Journal of Combinatorial Mathematics
and Combinatorial Computing
www.combinatorialpress.com/jcmcc

Application of Numerical Methods in the Study of the Impact of Agricultural Subsidy Policies on the Development of China's Soybean Industry

Bushuo Guo[1], Liqiu Xin[1,✉]

[1] *School of Economics and Management, Northeast Agricultural University, Harbin, Heilongjiang, 150030, China*

ABSTRACT

Due to its heavy reliance on imports, the futures and spot markets of China's upstream and downstream soybean products are vulnerable to the impact of the international market. In order to guarantee the security of the soybean industry, China introduced corresponding agricultural subsidy policies in 2008, 2014 and 2018, respectively. In order to test the impact of the subsidy policy on the development of the soybean industry, this paper utilizes an empirical mathematical planning model to evaluate the implementation effect of the subsidy policy for soybean producers ex ante, and explores the defects of the agricultural subsidy policy by simulating the production decisions of farmers. It also measured the efficiency of soybean subsidy, the efficiency of agricultural machinery purchase subsidy and the efficiency of agricultural insurance premium subsidy using a three-stage DEA model. In the empirical research part, the constructed numerical method of soybean producer subsidy policy unfolds the effect assessment. The empirical results show that the implementation of the soybean producer subsidy policy increases the proportion of soybean planting and soybean total factor productivity by 9.47% and 17.43%, respectively, and that the soybean producer subsidy policy has a facilitating effect on the expansion of soybean planting and total factor productivity. Accordingly, five policy recommendations are put forward with a view to promoting the healthy development of the soybean industry.

Keywords: subsidy policy, empirical mathematical planning, three-stage DEA model, production decision, numerical methods

1. Introduction

As a basic industry of the national economy, agriculture plays a vital role in the development of the national economy, and also plays a pivotal role in the stable development of society [1]. Due to a series of characteristics such as the weak nature of agriculture itself, positive external factors, countries have

✉ Corresponding author.
E-mail address: infinitywyyx6@163.com (L. Xin).
Received 10 January 2024; Revised 15 February 2024; Accepted 25 December 2024; Published Online 15 April 2025.
DOI: 10.61091/jcmcc127a-513

adopted various forms of policies for the development of their agriculture. According to the practical experience of developed countries, the Organization for Economic Cooperation and Development divides the internal support policy of agriculture into two categories, one is the support for farmers and agricultural products, mainly price support and subsidies, and the other is the general service support policy of the state to support agriculture [2-3]. Due to the particularity of China's agriculture, "ensuring supply" and "increasing income" are often regarded as the main policy objectives when formulating policies, and the "yellow box" policy for farmers or agricultural products is widely implemented. Among the domestic agricultural support policies, the "yellow box" policy mainly includes price support and linked subsidies. Among them, price support is the most direct and effective means to promote grain production and mobilize farmers' enthusiasm [4-5].

At present, the main contradiction of China's agricultural production has changed from “total shortage” to “structural contradiction”, which is a new development trend [6]. The focus is on "oversupply" and "undersupply", and "undersupply" is the main contradiction of "contradiction between supply and demand". However, from the perspective of China's agricultural product guarantee policy, its implementation has obvious path dependence, and it is difficult to adapt to the new supply and demand relationship [7-8]. Therefore, its policy regulation ability is relatively lagging behind.

The fundamental direction of China's agricultural subsidy policy reform is to reduce the distorting effect of the price support policy on the market, and to truly realize the market's allocation of resources, it is necessary to establish the consumption guidance of agricultural production. It is in this context that China proposed the target price subsidy policy [9-10]. And in 2014, it was decided to pilot the policy on two varieties of soybean and cotton. The implementation of the target price subsidy policy aims to stabilize China's agricultural production and promote China's agricultural commodity prices to gradually converge with the international market [11-12].

China is the country of origin of soybeans, was also the world's largest soybean producer. Into the 21st century, China's soybean consumption is increasing day by day, but the soybean sowing area does not increase but decreases, soybean self-sufficiency rate has been declining, for this reason, the Chinese government has been in the northeastern region of the implementation of the revitalization of the development plan for soybean, soybean temporary storage policy and soybean target price subsidy policy, in an attempt to improve the policy means to increase the farmers planting soybean enthusiasm, to expand the area of soybean planting [13-14]. However, this series of soybean production incentives did not bring obvious results, on the one hand, soybean production is depressed, the supply is seriously dependent on imports, on the other hand, corn, rice and other crops in the production, inventory and imports of the three quantities of the grain supply and demand for varieties of structural contradictions. In this context, it is necessary to improve the food price formation mechanism, play the decisive role of the market in the allocation of food resources, and guide farmers to adjust the planting structure [15-16].

In addition, China's agricultural subsidy policy and the consistency of WTO rules has gradually attracted the attention of Western countries, led by the United States, the Western countries frequently on China's agricultural subsidies compliance investigations and lawsuits to the WTO, how to reform the agricultural subsidy policy within the framework of the WTO rules appears to be particularly important [17-18]. For this reason, China began a new round of soybean subsidy policy reform, the soybean target price subsidy adjusted to soybean producer subsidies, in order to achieve the goal of expanding the soybean planting area, promoting the structural adjustment of soybean and corn planting, and alleviating the structural contradiction in the supply of agricultural products [19-20].

Literature [21] reviewed the types of policies used for agricultural production and noted that agricultural policies related to input support, output support and technical support promote agricultural production and the study provided some insights into the impact of agricultural policies on agricultural production. Literature [22] used a triple study approach to examine how agricultural policy subsidies affect the level of economic sustainability of farms, and the study noted that the role of agricultural policy subsidies shortens the income levels of farm workers and non-farmers, but also leads to the emergence of a two-eighths effect within the agricultural industry. Literature [23] describes how government agricultural policy subsidies are used in many forms to guide agricultural production and land use globally, which has led to a chronic surplus of global stocks of grains, cotton, and dairy products, and demonstrates that these agricultural subsidies have been detrimental to some extent to soil fertility, freshwater supply, and biodiversity. Literature [24] evaluates the EU Common Agricultural Policy (CAP) and argues that current agricultural subsidies need to be redesigned to better integrate the factors that influence farmers' decision-making, in order to improve farmers' attitudes towards policy and the environment, and to promote agricultural productivity while ensuring environmental benefits. The impact of agricultural policy subsidies in promoting agricultural production, environmental benefits, farmers' income from work, and agricultural inventories is examined multidimensionally through theory, agricultural policy subsidy research literature, and real-world case studies.

Many scholars have analyzed the influencing factors of China's soybean industry from the perspectives of food security, soybean breeding genetics, soybean global supply chain system, soybean trade, and environmental costs, which helps three-dimensional, objective and correct perception of the development status and future development trend of China's soybean industry. Literature [25] emphasized that the Chinese government's emphasis on food security is rooted in China's unique cultural and political-economic structure, and therefore the major shift in the political economy of China's agricultural sector, the analysis of the international food production and supply structure of soybeans and other food products, as well as China's influence in the world have contributed to the paradigm shift in China's food security strategy. Literature [26] illustrated the role of soybean as a strategic crop, and therefore emphasized the importance of soybean breeding production, so a systematic overview of the genetic diversity of VIR soybeans, pointing out that VIR soybeans are an excellent source of genes for soybean breeding, and need to be rationally utilized for selection and breeding of its excellent genetic resources. Literature [27] reviewed relevant studies on the current status of the supply chain in the international market for soybean and identified key themes, including soybean cultivation drivers, global soybean value chain governance, potential barriers to soybean cultivation, and some of the consequences of soybean cultivation, which deepened the understanding of the current status of the global supply chain for soybean. Literature [28] examined how trade barriers affect changes in global and domestic environmental costs due to changes in China's soybean demand, showing that in the short term soybean trade barriers between the U.S. and China lead to higher environmental costs due to transportation and U.S. soybean surpluses, but in the long term, due to the transformation of China's soybean imports from the U.S. to countries with higher environmental indicators of soybean production, such as Brazil, environmental costs will decline.

