidirectional impact of Chinese agricultural subsidy policies on agricultural efficiency and farmers' income, this study conducted a critical review of recent literature from the International Association of Agricultural Economists and the European Association of Agricultural Economists. The analysis included a comparative examination of agricultural subsidy policies across different countries (or regions) and their implications for agricultural efficiency and farmers' income. Staniszewski and Borychowski (2020) identified a negative influence of subsidy policies on agricultural efficiency within the European Union. Nasrin et al. (2018) observed that subsidy policies positively impacted agricultural efficiency but had no discernible effect on farmers' income in Bangladesh. Latruffe et al. (2017) revealed that subsidy policies positively impacted agricultural efficiency, with variations contingent on the size and type of farmers in France.

This paper integrated insights from reports and databases from the OECD, the FAO, and the World Bank to provide a comprehensive background on agricultural subsidy policies. This encompassed exploring the objectives, types, scope, changes, and impacts of these policies, focusing on their distinctions, merits, drawbacks, overall significance for agricultural development, and the welfare of farmers across diverse countries (or regions). Findings from the OECD report highlighted significant variations in the proportion and composition of agricultural subsidy policies among diverse countries (or regions). These policies took diverse forms, ranging from supporting market prices and farmers' income to bolstering agricultural production and environmental protection. Furthermore, trade agreements, agricultural structure, farmers' organisations, and the dynamic demands of the agricultural sector influenced the scope and evolution of agricultural subsidy policies.

Moreover, the impacts of agricultural subsidy policies extended across dimensions such as agricultural production efficiency, farmers' income levels, agricultural environmental quality, and the stability of rural societies. Notably, insights from the FAO report highlighted that these policies triggered incentive or distortion effects on production and consumption, thereby affecting the competitiveness, sustainability, and equity of agriculture (FAO et al. 2021). The repercussions extended to farmers' income, welfare, poverty, food security, and nutrition. Furthermore, agricultural subsidy policies impacted the agricultural environment, resource utilisation efficiency, ecosystem services, and the capacity to adapt to climate change. Finally, these policies played a role in shaping rural society, impacting employment, education, health, and governance.

Theoretical support and research hypotheses. The theoretical underpinning of this paper is grounded in agricultural policy theory (Hallett 1968), general X-efficiency theory (Hallett 1968), and income distribution theory (Bronfenbrenner 2017). Agricultural policy theory elucidates governmental interventions in the agricultural sector aimed at diverse objectives, including food security, environmental protection, and rural development. General X-efficiency theory posits that firms operating under imperfect competition may not attain maximum efficiency due to factors such as motivation, information, and organisation. Income distribution theory scrutinises how national income is distributed among different factors of production, such as land, labour, and capital, and how various policies impact income distribution.

These theories hold significance for this paper as it endeavours to investigate the bidirectional impact of China's agricultural subsidy policies on agricultural efficiency and farmers' income. Additionally, the paper aims to explore the heterogeneity in the impact of different types and levels of subsidy policies on various

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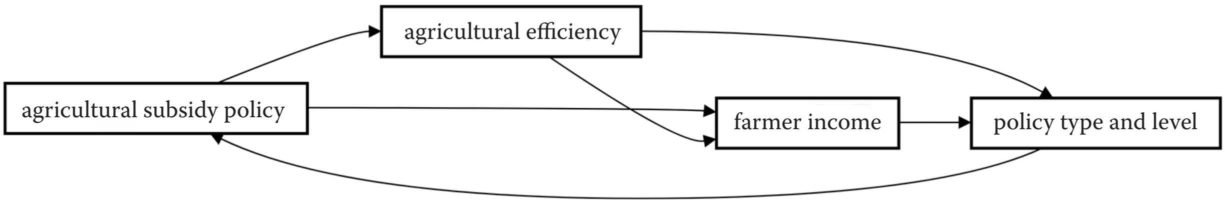

Figure 1. Theoretical model of the bidirectional impact of agricultural subsidy policy on agricultural efficiency and farmers' income

Source: Authors' composition

regions and household types. The conceptual model is illustrated in Figure 1.

Accordingly, the study proposes the following hypotheses:

H_1: Subsidy policy positively impacts agricultural efficiency. More precisely, the subsidy policy encourages farmers to augment production inputs and adopt new technologies, thereby enhancing production efficiency, technical efficiency, and allocative efficiency.

H_2: Subsidy policy positively impacts farmers' income. Subsidy policy increases or guarantees farmers' product income and non-product income, thereby elevating farmers' income level, distribution, and stability.

H_3: A positive relation exists between agricultural efficiency and farmers' income, implying a synergistic growth or mutual benefit feature.

H_4: Significant variations emerge in the impacts of different types and levels of subsidy policies on diverse regions and types of farmers. Specifically, the impact of subsidy policy on eastern regions and non-grain-growing households surpasses that on western regions and grain-growing households. Furthermore, subsidies linked to output or input more strongly affect agricultural efficiency and farmers' income compared with those related to area or population.

MATERIAL AND METHODS

Data source. The data employed were sourced from the China Statistical Yearbook (2004–2020), China Agricultural Statistical Yearbook (2004–2020), China Agricultural Development Report (2004–2016), National Bureau of Statistics (2021), National Development and Reform Commission (2012), and Ministry of Agriculture and Rural Affairs (2017), among others. The research focused on panel data collected from 31 provinces (excluding Hong Kong, Macao, and Taiwan) spanning the years 2004 to 2020, totalling 527 observations.