In this paper, while fully considering the impact of soybean producer subsidy policy on the agricultural production behavior of farmers, in-depth analysis of the impact of the market-oriented reform of food control policy on prices leads to changes in production relations and productivity changes. In the study of the planting structure adjustment effect of the policy, the response of the producer subsidy policy reform to the production behavior of farmers is examined based on the market effectiveness hypothesis, which enriches the mechanism of the agricultural subsidy policy on the planting structure adjustment. In the examination of soybean total factor productivity, the effect of China's soybean producer subsidy policy is simulated and analyzed for the first time based on the empirical mathematical planning (PMP) model. And a three-stage DEA model is used to eliminate the influence of external environment and random disturbances on the efficiency values of decision-making units, which makes up for the lack of research methodology in studies on the effects of agricultural subsidy policies that only use the DID method.

2. Theoretical foundations

2.1. Agricultural subsidy policy

2.1.1. Temporary storage policy. China began to implement a temporary soybean storage policy on October 17, 2008, with the NDRC implementing one or more storage periods based on market conditions and purchasing in accordance with the system's storage price. The purpose of the implementation of the temporary storage policy is to maintain the stability of the soybean market in mainland China, to protect China's food security, while expanding the soybean planting area. After the implementation of the relevant policy storage prices continue to increase, from 3,700 yuan per ton in 2008 rose to 4,600 yuan per ton of soybeans in 2012, accompanied by the price of the spot market in mainland China also began to go all the way up in 2012, the average spot price of up to 5,170 yuan / ton.

However, after the implementation of the policy, the purchase price is often seriously inverted with the real market price and foreign soybean prices, enterprises are reluctant to participate in the purchase, the state has become the only buyer. This led to the government's soybean inventory and financial pressure to increase, storage pressure increased dramatically.

2.1.2. Target price policy. On January 19, 2014, in order to reduce financial pressure and ease the disconnect between the soybean market and the free market, China proposed a pilot reform of the target price policy. The target price is determined by the cost and return of soybean production before the soybean is sown, and is set for one year. On May 17, 2014, China set the target price level for soybeans for the first time at 4,800 yuan per ton for soybeans. In addition, the target price level for both 2015 and 2016 is 4,800 yuan per ton. At the same time, the average spot price of soybeans also began to decline, falling to a low of 3,380 yuan per ton of soybeans in 2016. At the same time, the target price policy reduced the government's financial expenditures and effectively guaranteed farmers' basic income.

However, under the conditions of the established target price, market expectations have changed, and can not realize the soybean market price and the target price set by the government completely decoupled.

2.1.3. Producer subsidy policy. In 2016, corn began to implement market-based purchase and producer subsidy policies and achieved effective results. In this context, on May 9, 2017, the Ministry of Finance, the National Development and Reform Commission and the Ministry of Agriculture jointly issued the Notice on Adjustment and Improvement and Soybean Subsidy Policies, in which China began the reform of the soybean price support policy, with direct subsidies for soybean planting and producers, and the implementation of market-based purchasing across the industry, all of which will be referred to as the production subsidy policy in the following [29].

In Heilongjiang Province, the main soybean producing area, for example, the subsidy standards for soybean producers in Heilongjiang in 2017, 2018 and 2019 were 173.52 per mu, 320 yuan per mu and 270 yuan per mu, respectively. Spot prices fluctuated in a reasonable range as purchase prices were returned to the market. The new crown outbreak had a small impact on subsidized soybean prices, which were 238 yuan per acre and 248 yuan per acre in 2020 and 2021, respectively, but spot prices rose significantly due to inflation. This policy effectively realizes the separation of soybean market price formation and government intervention, and its degree of marketization has been further enhanced compared with the former, while giving established subsidies to producers to improve their planting incentives.

2.2. The market efficiency hypothesis

The market efficiency hypothesis assumes that an efficient market is one in which market participants have rapid access to all information, which is reflected in market price movements. Prices can reflect value information and price transmission reflects information transmission. Because market participants are rational, they can respond quickly and rationally to market information to produce equilibrium prices and improve the allocation of market resources. The efficient market hypothesis suggests that in a society where information is well communicated, market participants can learn specific information in a timely manner. Information asymmetry is one of the main reasons affecting the efficiency of market operation, but in an efficient market, the competitive nature of the price fluctuations can be timely and adequate access to different information, market participants will actively go to the market to transfer information, which in turn generates the volatility spillover effect between different markets and price risk transfer.

Because, market information is embedded in the price fluctuations of the product concerned, during the temporary storage policy, the overall market price is stable and fluctuates around the storage price, so the information transmission efficiency between the soybean products market is reduced. Target price policy, on the one hand, the degree of marketization, but on the one hand, the policy regulation of the soybean market is still sending the economic role, so the efficiency of information transfer is still subject to certain limitations. In addition, China's soybean temporary storage policy and target price policy is not the role of the Chinese market, the policy target object for the northeast and Inner Mongolia and other soybean producing areas, which makes the price information is not effective in the transfer between different markets.

After the implementation of the market acquisition and production subsidy policy, the policy effectively realizes the soybean market price formation and government intervention separation, the price of soybean products are mainly determined by market factors. After entering the market conditions, the price of soybean products should not only be affected by supply and demand, but also the influence of external factors. Therefore, in a mature market environment, efficient market theory suggests that information will be immediately reflected in the corresponding price, and this information will affect the price transmission between the prices of soybean products, thus showing efficient changes in volatility spillover effects between different markets. Therefore, under the production subsidy phase, efficient information transfer between the spot and futures markets is possible.

2.3. Farmers' production behavior response

Farmers' production behavior response is actually the production decision-making mechanism of farmers under external shocks. In terms of food supply, food subsidy policy is the most direct and effective external shock affecting the production decisions of farmers. Since the food subsidy policy formulated by the state ultimately needs to be realized through the behavioral changes of micro farmers, it leads to frequent interactions between the food subsidy policy and the behavior of farmers.

As a microeconomic subject under the conditions of market economy, the production behavior of farmers is increasingly rationalized, that is, the pursuit of profit maximization. Under the guidance of this “rational broker” thinking, farmers will naturally make different behavioral responses to different grain subsidy policies, and this behavioral response will in turn affect the implementation of the policy. Therefore, in the soybean producer subsidy policy reform and its goal of the transmission path, the production behavior of farmers to respond to the key, but also this paper focuses on the analysis of the focus point.