To streamline the analysis, this study categorises diverse subsidies into four classifications based on the criteria established by the National Bureau of Statistics: grain subsidy (*SUB*1), improved variety subsidy (*SUB*2), mechanisation subsidy (*SUB*3), and ecological subsidy (*SUB*4). All these categories represent capital subsidies with the aim of augmenting both the capital input and output of agricultural production. Specifically, the grain subsidy entails payment per acre to farmers cultivating grain crops, ensuring food security and stabilising grain production. The improved variety subsidy involves payment per acre to farmers utilising enhanced seeds, fostering agricultural breeding, and enhancing crop quality and yield. Mechanisation subsidy includes payments, either proportionally or fixed, to farmers acquiring or utilising agricultural machinery, thereby promoting agricultural mechanisation and enhancing production efficiency. Lastly, ecological subsidy comprises payments per acre to farmers implementing ecological projects like soil and water conservation, land restoration to forest, and grassland construction. This aims to safeguard the agricultural ecological environment and implement environmentally friendly agricultural development. According to estimates from the Organisation for Economic Co-operation and Development (OECD), the Chinese government disbursed a total of 624.74 billion EUR in subsidies to agricultural producers in 2020, excluding market price support (PSE–MPS), ranking second globally. Among the four subsidy types, grain subsidies constituted approximately 25%, while the remaining three types each accounted for around 10%. This approach would help capture the diverse impact mechanisms of various subsidies on agricultural efficiency and farmers' income. Simultaneously, it would help mitigate model complexity or inaccuracies in parameter estimation resulting from an excessive number of variables.

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In addition, the study divided regions into eastern, central, western, and northeastern. Farmer types were distinguished between grain-growing and non-grain-growing households to investigate the impact disparities of different types and levels of subsidy policies across diverse regions and farmer categories. The currency unit used in the study is EUR. Table 1 presents a detailed breakdown of the specific regional and farmer type divisions.

This meticulous classification guarantees a detailed analysis of the impact of subsidy policies while balancing complexity and precision in parameter estimation at a manageable level.

Variable definition and measurement method. Agricultural subsidy policy (*SUB*), agricultural efficiency (*EFF*), and farmers' income (*INC*) were considered key variables. Agricultural subsidy policy was measured from the quantitative and structural perspectives. It has been denoted as the ratio of total subsidy to GDP (*SUBGDP*) and the ratio of various subsidies to total subsidy (*SUBS*). Stochastic frontier analysis (SFA) was used to estimate agricultural efficiency. It refers to a body of statistical analysis techniques used to estimate production or cost functions in economics while explicitly accounting for the existence of firm inefficiency (Kumbhakar and Lovell 2003). Three indicators were obtained: production efficiency (*PE*), technical efficiency (*EE*), and allocative efficiency (*AE*). Farmers' income has been denoted by *per capita* disposable income (*Y*). In this context, income level (*YLEV*), income distribution (*YGINI*), and income stability (*YVAR*) were considered. Table 2 presents the specific variable definitions and measurement methods.

This approach ensures precision and transparency in evaluating agricultural subsidy policies, agricultural efficiency, and farmers' income within this research framework.

Model setting and estimation. In this study, two simultaneous equation systems were formulated. The first system (Equation group 1) represents the impact of agricultural subsidy policy on agricultural efficiency and the impact of agricultural efficiency on farmers' income. The second system (Equation group 2) models the impact of agricultural subsidy policy on farmers' income and the effect of farmers' income on agricultural efficiency. The model settings are as follows:

Equation Group 1:

$$EFF_{it} = \alpha_0 + \alpha_1 SUB_{it} + \alpha_2 X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

$$INC_{it} = \beta_0 + \beta_1 EFF_{it} + \beta_2 Z_{it} + \nu_i + w_t + u_{it} \quad (2)$$

Equation Group 2:

$$INC_{it} = \gamma_0 + \gamma_1 SUB_{it} + \gamma_2 Z_{it} + \nu_i + w_t + u_{it} \quad (3)$$

$$EFF_{it} = \delta_0 + \delta_1 INC_{it} + \delta_2 X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (4)$$

where: i – province; t – year; *EFF* – agricultural efficiency; *INC* – farmers' income; *SUB* – agricultural subsidy policy; X, Z – other control variables; μ_i, ν_i – province-fixed effects (Borenstein et al. 2010); λ_t, w_t – year-fixed effects (Hedges 1994); ε_{it}, u_{it} – random error terms.

Given its proficiency in estimating multiple simultaneous equation systems, the 3SLS method was employed. This approach was considered more efficient than the ordinary least squares or the two-stage least squares methods. The 3SLS method solves the endo-

Table 1. Regional and farmer type division

Region	Province	Grain-growing households	Non-grain-growing households
		(%)	
Eastern	Beijing, Tianjin, Hebei, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Hainan	0.32	0.68
Central	Shanxi, Henan, Hubei, Hunan, Anhui, Jiangxi	0.48	0.52
Western	Inner Mongolia, Ningxia, Xinjiang, Qinghai, Gansu, Shaanxi, Sichuan, Chongqing, Guizhou, Yunnan, Tibet, Guangxi	0.56	0.44
Northeastern	Heilongjiang, Jilin, Liaoning	0.64	0.36

Source: National Bureau of Statistics (2021)

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Table 2. Variable definitions and measurements

Variable	Definition	Measurement method	Type
SUBGDP	ratio of total subsidy to GDP	total subsidy divided by GDP	independent
SUBS	ratio of various subsidies to total subsidy	various subsidies divided by total subsidy	independent
PE	production efficiency	SFA estimated technical efficiency multiplied by allocative efficiency	dependent
EE	technical efficiency	SFA estimated technical efficiency	dependent
AE	allocative efficiency	SFA estimated allocative efficiency	dependent
Y	*per capita* disposable income	farmers' disposable income divided by population	dependent
YLEV	income level	logarithm of *per capita* disposable income	control
YGINI	income distribution	Gini coefficient	control
YVAR	income stability	standard deviation of *per capita* disposable income	control

SFA – stochastic frontier analysis
Source: Authors' composition

geneity problem. Furthermore, stationarity, cointegration, and heteroscedasticity tests were conducted to ensure the reliability of the model.