Figure 1 shows the interactive model of soybean producer subsidy policy and farmers' production behavior response constructed in this paper. According to the established target system, the government formulates corresponding support policies and subsidy methods, and in the whole process, the target system is the key. In terms of the logical relationship, the target system determines the government's decision-making, which in turn affects the government's choice of subsidy methods. Under the impact of the policy, the production behavior of farmers will be subject to both internal and external constraints, the internal constraints mainly include land, labor and capital, and the external constraints mainly include the national macroeconomic policy, market conditions, etc. The internal and external constraints affect the farmers' expected returns on food production in the future, which in turn affects the production behavior of farmers.

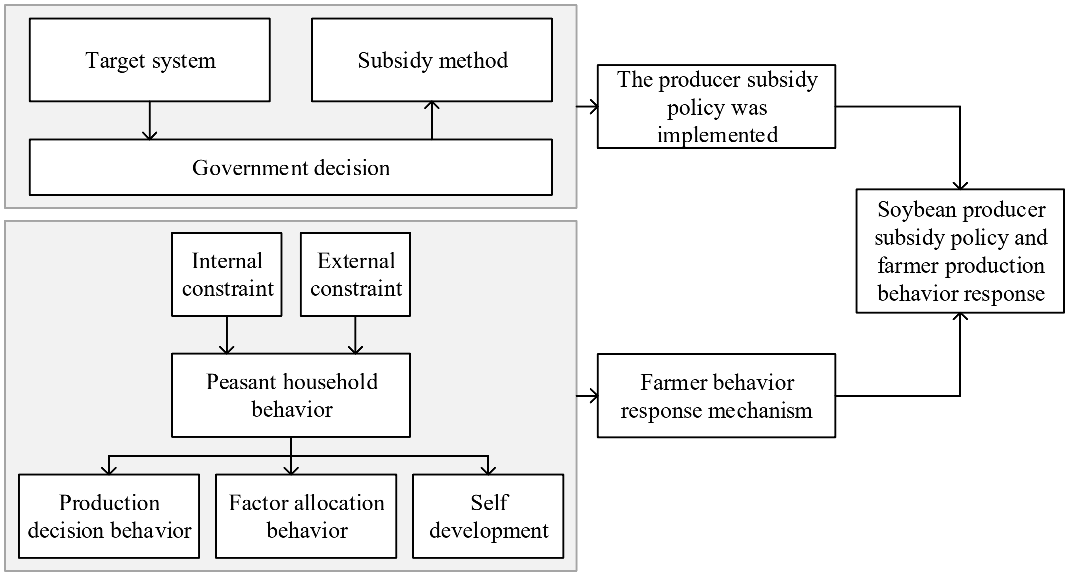

Fig. 1. Interaction model of soybean subsidy policy and farmers' production behavior response

Farmers' behavior mainly includes production decision-making behavior, factor allocation behavior and self-development. Production decision-making behavior refers to farmers' decisions on what crops to plant and how much to plant; factor allocation behavior refers to the level of labor and capital allocation in the planting process. Self-development refers to the behavioral decisions made by farmers to maximize their interests outside of food production.

3. Study design

3.1. Model Setting and Variable Selection

3.1.1. Model setup. Traditional econometric models can be divided into conditional mean models, which reflect the centralized form of the conditional distribution, and conditional volatility models, which reflect the decentralized form of the conditional distribution. The quantile regression model can encompass both the centralized and decentralized forms of the conditional distribution, examining the relationship between the independent variable and the dependent variable in a holistic pattern. Compared with the least squares regression on the mean, the quantile regression model can obtain more information about the distribution of the dependent variable other than the mean, which in turn allows us to examine the differences in the effects of the independent variable on the different distributions of the dependent variable, thus making the estimation results more robust and reliable. The difficulty in this section remains how to strip away the influence of other factors on farmers' soybean production behavior, and the quantile regression model is lacking in solving the endogeneity problem. For this reason this paper constructs instrumental variable estimation methods based on the quantile regression model. The functional form of the quantile is:

$$Y \equiv Q_{Y_{it}}(\tau \mid X_{it}) = \alpha_i(\tau) + X_{it}^{'}\beta(\tau) \tag{1}$$

where $Q(\cdot)$ is the quantile equation and is a strictly increasing function on τ, X and Y are the explanatory and interpreted variables, respectively, and α and β are the parameters to be estimated.

Due to the endogeneity problem, the quantile estimation may be biased, and the objective function after introducing the instrumental variable (Z) is defined as:

$$\min \sum_{a,b}^{J} \sum_{j=1}^{N} \sum_{t=1}^{T} \omega_j \rho_{\dot{g}} (Y_{it} - \alpha_i - X_{it}^{'} \beta(\tau_j) - Z^{'} \gamma(\tau_j)) \tag{2}$$

where ω_j is the weight, controlling for the effect of J quartiles τ in the estimation, and γ is the parameter to be estimated.

3.1.2. Selection of variables. The explanatory variables selected in this paper are the soybean planting share (i.e., the ratio of the soybean production area of farmers to the total area of cultivated land) and the total factor productivity of soybeans.

The core explanatory variable is the soybean producer subsidy policy (Pol), which is mainly selected from the producer subsidy standards announced by the government in 2018-2023.

The control variables are mainly selected:

One is to follow the explanatory variables that were the focus of the previous theoretical and empirical analyses, i.e., past cropping decisions ($Dect-1$) and relative expected yields with respect to the main competing crop (ERY).

The second is farmer and household characteristics, which mainly include gender (Sex), age of the decision maker (Age), education level (Edu), whether or not they are village cadres (Cgb), whether or not they have received agricultural training (Px), and the degree of part-time employment (Jy).

Instrumental variables consisted of two main items:

One is the number of non-laborers ($Non-Lab$), which is a variable that focuses on the number of members of a farm household who are older than 60 and younger than 16. The number of non-labor force members in a farm household is not involved in agricultural production, however, the decision makers of agricultural production in a farm household take into account their subsistence consumption and so on. Although it does not have a direct effect on agricultural production, it indirectly affects the agricultural production situation. Since the number of non-laborers in a farm household is related to agricultural production but not due to producer subsidies, this variable is often used as an instrumental variable to explain the relationship between agricultural policy and agricultural production. Therefore, in this section, this variable was chosen as the main instrumental variable to identify the relationship between soybean producer subsidy policies and the production behavior of farm households.

The second is historical soybean yield ($His-Yield$). In order to further analyze the production behavior of farmers under the influence of policy, this chapter chooses historical soybean yield as an instrumental variable when doing the robustness test. There is no direct relationship between historical soybean yield and current producer subsidy amount and farmers' production behavior, but farmers can anticipate future planting returns through historical soybean yield, thus adjusting their production behavior, which leads to indirect impacts on planting structure and total factor productivity. Therefore, this variable is chosen in this chapter to test the relationship between soybean producer subsidy policy reform and farmers' production behavior. Since the data interval used in this chapter is 2012-2023, the historical soybean production corresponding to this household from 2012-2016 (before the soybean producer subsidy policy reform) is chosen as the instrumental variable here, i.e., 2012 corresponds to the historical wheat production in 2018, and so on, in kg/household.

3.2. Numerical methods

3.2.1. Measuring the efficiency of subsidy policies. The traditional DEA model has some defects, and the DEA model only considers the internal controllable factors when measuring the efficiency of decision-making units, and does not consider the uncontrollable external environment and stochastic disturbances and other factors. In order to overcome the shortcomings of the traditional DEA model, a three-stage DEA model was developed by combining the traditional DEA model with the stochastic frontier model (SFA) [30]. The three-stage DEA model puts the decision-making unit under the same level of luck and external environment, removes the influence of the external environment and stochastic interference on the efficiency value of the decision-making unit, so that the measured efficiency value can reflect the real and accurate reflection of the decision-making unit's internal management efficiency and scale efficiency. The three steps of the three-stage DEA model are:

1) First stage. Using input-output indicators, calculate the traditional DEA efficiency values as well as the slack variables of the input-output indicators.

2) Second stage. Using the slack values of the input-output indicators obtained in the first stage, the SFA model is used to decompose the slack values. In this stage, the main purpose is to establish the regression model between the slack variables of input-output indicators and environmental variables. This paper believes that the output indicator of this paper - per capita disposable income of farmers is more seriously affected by the external environment, so it is necessary to adjust the output indicator:

$$S_{ni} = f(Z_i;\beta_n) + v_{ni} + \mu_{ni}; i = 1,2,L,I; n = 1,2,L,N \tag{3}$$

where S_{ni} is the relaxation value of the n rd output indicator of the i nd decision unit, Z_i is the environmental indicator, in this paper, GDP per capita and openness to the outside world are chosen as environmental indicators in the specific measurement process, β_n is the regression coefficient of the environmental variables. $v_{ni} + \mu_{ni}$ is called the mixed error term, of which μ_{ni} is the management inefficiency term, that is, μ_{ni} obeys the truncated normal distribution on 0, $\mu_{ni} \sim N^+(0,\sigma_\mu^2)$, v_{ni} is the random interference term, $v_{ni} \sim N(0,\sigma_v^2)$. The purpose of the SFA regression is to eliminate the influence of external environmental factors and random interference factors on the efficiency of decision-making units, and to make all the decision-making units in the same external environment after the adjustment is completed. The specific adjustment formula is:

$$\begin{aligned} X_{ni}^A &= X_{ni} + \left[ma\,x(f(Z_i;\beta_n)) - f(Z_i;\beta_{ni})\right] \\ &+ [\max(v_{ni}) - v_{ni}]; i = 1,2,L,I; n = 1,2,L,N \end{aligned} \tag{4}$$

where X_{ni}^A is the output after adjustment and X_{ni} is the output before adjustment. $[max(f(Z_i;\beta_n)) - f(Z_i;\beta_{ni})]$ is the adjustment to the external environment, and $[\max(v_{ni}) - v_{ni}]$ is the adjustment to random disturbances so that all decision-making units are adjusted below the same level of luck.

The following formula is used to separate the management inefficiency term:

$$E(\mu \mid \varepsilon) = \sigma^* \left[\frac{\phi(\lambda \frac{\varepsilon}{\sigma})}{\phi(\lambda \frac{\varepsilon}{\sigma})} + \lambda \frac{\varepsilon}{\sigma} \right] \tag{5}$$

where $\sigma^* = \frac{\sigma_\mu \sigma_v}{\sigma}, \sigma = \sqrt{\sigma_\mu^2 + \sigma_v^2}, \lambda = \frac{\sigma_\mu}{\sigma_v}$, followed by the separation of the random interference term.

The following formula is used for the calculation:

$$E[v_{ni} \mid v_{ni} + \mu_{ni}] = S_{ni} - f(Z_i;\beta_n) - E[\mu_{ni} \mid v_{ni} + \mu_{ni}] \tag{6}$$

3) Third stage. Using the adjusted input-output variables, the DEA analysis of the first stage is carried out again. After the second stage to remove the influence of the external environment and random

interference terms, this time the measured efficiency of soybean producer subsidy policy is relatively real and credible.

3.2.2. Simulation of subsidy policy effects. Commonly used models for agricultural policy analysis are econometric models, computable general equilibrium models, and empirical mathematical programming (PMP) models. Currently econometric models are very commonly used, but their defective nature is also very obvious. In this paper, the PMP model is used to simulate and analyze the effect of soybean producer subsidy policy in China [31].

First, a profit maximization model for farmers' planting decisions is established:

$$MaxTGM = \sum_{i=1}^{n}(r_i\, x_i - b_i x_i^2) \tag{7}$$

$$\sum_{i=1}^{n} x_i \le L \tag{8}$$

where, TGM is the total revenue from all crops of the farmer, who, as a rational economic agent, also seeks to maximize profit, and whose decision-making is based on considering how to allocate limited land to various crops. r_i is the observed value of revenue per unit area of crop i, x_i is the area planted with the ith crop, $b_i x_i^2$ is the cost function of the ith crop, and b_i is the parameter to be estimated. L is the total sown area of all crops of the farmer, and L_i is the actual observed area planted with the ith crop.

It is known from the Kuhn I Tucker condition:

$$r_i - 2b_i x_i^* - \lambda^* \equiv 0 \tag{9}$$

where x_i^* is the observed value of the crop i for the planted area x_i for the observation period; and λ^* is the Lagrange multiplier equilibrium value. The value of coefficient b_i can be determined only if the value of λ^* is found. Let $x_i^* = \dot{x}_t$, which is substituted into equation (9), give $r_i - 2b_i\dot{x}_i - \lambda^* \equiv 0$, which is the area planted to crop i of a typical farmer using the weighted average $\dot{x}_i$ as the observed value of x_i. The value of λ^* is solved by building an auxiliary linear regression model.

That is, the model established is:

$$MaxTGM = \sum_{i=1}^{n}(r_i\, x_i - c_i x_i) \tag{10}$$

$$\begin{cases} \sum_{i=1}^{n} x_i \le L & \text{General constraint} \\ x_i \le L_i & \text{Calibration constraint} \end{cases} \tag{11}$$

where r_i is the observed value of returns per unit area of crop i, x_i is the planted area of crop i; and c_i is the observed value of cost per unit area of crop i.

Assume that $\lambda_{cal(i)}$ is the dyadic value of the calibration condition in equation (10) and λ^* is the dyadic value of the general constraint. As rational farmers, their profit maximization requires equal marginal returns for each product. The dyadic value of the calibration constraint $\lambda_{cal(i)}$ must be equal to the difference between the marginal returns of the different crops, i.e:

$$\lambda_{cal(i)} = MR_i - MR_j \tag{12}$$

A first-order derivation of Eq. (10) with respect to x_i based on the Kuhn I Tucker condition is obtained:

$$r_i - c_i - \lambda^* - \lambda_{cal(i)} \equiv 0 \tag{13}$$

Therefore, $\lambda^* \equiv r_i - c_i - \lambda_{cal(i)}$. Substituting λ^* into Equation $r_i - 2b_i \dot{x}_i - \lambda^* \equiv 0$ solves for the value of b_i:

$$b_i = \frac{c}{i} + \lambda_{cal(i)} 2\dot{x}_i \tag{14}$$

Substituting the value of b_i into the model gives a model that can be used in the analysis of agricultural subsidy policy:

$$\begin{gathered} MaxTGM = \sum_{i=1}^{n} (r_i x_i + sub_i - \frac{c_i + \lambda_{cal(i)}}{2\dot{x}_i} x_i^2) \\ \sum_{i=1}^{n} x_i \leq L \end{gathered} \tag{15}$$

In the model, we assume that the agricultural subsidy sub_i is paid out in relation to a fixed contracted area of the farm household. If it is necessary to predict the impact of food subsidies on different food acreage, the optimization problem of the model can be solved by assuming that the food subsidies are linked to the acreage of the farmers.