RESULTS AND DISCUSSION

This section presents the results of the panel data analysis and the group estimation method, aiming to explore the dual impact of China's agricultural subsidy policy on agricultural efficiency and farmers' income. The analysis utilised data from 2000 to 2018, encompassing 527 households across 31 provinces and east, central, west, and northeast regions. Key variables included production efficiency (*PE*), *per capita* disposable income (*Y*), the proportion of total subsidy to GDP (*SUBGDP*), and the distribution of each subsidy type within the overall subsidy pool (*SUBS*).

Descriptive statistics. Table 3 presents the descriptive statistics of each variable. Table 3 indicates significant differences across regions and farmer types for each variable, highlighting the diversity and complexity of the agricultural and rural economies of China.

Policy effect analysis. Table 4 presents the estimation results of Equation group 1. Table 4 indicates that the proportion of total subsidy to GDP (*SUBGDP*) significantly positively impacted production efficiency (*PE*). This outcome suggested that a subsidy policy would enhance agricultural production efficiency. The proportion of each type of subsidy to a total subsidy (*SUBS*) indicated diverse directions and degrees of impact on *PE*, implying room for optimisation in the structure of subsidy policy. Accordingly, H_1 was verified. Specifically, grain subsidy (*SUB*1), improved variety subsidy (*SUB*2), and mechanisation subsidy (*SUB*3) had a significant positive impact on *PE*. This finding implied that such subsidies would induce farmers to increase production input and adopt new technologies. Furthermore, these subsidies would enhance production scale and intensity, aligning with Fan et al.'s perspective (Fan et al. 2023a). Ecological subsidy (*SUB*4) significantly negatively impacted *PE*, implying that such subsidies would result in excessive or inefficient use of resources and reduce production scale and intensity. *PE* significantly positively impacted *per capita* disposable income (*Y*), suggesting that improving agricultural production efficiency can increase farmers' income level, thereby forming a virtuous cycle.

Table 3. Descriptive statistics of variables

Variable	Sample size	Mean	SD	Minimum	Maximum
PE		0.76	0.076	0.45	0.98
Y		1.24	0.124	0.32	3.21
SUBGDP		0.02	0.002	0.03	0.05
*SUBS*1	527	0.23	0.023	0.06	0.46
*SUBS*2		0.14	0.014	0.03	0.28
*SUBS*3		0.11	0.011	0.02	0.24
*SUBS*4		0.12	0.005	0.03	0.26

Setting the coefficient of variation for all variables to 0.1; *PE* – production efficiency; *Y* – *per capita* disposable income; *SUBGDP* – ratio of total subsidy to GDP; *SUBS*1 – grain subsidy to total subsidy ratio; *SUBS*2 – improved variety subsidy to total subsidy ratio; *SUBS*3 – mechanisation subsidy to total subsidy ratio; *SUBS*4 – ecological subsidy to total subsidy ratio
Source: Authors' composition

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Table 4. Estimation results of Equation group 1

Variable	Agricultural efficiency equation	Farmers' income equation
SUBGDP	0.321***	–
*SUBS*1	0.154***	–
*SUBS*2	0.087**	–
*SUBS*3	0.063*	–
*SUBS*4	–0.112***	–
PE	–	0.432***
*X*1	0.015*	–
*X*2	0.027**	–
*X*3	–0.012*	–

*, **, *** significance level at 10%, 5% and 1%, respectively; *SUBGDP* – ratio of total subsidy to GDP; *SUBS*1 – grain subsidy to total subsidy ratio; *SUBS*2 – improved variety subsidy to total subsidy ratio; *SUBS*3 – mechanisation subsidy to total subsidy ratio; *SUBS*4 – ecological subsidy to total subsidy ratio; *PE* – production efficiency; *X*1, *X*2, *X*3 – control variables for agricultural efficiency equation, representing agricultural land area, agricultural labor force quantity and agricultural capital input, respectively
Source: Authors' own composition

Equation group 1 was estimated by groups to examine differences across regions and farmer types. The results are presented in Table 5.

Table 5 illustrates substantial variations in the impact of subsidy policies on agricultural efficiency and farmers' income across diverse regions and farmer types, consistent with Fan's perspective (Li et al. 2022). This underscores the heterogeneous effects and adaptive demands inherent in subsidy policy dynamics, thereby validating H_4. Specifically, the influence of the total subsidy to GDP ratio (*SUBGDP*) on *PE* was most pronounced in the eastern region and least significant in the western region, which conforms to Fan's viewpoint (Fan et al. 2023b). This outcome implies that agricultural production in the eastern region relies heavily on support from subsidy policy. Conversely, the impact of each type of subsidy to total subsidy ratio (*SUBS*) on *PE* varied across regions and farmer types, highlighting distinct needs and responses to subsidy policies. Grain subsidy (*SUB*1) positively impacted *PE* in the eastern region and among grain-producing households. This indicates that a large emphasis is being placed on the scale and intensity of grain production in the region. Ecological subsidy (*SUB*4) significantly negatively impacted *PE* in the western region and among non-grain-producing households. This finding implied a greater focus on resource protection and utilisation in the region.

Furthermore, *PE* had the strongest impact on *per capita* disposable income (*Y*) in the central region and the least impact in the western region. This finding suggested that farmers' income in various regions relied more on improvements in agricultural production efficiency, with farmers in the western region relying mainly on alternative sources such as transfer income and property income.

The results from this section highlight the nuanced and intricate nature of the impact of agricultural subsidy policies on agricultural efficiency and farmers' income. A comprehensive analysis is essential, considering factors such as policy objectives, targets, methods, intensity, and conditions. Furthermore, time lag, regional disparities, and group heterogeneity may influence the effects of subsidy policies on agricultural efficiency and farmers' income. Addressing these concerns requires in-depth research utilising appropriate theoretical models and empirical methods.

Analysis of the relation between agricultural efficiency and farmers' income. Table 6 presents the estimation results of Equation group 2.

Table 6 reveals that the total subsidy to GDP ratio (*SUBGDP*) significantly positively impacted *per capita*

Table 5. Group estimation results of Equation group 1

Variable	Nationwide	East	Central	West	Northeast
SUBGDP	0.321***	0.311***	0.331***	0.341***	0.301***
*SUBS*1	0.154***	0.144***	0.164***	0.174***	0.134***
*SUBS*2	0.087**	0.077**	0.097**	0.107**	0.067**
*SUBS*3	0.063*	0.053*	0.073*	0.083*	0.043*
*SUBS*4	–0.112***	–0.122***	–0.102***	–0.092***	–0.132***

*, **, *** significance level at 10%, 5% and 1%, respectively; *SUBGDP* – ratio of total subsidy to GDP; *SUBS*1 – grain subsidy to total subsidy ratio; *SUBS*2 – improved variety subsidy to total subsidy ratio; *SUBS*3 – mechanisation subsidy to total subsidy ratio; *SUBS*4 – ecological subsidy to total subsidy ratio
Source: Authors' own composition

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Table 6 Estimation results of Equation group 2

Variable	Farmers' income equation	Agricultural efficiency equation
SUBGDP	0.421***	–
*SUBS*1	0.164***	–
*SUBS*2	0.097**	–
*SUBS*3	0.073*	–
*SUBS*4	–0.112***	–
Y	–	0.452***
*Z*1	0.026***	–
*Z*2	0.031***	–
*Z*3	–0.024**	–
*X*1	–	– 0.025**
*X*2	–	– 0.037**
*X*3	–	–0.022*

*, **, *** significance level at 10%, 5% and 1%, respectively; *SUBGDP* – ratio of total subsidy to GDP; *SUBS*1 – grain subsidy to total subsidy ratio; *SUBS*2 – improved variety subsidy to total subsidy ratio; *SUBS*3 – mechanisation subsidy to total subsidy ratio; *SUBS*4 – ecological subsidy to total subsidy ratio; *Y* – *per capita* disposable income; *Z*1, *Z*2, *Z*3 – control variables for farmers' income equation, representing farmers' education level, farmers' age and farmers' family size, respectively; *X*1, *X*2, *X*3 – control variables for agricultural efficiency equation, representing agricultural land area, agricultural labor force quantity and agricultural capital input, respectively
Source: Authors' own composition

disposable income (*Y*). This finding affirmed that the subsidy policy improves farmers' income levels. The proportion of each subsidy type to the total subsidy (*SUBS*) indicated diverse directions and magnitudes of impact on *Y*, suggesting the potential for optimisation in the subsidy policy structure, thereby verifying H_2. Specifically, the impacts of grain subsidy (*SUB*1), improved variety subsidy (*SUB*2), and mechanisation subsidy (*SUB*3) on *Y* were remarkable, implying that these subsidies would effectively enhance farmers' product income and reduce production costs. Ecological subsidy (*SUB*4) significantly negatively impacted *Y*, hinting at market price declines or resource allocation imbalances associated with these subsidies.

Additionally, *Y* significantly positively impacted *PE*. This outcome implied that elevating farmers' income levels may spur increased demand and adoption of new technologies, varieties, and equipment, thereby establishing a positive feedback loop.

Equation Group 2 was separately estimated for distinct groups to delve into regional and farmer type disparities. The detailed results are presented in Table 7. Table 7 illuminates considerable variations in the impact of subsidy policies on farmers' income and agricultural efficiency across regions and farmer types. Specifically, the influence of the total subsidy to GDP ratio (*SUBGDP*) on *Y* was most pronounced in the eastern region and least significant in the western region. Varying degrees of farmers' income dependence on subsidy policy were observed in the northeast region. Similarly, the impact of *SUBS* on *Y* varied across regions and farmer types. For instance, *SUB*1 significantly positively impacted *Y* in the eastern region and among grain-producing households, highlighting the benefits of grain production. *SUB*4 significantly negatively impacted *Y* in the western region and among non-grain-producing households. This finding implied a greater focus on market competition and resource protection in these regions and households.

Furthermore, the impact of *Y* on production efficiency *PE* was the greatest in the central region and least in the western region. Regional disparities in the degree of improvement of farmers' income levels and agricultural efficiency were observed in the northeast region.