3.3. Data sources

The focus of this study is to examine the impact of China's soybean producer subsidy policy on the development of the soybean industry. That is, what is examined is the impact of the soybean producer subsidy policy producer subsidies on farmers' sown area, yield and income.

The data include the sown area of soybean, the actual harvested area, the total soybean production, the total income, the total cost, the total labor input working day time of soybean, the amount of money sold, the direct subsidy of soybean, the seed subsidy, the comprehensive agricultural subsidy, and the subsidy for the purchase of agricultural machinery. There are five input indicators in this paper, namely, the amount of financial subsidies, primary industry employment, total power of agricultural machinery, the amount of agricultural fertilizer applied, and the area of soybean sown in each region. The output indicators are selected as soybean production and per capita disposable income of farmers. The relevant data were obtained from the China Statistical Yearbook, the China Rural Statistical Yearbook and other statistical yearbooks.

4. Empirical analysis

4.1. Background on the implementation of the soybean phase-in subsidy policy

4.1.1. Analysis of soybean supply. Soybean subsidy policy as an important means to promote soybean farmers to increase income and ensure food security, the new century has experienced the soybean temporary storage policy (2008-2014), target price subsidy policy (2014-2017), producer subsidy policy (2018-present), target price policy and producer subsidy policy began to be implemented in 2014 and the beginning of 2018, respectively.

China's soybean supply in 2012-2023 is shown in Figure 2, which shows that in the implementation stage of the temporary soybean storage policy and target price subsidy policy, the policy effect is not obvious, and the total soybean output and sowing area in mainland China are not satisfactory. During the implementation period of the temporary storage policy and the target price policy, the total soybean production in mainland China decreased from 16,984,700 tons in 2012 to 13,409,300 tons in 2017, with an average annual growth rate of -5.26%. The sown area also declined, from 9,465.34

thousand hectares in 2012 to 7,150.14 thousand hectares in 2017, with an average annual growth rate of -6.11%.

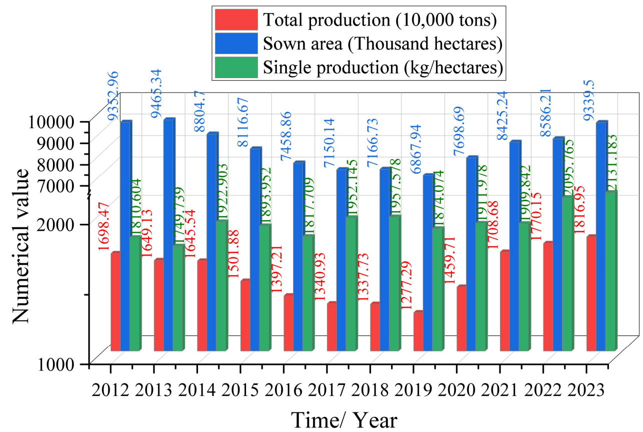

Fig. 2. China's soybean supply of 2012-2023

And after the implementation of the producer subsidy policy (2018-present), the supply of soybean in mainland China has grown significantly, with the total output growing from 13,377,300 tons in 2018 to 18,169,500 tons in 2023, with an average annual growth rate of 7.16%. The sown area grows from 71,667,300 hectares in 2018 to 93,395,000 hectares in 2023, with an average annual growth rate of 6.06%.The growth rate of soybean mu yield from 2018 to 2023 is 1.77%, which is a slight increase. Both total production, sown area, and yields are higher after the implementation of the producer subsidy policy than during the period of the temporary soybean storage policy and the target price policy, and the implementation of the producer subsidy policy has effectively safeguarded the supply of soybean edible functions for residents of mainland China.

4.1.2. Analysis of soybean price volatility. The subsidy policy for soybeans, as one of the many subsidies for Chinese agriculture, is mainly aimed at stabilizing the cost of agricultural production and thus suppressing the price of soybeans.

The 2003-2023 China soybean producer price index is shown in Figure 3, from the perspective of Chinese mainland's foreign trade environment, after China's accession to the WTO in 2003, the fluctuation range of mainland agricultural product prices increased, especially the "soybean turmoil" in international trade from 2003 to 2004, which caused the soybean price in Chinese mainland to fall sharply by 29.268 points in 2005 and a sharp increase of 29.351 points in 2007. Even when the Chinese government abolished the agricultural tax based on the reality that agricultural production prices had risen sharply in 2006-2007, the volatility of production prices continued to have an impact for several years.

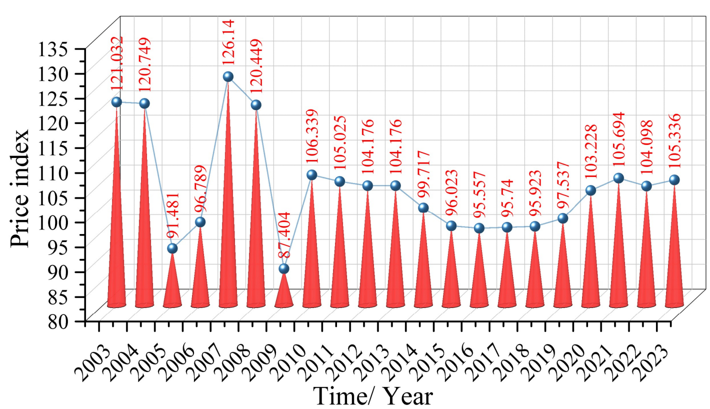

Fig. 3. Soybean producer price index in China, 2003-2023

In this regard, after 2008 China's soybean implementation of temporary storage policy, the policy in the following years obviously mobilized farmers to plant soybean enthusiasm, after 2010 China's soybean production prices have fallen, fluctuations in the amplitude of the obvious narrowing of the year. 2014 China canceled the three northeastern provinces and a region of the soybean temporary storage policy and the implementation of the pilot work of the target price subsidies, since then the three provinces and a region of the average market price of soybeans lower for two consecutive years, the policy was implemented so that the soybean market price could be aligned with actual demand. After 2018, mainland China began to implement a market-based acquisition plus subsidy mechanism of soybean producer subsidy policy, more fully play the role of the market mechanism, and further make the production, supply and marketing of a closer combination, and thus ensure food security.

4.1.3. Analysis of demand for soybeans. Soybeans are functional and comprehensive, and residents' demand for them lies mainly in the acquisition of vegetable protein, as well as the use of soybean oil and the function of animal feed. With the improvement of the material level in mainland China and the upgrading of the dietary structure of the residents, the demand for meat, poultry, eggs and milk continues to grow, and the demand for soybeans also continues to increase. Per capita pork consumption among urban residents in 2008-2020 changed little, from 19.2 kg to 18.9 kg. However, the per capita pork consumption of rural residents is growing rapidly, rising from 11.5 kg to 18.3 kg in 2008, and with the number of rural residents in the seventh census standing at 552 million, the rural population's pork consumption is undoubtedly huge.