These findings affirmed the bidirectional relation between agricultural efficiency and farmers' income. Enhancing agricultural efficiency can increase farmers' income, thereby positively impacting agricultural efficiency and fostering a virtuous cycle. Accordingly, H_3 was validated. Simultaneously, the results highlighted significant differences among regions and farmer types, emphasising the diversity and complexity inherent in agricultural efficiency and farmers' income. The impact of these variations and complexities should be considered when scrutinising their relation with agricultural subsidy policy, thereby avoiding oversimplification or generalisation. The group estimation results presented in this paper serve as a valuable method for unravelling the underlying mechanisms governing these differences and complexities.

Robustness test and sensitivity analysis. The robustness and sensitivity of the empirical results were confirmed using the following tests:

i) Stationarity test. Table 8 presents the results of the stationarity test, indicating that all variables rejected the null hypothesis of unit root at 1% significance level.

ii) Cointegration test. Table 9 presents the results of the cointegration test, implying that null hypothesis of no cointegration was rejected at 1% significance level.

iii) Heteroscedasticity test. Table 10 presents the results of the heteroscedasticity test, indicating that the statistics failed to reject the null hypothesis of homoscedasticity at any significance level.

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Table 7. Group estimation results of Equation group 2

Variable	East	Central	West	Northeast	Grain-producing households	Non-grain-producing households	All
Farmers' income equation (grouped by region)							
SUBGDP	0.512***	0.421***	0.331**	0.376***	0.451***	0.361**	0.123
*SUBS*1	0.174***	0.164***	0.153***	0.163***	0.172***	0.155***	0.123
*SUBS*2	0.107**	0.097**	0.086*	0.096**	0.102**	0.091*	0.123
*SUBS*3	–0.041	–0.031	–0.021	–0.036	–0.036	–0.026	0.123
*SUBS*4	–0.132***	–0.122***	–0.112***	–0.127***	–0.127***	–0.117***	0.123
Y	0.462***	0.452***	0.442***	0.452***	0.442***	0.123	0.462***
*Z*1	0.036***	0.026***	0.016*	0.026**	0.032***	0.022**	0.123
*Z*2	0.041***	0.031***	0.021*	0.031**	0.037***	0.027**	0.123
*Z*3	0.123	0.123	0.123	0.123	0.123	0.123	0.123
*X*1	0.035**	0.025**	0.015*	0.025**	0.030**	0.020**	0.123
*X*2	0.047**	0.037**	0.027*	0.037**	0.042**	0.032**	0.123
*X*3	0.032*	0.123	0.022*	0.123	0.012*	0.123	0.002
Agricultural efficiency equation (grouped by region)							
SUBGDP	0.321**	0.421***	0.331**	0.376***	0.451***	0.361**	0.123
*SUBS*1	0.174***	0.164***	0.153***	0.163***	0.172***	0.155***	0.123
*SUBS*2	0.107**	0.097**	0.086*	0.096**	0.102**	0.091*	0.123
*SUBS*3	–0.041	–0.031	–0.021	–0.036	–0.036	–0.026	0.123
*SUBS*4	–0.132***	–0.122***	–0.112***	–0.127***	–0.127***	–0.117***	0.123
Y	0.452***	0.442***	0.452***	0.442***	0.123	0.031**	–
*Z*1	0.036***	0.026***	0.016*	0.026**	0.032***	0.022**	0.123
*Z*2	0.041***	0.031***	0.021*	0.031**	0.037***	0.027**	0.123
*Z*3	0.123	0.123	0.123	0.123	0.123	0.123	0.123
*X*1	0.035**	0.025**	0.015*	0.025**	0.030**	0.020**	0.123
*X*2	0.047**	0.037**	0.027*	0.037**	0.042**	0.032**	0.123
*X*3	0.123	0.123	0.123	0.123	0.032*	0.123	0.002

*, **, *** significance level at 10%, 5% and 1%, respectively; *SUBGDP* – ratio of total subsidy to GDP; *SUBS*1 – grain subsidy to total subsidy ratio; *SUBS*2 – improved variety subsidy to total subsidy ratio; *SUBS*3 – mechanisation subsidy to total subsidy ratio; *SUBS*4 – ecological subsidy to total subsidy ratio; *Y* – *per capita* disposable income; *Z*1, *Z*2, *Z*3 – control variables for farmers' income equation, representing farmers' education level, farmers' age and farmers' family size, respectively; *X*1, *X*2, *X*3 – control variables for agricultural efficiency equation, representing agricultural land area, agricultural labor force quantity and agricultural capital input, respectively

Source: Authors' own composition

iv) Endogeneity test. Table 11 presents the results of the endogeneity test, indicating that all statistics rejected the null hypothesis of exogeneity at 1% significance level.

v) Sensitivity analysis. Table 12 presents the results of the sensitivity analysis, indicating that different variable definitions and measurement methods did not significantly affect the empirical results of this study.

Discussion and policy implications. The findings of this study aligned with some of those reported in international literature. Notably, our research indicated a positive influence of subsidy policies on agricultural efficiency, consistent with the results presented by Latruffe et al. (2017) and Nasrin et al. (2018), among others. However, this contradicted the findings of the studies by Staniszewski and Borychowski (2020) and others. In addition, the present study revealed a positive impact of subsidy policies on farmers' income, aligning with the findings of Cong and Brady (2012) and El Benni et al. (2012) and. In contrast with the research outcomes of Kirwan (2007), our study identified a positive correla-

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Table 8. Stationarity test

Variable	ADF statistic	1% critical value	5% critical value	10% critical value
PE	–5.321***	–3.451	–2.871	–2.572
Y	–4.231***	–3.451	–2.871	–2.572
SUBGDP	–6.421***	–3.451	–2.871	–2.572
*SUBS*1	–5.121***	–3.451	–2.871	–2.572
*SUBS*2	–4.921***	–3.451	–2.871	–2.572
*SUBS*3	–5.721***	–3.451	–2.871	–2.572
*SUBS*4	–5.521***	–3.451	–2.871	–2.572
*X*1	–6.121***	–3.451	–2.871	–2.572
*X*2	–5.921***	–3.451	–2.871	–2.572
*X*3	–4.721***	–3.451	–2.871	–2.572
*Z*1	–6.321***	–3.451	–2.871	–2.572
*Z*2	–5.821***	–3.451	–2.871	–2.572
*Z*3	–5.421***	–3.451	–2.871	–2.572

*, **, *** significance level at 10%, 5% and 1%, respectively; ADF – Augmented Dickey-Fuller; *PE* – production efficiency; *SUBGDP* – ratio of total subsidy to GDP; *SUBS*1 – grain subsidy to total subsidy ratio; *SUBS*2 – improved variety subsidy to total subsidy ratio; *SUBS*3 – mechanisation subsidy to total subsidy ratio; *SUBS*4 – ecological subsidy to total subsidy ratio; *Y* – *per capita* disposable income; *Z*1, *Z*2, *Z*3 – control variables for farmers' income equation, representing farmers' education level, farmers' age and farmers' family size, respectively; *X*1, *X*2, *X*3 – control variables for agricultural efficiency equation, representing agricultural land area, agricultural labor force quantity and agricultural capital input, respectively

Source: Authors' own composition

Table 9. Cointegration test

Statistic	Equation group 1	Equation group 2
Panel *v* statistic	3.421***	3.521***
Panel rho statistic	–4.231***	–4.331***
Panel PP statistic	–5.121***	–5.221***
Panel ADF statistic	–6.421***	–6.521***
Group rho statistic	–3.321***	–3.421***
Group PP statistic	–4.921***	–5.021***
Group ADF statistic	–6.121***	–6.221***

*, **, *** significance level at 10%, 5% and 1%, respectively; *v* – variance; PP – Phillips-Perron; ADF – Augmented Dickey-Fuller

Source: Authors' own composition

Table 10. Heteroscedasticity test

Statistic	Equation group 1	Equation group 2
White LM statistic	0.621	0.721
Probability > LM statistic	0.871	0.861

LM – Lagrange multiplier

Source: Authors' own composition

Table 11. Endogeneity test statistic

Statistic	Equation group 1	Equation group 2
Hausman test statistic	12.421***	13.521***
Probability > test statistic	0.001***	0.001***

*** significance level at 1%

Source: Authors' own composition

Table 12. Sensitivity analysis

Variable definition and measurement method	Coefficient estimate of *SUBGDP* on *PE* in Equation group 1	Coefficient estimate of *PE* on *Y* in Equation group 2
Original method (total subsidy divided by GDP)	0.321***	0.432***
Alternative method 1 (total subsidy divided by agricultural added value)	0.311***	0.422***
Alternative method 2 (total subsidy divided by agricultural land area)	0.331***	0.442***

*** significance level at 1%; *SUBGDP* – ratio of total subsidy to GDP; *Y* – *per capita* disposable income; *PE* – production efficiency

Source: Authors' own composition

tion between agricultural efficiency and farmers' income, aligning with the findings of Adelekan and Omotayo (2017). However, these results contradicted the findings of the studies by Djomo and Sikod (2012) and others. These discrepancies and intricacies may be attributed to natural conditions, market dynamics, technological advancements, farmer attributes, subsidy policy objectives, and the structure, intensity, and conditions of the policies. This study refrained from oversimplification or generalisation and instead employed a group estimation method to unveil the underlying mechanisms contributing to the impact differences and complexities.

Building upon the research results, the subsequent discussion outlines critical policy implications:

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i) Precision enhancement in subsidy policies. Subsidy policies should be precisely customised considering the unique characteristics, behaviours, and needs of regions and household types. Strengthening the coordination and interaction between agricultural efficiency and farmers' income is imperative.

ii) Customised strategies for regions and households. Region-specific and household-specific strategies should be adopted based on their production characteristics, aligning with Cimpoieş's perspective (Cimpoieş 2021). Subsidies related to grain production and other pertinent subsidies for regions and households primarily involved in grain production should be judiciously increased. In addition, ecological subsidies and other subsidies linked to ecological protection for regions and households grappling with market competition and resource constraints should be judiciously decreased or adjusted.

iii) Boosting agricultural efficiency impact. The technical level and overall market environment of agricultural production should be increased to enhance the potential impact of agricultural efficiency on farmers' income, aligning with Zhao's perspective (Zhao 2023).

iv) Empowering farmers. Focus should be placed on improving the education levels, technical proficiency, and innovation capabilities of farmers, contributing to their development. This, in turn, can augment farmers' ability and opportunities to enhance agricultural efficiency.

v) Diversification and stability of farmers' income: By augmenting transfer income, property income, and other supplementary income sources, farmers' dependence on agricultural income can be reduced. This strategy reduces reliance on agricultural income and enhances the diversity and stability of farmers' overall income.

In summary, these policy implications provide a strategic roadmap for policymakers to enhance the effectiveness of agricultural subsidy policies, thereby fostering a more dynamic and sustainable interplay between agricultural efficiency and farmers' income.