Changes in consumption structure lead to a substantial increase in demand for soybeans, feed grain consumption is growing rapidly. 2020 China's mainland soybean feed grain price growth, imports hit a record high, soybean foreign dependence exceeded 80%, and the future development of the livestock industry will continue to expand the scale of the rapid demand for feed grains, the gap between production and demand will continue to expand. 2003-2023 China's mainland soybean per catty of the average sales Price as shown in Figure 4, in the face of changes in soybean consumption demand, in order to protect the interests of soybean farmers in mainland China, as well as eating some of the soybean food security, the state in the continuous improvement of the soybean subsidy policy framework, the soybean production price range is significantly lower, fluctuations in the range is shrinking. It can be seen that the fluctuation of the average selling price per kilogram of soybeans after 2008 is relatively stable, except for 2020, which was affected by the trade war between China and the United States as well as the impact of unexpected events such as the new crown pneumonia and other unexpected events, the average selling price per kilogram of soybeans in mainland China during the period of 2008-2019 is relatively stable.

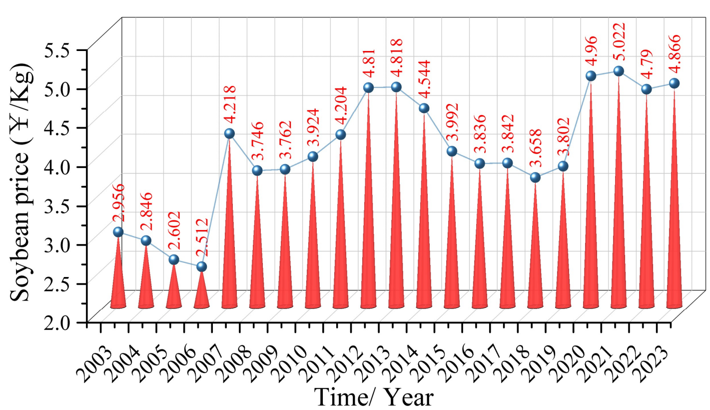

Fig. 4. Average selling price per pound of soybeans in China, 2003-2023

4.2. Impact of soybean producer subsidy policies on industrial development

4.2.1. Sample descriptive statistics. This paper starts the analysis based on panel data of 91 prefecture-level cities in 11 major soybean producing regions in China from 2013 to 2023, which are distributed as 19 prefecture-level cities within the three provinces of Heiji-Liao, 12 in Anhui, 11 in Henan, 13 in Hebei, 15 in Shandong, 12 in Shanxi, 9 in Shaanxi, and Chongqing Municipality. The descriptive statistics of the variables are shown in Table 1, and the total amount of evaluated soybean production in the sample during the study period amounted to 10,183.03 Kg per household. Among the control variables, Edu variables were assigned with a 4-level scale, where elementary school or below = 1, junior high school = 2, senior high school = 3, and bachelor's degree, college degree or above = 4. Cgb and Px variables were assigned with the same value, where yes = 1 and no = 0.

Table 1. Descriptive statistics of variables

Category	Variable	Mean	SD
Input-output variable	Total production ($Yield$)	10183.03	13217.45
	Planting area ($Land$)	37.06	45.45
	Material service charges (Wz)	78.36.52	9772.05
	Workforce (Lab)	2.25	0.83
Explained variable	Proportion of soybean planting (Psb)	62.24%	33.19%
	Soybean total factor productivity (Sfp)	48.93%	21.75%
Interpretation variable	Soybean producer subsidy policy (Pol)	155.82	34.74
Control variable	Delayed one phase planting decision (Dec_{t-1})	48.18%	26.05%
	Expected relative yield per unit (ERY)	37.15%	12.66%
	Gender (Sex)	1.53	0.41
	Age of decision maker (Age)	50.15	8.72
	Educational level (Edu)	2.04	0.81
	Whether it is a village cadre (Cgb)	0.45	0.68
	Have you received agricultural training (Px)	0.82	0.55
	Degree of part-time employment (Jy)	62.34%	30.33%
Tool variable	Non-labor force (Non-$Yield$)	1.17	0.95
	Historical soybean production (His-$Yield$)	8356.72	16134.57

4.2.2. Simulation analysis of subsidy policies. Table 2 shows the estimation results based on the simulation of the impact of the soybean producer subsidy policy on the soybean industry using the PMP model. Among them, model (1) and model (3) are the simulation results without adding control variables (soybean producer subsidy policy), and model (2) and model (4) are the simulation results with adding control variables. As can be seen from the results in the table, the soybean producer subsidy policy has a negative effect on the proportion of soybean planting (Psb) when no control variables are introduced, and the proportion of soybean planting in prefecture-level cities decreases by 15.82%. It has a negative effect on the total factor productivity of soybean (Sfp), and the total factor productivity of prefecture-level cities decreases by 40.81%. And both simulation results are significant at 1% level. From model (2) and model (4), it shows that when adding control variables, the soybean producer subsidy policy has a promotional effect on the proportion of soybean planting and soybean total factor productivity, both of which are significantly improved (the proportion of soybean planting is improved by 9.47%, and the total factor productivity of soybean is improved by 17.43%,), which is in the same direction of the effect when no control variables are added.

Table 2. Effects of soybean producer subsidies on soybean production

	Proportion of soybean planting (Psb)		Soybean total factor productivity (Sfp)	
After*treat	-0.1582***	-0.0635***	-0.4081***	-0.2338***

	(33.54)	(37.82)	(4.75)	(4.09)
Control variable	Uncontrolled	Controls	Uncontrolled	Controls
Time control effect	Controls	Controls	Controls	Controls
Individual control effect	Controls	Controls	Controls	Controls
Sample size	91	91	91	91
R^2	0.8992	0.8906	0.9511	0.9838
Adjusted R-squared	0.8872	0.8834	0.9495	0.9806

Note: *, **, *** indicate significance levels of 10%, 5%, 1%, respectively.

4.2.3. Parallel trend test. Based on the consistency assumption of the three-stage DEA model above, i.e., the pilot and non-pilot regions should have the same trend of change before the policy is implemented. Considering that China made a soybean policy adjustment in 2014, this paper chooses not to analyze the years before 2014 and only examines the data between 2014 and 2023 to avoid other policy changes interfering with the estimation results. This paper takes 2016 as the base year to estimate the double-difference coefficient α_t. If the coefficient α_t is not significantly different from 0 in the pre-pilot years, it indicates that the sown area of soybean in the pilot and non-pilot regions had a trend consistency before the release of the policy, which satisfies the premise assumption of double-difference.

Based on the three-stage DEA model to test the parallel trend of soybean sowing proportion (Psb), the empirical results are shown in Figure 5, according to the analysis results, it can be seen that the value of coefficient α_t is not significantly different from 0 in the pre-pilot years, that is, there is no significant difference between the soybean sowing area in the northeast region (the policy pilot area) and the rest of the remaining other soybean producing areas before 2017, which meets the consistency assumption. Meanwhile, 2018-2023 are significantly different from 0, and the soybean sown area is positive and significant, consistent with the previous empirical results.

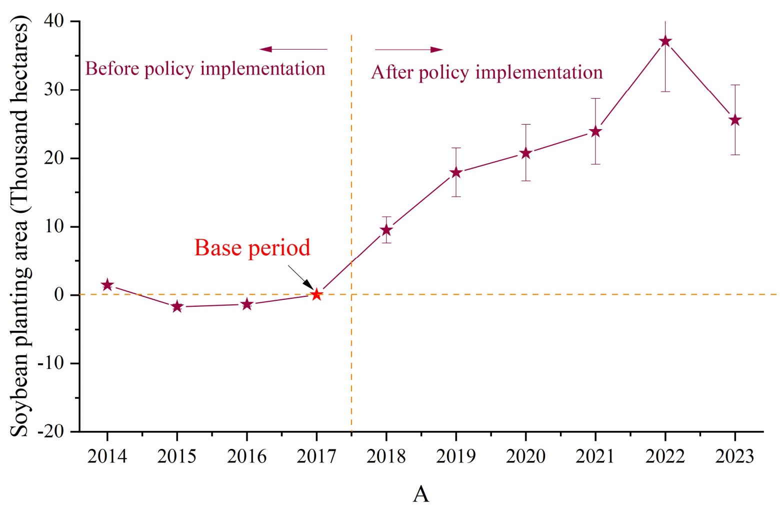

Fig. 5. Results of parallel trend test of soybean seeding ratio

Based on the three-stage DEA model to test the parallel trend of soybean total factor productivity (Sfp), the empirical results are shown in Figure 6. According to the results, it can be seen that none of the unit area production in the years before the critical point is significantly different from 0, i.e., there is no significant difference in soybean unit area production in the Northeast region and the remaining other soybean producing areas before 2018, which satisfies the basic assumption of double differencing. At the same time, 2018-2023 are significantly different from 0, and the total factor productivity of soybean is positive and significant, consistent with the previous empirical results.

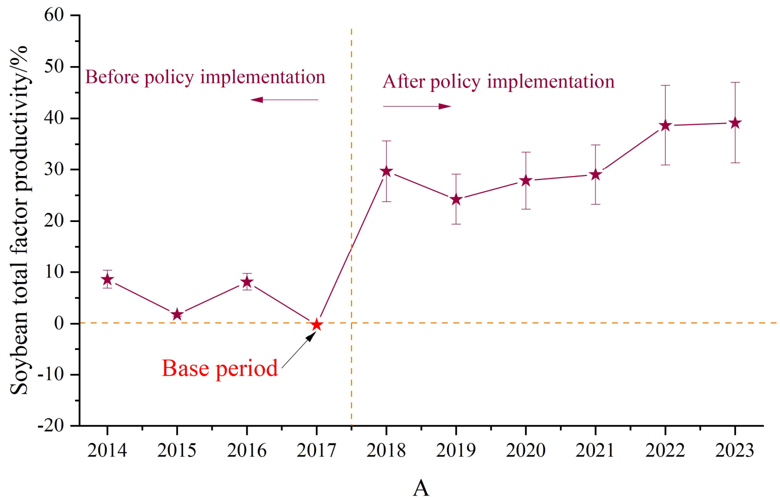

Fig. 6. Parallel trend test of soybean total factor productivity

4.3. Robustness analysis of policy effects

In order to ensure the robustness of this paper's evaluation methodology and the explanatory power of the indicators, this paper realizes the robustness test of the model by replacing the dependent variable, and selects the proportion of soybean sown area to the total planted area of crops, i.e., the proportion of soybean planted area, as an explanatory variable to regress the model, and here the data are collected from the statistical yearbooks of each province. If the value of coefficient $\alpha_t > 0$, it means that the soybean subsidy policy has a promoting effect on soybean sowing, i.e., it is consistent with the previous conclusion.

The results of the robustness test are shown in Table 3, at the 1% significance level, the average increase in the percentage of soybean sown area in the region where the soybean producer subsidy policy is implemented is 3.84%, and the expansion of soybean planting scale in the pilot region is realized under the effect of the producer subsidy policy, which is in line with the previous conclusion, and passes the robustness test. On the other hand, it can be seen that the increase in the proportion of soybean sown area makes the proportion of planted area of its competing crops decrease, and the crop planting structure changes, that is, the soybean producer subsidy policy will have an impact on China's planting structure, and has a more long-term effect of expanding the planting.

Table 3. Robustness test results

	Soybean planting area proportion
After*treat	-0.0384*** (0.3054)
Control variable	Controls
Time control effect	Controls
Individual control effect	Controls
Sample size	91
R^2	0.8728
Adjusted R-squared	0.8691

Note: *, **, *** indicate significance levels of 10%, 5%, 1%, respectively.

In order to further reduce the endogenous interference of the control variables, this paper lags the control variables by one period of treatment for testing, and the results are shown in Table 4. The results show that the coefficient of soybean yield per unit area is significantly negative at the 5% level, and the coefficient of soybean sown area is significantly positive at the 5% level, which is consistent with the previous regression results.

Table 4. Test results with a lag of one phase

	Soybean yield per unit area	Soybean acreage
After*treat	-121.56** (33.03)	4.88** (2.56)
Control variable	Controls	Controls
Time control effect	Controls	Controls
Individual control effect	Controls	Controls
Sample size	91	91
R^2	0.9094	0.9715
Adjusted R-squared	0.8933	0.9688

Note: *, **, *** indicate significance levels of 10%, 5%, 1%, respectively.

4.4. Policy recommendations

Through empirical analysis of the impact of agricultural subsidy policy on the development of soybean industry, this paper puts forward the following policy recommendations:

1) Attention should be paid to the problem of subsidized land rental erosion of agricultural business profits. Subsidies based on the actual sowing area tend to strengthen the expectation of land business income, rural land contractors through the upward adjustment of agricultural land transfer rent, sharing part of the share of subsidies issued to the land operators. Subsidized land rentalization raises the costs of rental land operators, which in turn generates problems such as land rent erosion of profits. Empirical results show that soybean producer subsidies will be transformed into the cost of soybean land, which in turn erodes the reform effect of the abolition of the temporary soybean storage policy. Therefore, it is necessary to pay attention to the problem of sharing the economic benefits brought by subsidies, focusing on the reasonable distribution of different stakeholders, improving the benefit compensation mechanism, guaranteeing the enthusiasm of actual soybean producers, stabilizing soybean production, and guaranteeing national food security.

2) Changing the policy of "market pricing and separation of price compensation" to a target price policy formulated according to the principle of production cost, and the policy of "separation of market pricing and price compensation" is likely to lead to the risk of price fluctuations in the grain market and the fluctuation of land costs caused by land leases. However, in the past, the soybean price policy is based on the principle of production costs and moderate profitability, but in practice, often from the “minimum price” to “maximum price”. Therefore, the implementation of the soybean target price policy based on the cost of production, the target price is set at a low level, the land lease operators can be based on the national soybean target price announced in advance to determine the size of the farmland lease and determine the cost of land. This is not only able to suppress the risk of soybean market prices, but also to avoid the target price of soybeans rigidly rising to raise the cost of land. Avoid land “non-food” tendency, reduce the negative impact on soybean security.

3) Seek a new type of subsidy that is decoupled from the land element and makes it profitable for farmers to grow soybeans. Seek new subsidy methods that are decoupled from land elements, and change the basis for soybean producer subsidies from land elements to soybean sales volume. Soybean producer subsidies based on land elements reinforce the value of land, which in turn raises the cost of land. Using the volume of soybean sales as the basis for subsidies not only reduces the “gold content” of land elements, but also stimulates the intensification of operations by leaseholders, and helps to achieve the policy goals of protecting the interests of soybean producers and guaranteeing national food security.