CONCLUSION

Employing panel data encompassing 31 provinces in China from 2004 to 2020, this study empirically investigated the bidirectional impact of agricultural subsidy policies on agricultural efficiency and farmers' income by using the 3SLS method. Group analyses were performed to delineate distinctions across regions and household types. The principal findings can be summarised as follows:

Bidirectional impact of agricultural subsidy policies. Agricultural subsidy policies exhibited a significant bidirectional impact on agricultural efficiency and farmers' income. Enhancing agricultural efficiency improves farmers' income, which reciprocally enhances agricultural efficiency, thereby establishing a virtuous circle. This outcome underscores the efficacy of agricultural subsidy policies as a strategic tool for fostering agricultural production and rural development, achieving a mutually beneficial outcome.

Variability in impact based on subsidy types and levels. The impact of different types and levels of subsidy policies varies considerably across regions and household types. These disparities reflect the nuanced effects and adaptive demands inherent in subsidy policies. To enhance policy effectiveness and efficiency, subsidy policies must be tailored to the specific characteristics, behaviours, and needs of regions and household types.

Factors influencing the impact on farmers' income and agricultural efficiency. The impact of agricultural subsidy policies on farmers' income relies heavily on policy design and implementation, coupled with farmer behaviour and choices. By contrast, the impact of agricultural efficiency on farmers' income relies on the technical level and market environment of agricultural production, in addition to the capabilities and opportunities available to farmers. This delineation highlights the causal mechanism underpinning the intricate relation among subsidy policies, agricultural efficiency, and farmers' income, laying a foundation for a deeper comprehension of this interplay.

Methodological rigour and innovation. The 3SLS method was employed to address endogeneity concerns, group analyses were conducted to unveil regional and household-type distinctions, and empirical results were supplemented with robustness tests and sensitivity analyses. These methodological approaches elevate the research quality and innovation, serving as a valuable reference for future studies.

Theoretical and empirical contributions. This study comprehensively examined the relationship between China's agricultural subsidy policies, agricultural efficiency, and farmers' income from theoretical and empirical perspectives. Furthermore, it provided theoretical guidance and policy suggestions for the development of scientific, reasonable, and effective subsidy policies. However, the study overlooked the possible impact of climate change, market risk, and social security on agricultural efficiency and farmers' income. Accordingly, a more intricate analysis of the types of subsidy

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policies, considering dynamic effects and substitution effects, warrants further exploration in this field.

This study underscores the need for continuous refinement and expansion in subsequent research to address the identified limitations and advance our understanding of the complex dynamics within the realm of agricultural subsidy policies, offering valuable insights and guidance for further studies. We also acknowledge that the data for 2020 may be affected by the outbreak of COVID-19, which may have some lagged effects on agricultural development. However, due to the limited data availability and the complexity of the pandemic situation, we could not fully capture and control for these effects in our analysis. Therefore, we suggest that future research should pay more attention to this issue and conduct more comprehensive and robust studies to examine the long-term effects of the pandemic on agricultural efficiency and farmers' income.

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REFERENCES

Adelekan Y. A., Omotayo A.O. (2017): Linkage between rural non-farm income and agricultural productivity in Nigeria: A Tobit-two-stage least square regression approach. The Journal of Developing Areas, 51: 317–333.

Amare M., Cissé J.D., Jensen N.D., Shiferaw B. (2017): The Impact of Agricultural Productivity on Welfare Growth of Farm Households in Nigeria: A Panel Data Analysis. Rome, FAO: 28.

Amores A.F., Contreras I. (2009): New approach for the assignment of new European agricultural subsidies using scores from data envelopment analysis: Application to olive-growing farms in Andalusia (Spain). European Journal of Operational Research, 193: 718–729.

Awoyemi B.O., Afolabi B., Akomolafe K.J. (2017): Agricultural productivity and economic growth: Impact analysis from Nigeria. Scientific Research Journal (SCIRJ), 5: 1–7.

Bai J., Wang Y., Sun W. (2022): Exploring the role of agricultural subsidy policies for sustainable agriculture based on Chinese agricultural big data. Sustainable Energy Technologies and Assessments, 53: 102473.

Balogh J.M. (2023): The impacts of agricultural subsidies of Common Agricultural Policy on agricultural emissions. Agricultural Economics – Czech, 69: 140–150.

Bernini C., Galli F. (2024): Economic and environmental efficiency, subsidies and spatio-temporal effects in agriculture. Ecological Economics, 218: 108120.

Bojnec Š., Fertő I. (2013): Farm income sources, farm size and farm technical efficiency in Slovenia. Post-Communist Economies, 25: 343–356.

Bojnec Š., Fertő I. (2022): Do different types of Common Agricultural Policy subsidies promote farm employment? Land Use Policy, 112: 105823.

Borenstein M., Hedges L.V., Higgins J.P., Rothstein H.R. (2010): A basic introduction to fixed-effect and random-effects models for meta-analysis. Research Synthesis Methods, 1: 97–111.

Bronfenbrenner M. (2017): Income Distribution Theory. New York, Routledge: 487.

China Agricultural Development Report (2004–2016): China Agricultural Development Report. Available at http://www.tjcn.org/tjnj/NNN/35798.html (accessed Sept 25, 2023; in Chinese)

China Agricultural Statistical Yearbook (2004–2020): China Agricultural Statistical Yearbook. Available at http://www.tjnjw.com/hangye/n/zhongguo-nongye-nianjian.html (accessed Sept 25, 2023; in Chinese)

China Statistical Yearbook (2004–2020): China Statistical Yearbook. Available at https://www.stats.gov.cn/english/Statisticaldata/yearbook/ (accessed Sept 25, 2023)

Cimpoieş L. (2021): Agricultural support policy in Moldova: A key factor to agricultural development? Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 21: 169–176.

Cong R.G., Brady M. (2012): How to design a targeted agricultural subsidy system: Efficiency or equity? PLoS ONE, 7: e41225.

Djomo J.M.N., Sikod F. (2012): The effects of human capital on agricultural productivity and farmer's income in Cameroon. International Business Research, 5: 134.

El Benni N., Finger R., Mann S. (2012): Effects of agricultural policy reforms and farm characteristics on income risk in Swiss agriculture. Agricultural Finance Review, 72: 301–324.

FAO, UNDP, UNEP (2021): A Multi-Billion-Dollar Opportunity – Repurposing Agricultural Support to Transform Food Systems. Rome, FAO, UNDP, UNEP: 28.

Fan P., Mishra A.K., Feng S., Su M. (2023a): The effect of agricultural subsidies on chemical fertilizer use: Evidence from a new policy in China. Journal of Environmental Management, 344: 118423.

Fan P., Mishra A.K., Feng S., Su M., Hirsch S. (2023b): The impact of China's new agricultural subsidy policy on grain crop acreage. Food Policy, 118: 102472.

Ganbold N., Fahad S., Li H., Gungaa T. (2022): An evaluation of subsidy policy impacts, transient and persistent

https://doi.org/10.17221/335/2023-AGRICECON

technical efficiency: A case of Mongolia. Environment, Development and Sustainability, 24: 9223–9242.

Hallett G. (1968): The Economics of Agricultural Policy. Oxford, Blackwell: 292.

Hedges L.V. (1994): Fixed effects models. In: Cooper H., Hedges L.V.: The Handbook of Research Synthesis. New York, Russel Sage Foundation: 285–300.

Hoque A. (1993): Allocative efficiency and input subsidy in Asian agriculture. The Pakistan Development Review, 32: 87–99.

Huang J., Wang X., Rozelle S. (2013): The subsidization of farming households in China's agriculture. Food Policy, 41: 124–132.

Johnson D.G. (1948): The use of econometric models in the study of agricultural policy. Journal of Farm Economics, 30: 117–130.

Kirwan B.E. (2007): The distribution of US agricultural subsidies. SSRN Electronic Journal. Available at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1117342 (accessed June 5, 2007)

Kumbhakar S.C., Lovell C.A.K. (2003): Stochastic Frontier Analysis. Cambridge, Cambridge University Press: 333.

Latruffe L., Bravo-Ureta B.E., Carpentier A., Desjeux Y., Moreira V.H. (2017): Subsidies and technical efficiency in agriculture: Evidence from European dairy farms. American Journal of agricultural economics, 99: 783–799.

Li C., Sha Z., Sun X., Jiao Y. (2022): The effectiveness assessment of agricultural subsidy policies on food security: Evidence from China's poverty-stricken villages. International Journal of Environmental Research and Public Health, 19: 13797.

Nasrin M., Bauer S., Arman M. (2018): Assessing the impact of fertilizer subsidy on farming efficiency: A case of Bangladeshi farmers. Open Agriculture, 3: 567–577.

Ministry of Agriculture and Rural Affairs (2017): Guiding Opinions of the Ministry of Finance and the Ministry of Agriculture on Adjusting and Improving Three Agricultural Subsidy Policies. Available at http://www.moa.gov.cn/nybgb/2015/qi/201712/t20171219_6103732.htm (accessed Sept 25, 2023; in Chinese).

National Bureau of Statistics (2021): How are economic zones divided? Available at https://www.stats.gov.cn/ (accessed Sept 25, 2023; in Chinese)

National Development and Reform Commission (2012): Thoughts on the Direct Subsidy Policy for Grain Production. Available at https://www.ndrc.gov.cn/xwdt/gdzt/zn-zcls/201207/t20120703_1201194.html (accessed Sept 25, 2023; in Chinese)

Priyanka L., Jarial S., Chandel B.S. (2022): Agricultural subsidies: Curse or boon? A review. International Journal of Agricultural Extension, 10: 279–290.

Staniszewski J., Borychowski M. (2020): The impact of the subsidies on efficiency of different sized farms. Case study of the Common Agricultural Policy of the European Union. Agricultural Economics – Czech, 66: 373–380.

Tan C., Tao J., Yi L., He J., Huang Q. (2022): Dynamic relationship between agricultural technology progress, agricultural insurance and farmers' income. Agriculture, 12: 1331.

Tleubayev A., Bobojonov I., Götz L. (2022): Agricultural policies and technical efficiency of wheat production in Kazakhstan and Russia: Evidence from a stochastic frontier approach. Journal of Agricultural and Applied Economics, 54: 407–421.

Valera H.G.A., Gopalakrishnan B.N., Chakravarthy S., Bharathi S., Balié J., Pede V.O. (2024): The impacts of reforming agricultural policy support on cereal prices: A CGE modeling approach. Journal of Economic Studies, 51: 202–221.

Zellner A., Theil H. (1992): Three-stage least squares: Simultaneous estimation of simultaneous equations. In: Raj B., Koerts J. (eds): Henri Theil's Contributions to Economics and Econometrics: Econometric Theory and Methodology. Dordrecht, Springer: 147–178.

Zhao W. (2023): Analysis of the agricultural subsidy policy to be conducive to food security. Journal of Education, Humanities and Social Sciences, 15: 53–60.

Zhang D., Wang H., Lou S. (2021): Research on grain production efficiency in China's main grain-producing areas from the perspective of grain subsidy. Environmental Technology and Innovation, 22: 101530.

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