4) Strengthen policy coordination and adopt differentiated subsidies. Strengthen the soybean price policy, agricultural subsidy policy and agricultural investment policy, local government incentive

policy combination, multi-party cooperation, to guide production. Provincial governments can establish a dynamic adjustment mechanism for soybean price policy according to local realities, focusing on strengthening general public services such as infrastructure construction to support agricultural development, guaranteeing farmers' income and national food security on the basis of enhanced risk-resistant capacity, and promoting high-quality and high-efficiency development of agriculture. The development of agricultural moderate-scale operation, play the guiding role of subsidies, subsidies should be inclined to the main soybean producing areas, planting counties, regulating the structure of soybean planting, and accelerating the development of agricultural industrialization. In addition, the importance of playing the guiding role of subsidy policy, pay attention to the policy in the supply-side structural reform, the role of green and sustainable development of agriculture, to ensure that the soybean production of the origin of the environment, the production of more and better green and high-quality soybean products, and to promote the construction of high-standard farmland in accordance with local conditions, to achieve high-quality development.

5) Establishing risk compensation mechanisms to reduce the risk of price fluctuations. Agricultural prices, production costs and policy changes are the factors that farmers are most concerned about in the production and management process. However, soybean price policy is unstable, and producers will face the risk of policy adjustment. For example, the reform of the soybean storage system before 2014, the producer subsidy policy played a supporting role in supporting the abolition of the temporary storage system will reduce the scale of soybean planting, while the implementation of the producer subsidy increased the scale of soybean planting. From a long-term perspective, farmers are still facing the hidden risks of planting, so it is necessary to establish a risk compensation mechanism, explore the path of financial support for agricultural development, and play the function of financial assistance for soybean production, to protect the interests of producers, to ensure the safety of soybean production, and to enhance the competitiveness of soybean price policy.

5. Conclusion

The reform of soybean producer subsidy policy is situated in the context of multiple eras, namely, the transition stage of China's grain price support policy withdrawal and market-oriented reform, the mid-term stage of agricultural supply-side structural reform, and the initial stage of soybean revitalization. This has resulted in a unique evolutionary history of soybean support policy, which has important research value for exploring the development direction of market-oriented reform of China's agricultural support policy, adjusting the agricultural planting structure, and realizing the revitalization of soybeans. Specifically, the reform of soybean producer subsidy policy promotes the effective improvement of soybean total factor productivity, which increases due to three reasons: firstly, the enhancement of the anticipation effect, secondly, the failure of the resource overdraft effect, and thirdly, the slowing down of the growth rate of the degree of market distortion. It was also found that the soybean producer subsidy policy reform promoted the proportion of soybean planted by farmers. However, the promotion effect of soybean producer subsidy policy reform on farm household planting structure adjustment has a large difference in different quartiles, the lower or higher the proportion of soybean planted by the original farm household family, the more the producer subsidy policy reform is not conducive to stimulating the family's incentive to increase the planting of soybeans. This shows that the soybean producer subsidy policy is more beneficial to the country and the people than the protective trade policy, and has value for the sustainable development of China's soybean industry.

Funding

This research is funded by the Heilongjiang Philosophy and Social Science Research Planning Project: "Research on the Mechanism, Effect and Path of Fintech Enabling High-quality Agricultural Development in Heilongjiang Province" (23JYD271).

References

[1] Ehlers, M. H., Huber, R., & Finger, R. (2021). Agricultural policy in the era of digitalisation. Food policy, 100, 102019.

[2] Garrone, M., Emmers, D., Olper, A., & Swinnen, J. (2019). Jobs and agricultural policy: Impact of the common agricultural policy on EU agricultural employment. Food Policy, 87, 101744.

[3] Garrone, M., Emmers, D., Lee, H., Olper, A., & Swinnen, J. (2019). Subsidies and agricultural productivity in the EU. Agricultural Economics, 50(6), 803-817.

[4] Springmann, M., & Freund, F. (2022). Options for reforming agricultural subsidies from health, climate, and economic perspectives. Nature communications, 13(1), 82.

[5] Schmitz, A., Moss, C. B., Schmitz, T. G., van Kooten, G. C., & Schmitz, H. C. (2022). Agricultural policy, agribusiness, and rent-seeking behaviour. University of Toronto Press.

[6] Guo, L., Li, H., Cao, X., Cao, A., & Huang, M. (2021). Effect of agricultural subsidies on the use of chemical fertilizer. Journal of Environmental Management, 299, 113621.

[7] Hazell, P., & Varangis, P. (2020). Best practices for subsidizing agricultural insurance. Global Food Security, 25, 100326.

[8] Heyl, K., Döring, T., Garske, B., Stubenrauch, J., & Ekardt, F. (2021). The Common Agricultural Policy beyond 2020: A critical review in light of global environmental goals. Review of European, Comparative & International Environmental Law, 30(1), 95-106.

[9] Chen, Y. H., Wen, X. W., Wang, B., & Nie, P. Y. (2017). Agricultural pollution and regulation: How to subsidize agriculture?. Journal of cleaner production, 164, 258-264.

[10] Graddy-Lovelace, G., & Diamond, A. (2017). From supply management to agricultural subsidies—and back again? The US Farm Bill & agrarian (in) viability. Journal of rural studies, 50, 70-83.

[11] Laborde, D., Mamun, A., Martin, W., Piñeiro, V., & Vos, R. (2021). Agricultural subsidies and global greenhouse gas emissions. Nature communications, 12(1), 2601.

[12] Lopez, R. A., He, X., & De Falcis, E. (2017). What drives China's new agricultural subsidies?. World Development, 93, 279-292.

[13] Greenwood, L. (2022). China's interests in US agriculture: Augmenting food security through investment abroad. US-China Economic and Security Review Commission, Staff Research Report, 11.

[14] Hemming, D. J., Chirwa, E. W., Dorward, A., Ruffhead, H. J., Hill, R., Osborn, J., ... & Phillips, D. (2018). Agricultural input subsidies for improving productivity, farm income, consumer welfare and wider growth in low-and lower-middle-income countries: a systematic review. Campbell Systematic Reviews, 14(1), 1-153.

[15] Zhang, H. (2018). Securing the 'Rice Bowl': China and global food security. Springer.

[16] Dupraz, P., & Guyomard, H. (2019). Environment and climate in the common agricultural policy. EuroChoices, 18(1), 18-25.

[17] 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(3), 783-799.

[18] Hogan, M., & Hufbauer, G. C. (2023). Despite disruptions, US-China trade is likely to grow. Peterson Institute for International Economics Policy Brief, 23-14.

[19] Shikata, N. (2020). US Trade Policy toward China: the Trump Administration and Future Prospects. Harvard Program on US-Japan Relations Occasional Paper Series.

[20] Scown, M. W., Brady, M. V., & Nicholas, K. A. (2020). Billions in misspent EU agricultural subsidies could support the sustainable development goals. One Earth, 3(2), 237-250.

[21] Lencucha, R., Pal, N. E., Appau, A., Thow, A. M., & Drope, J. (2020). Government policy and agricultural production: a scoping review to inform research and policy on healthy agricultural commodities. Globalization and health, 16(1), 11.

[22] Guth, M., Smędzik-Ambroży, K., Czyżewski, B., & Stępień, S. (2020). The economic sustainability of farms under common agricultural policy in the European Union countries. Agriculture, 10(2), 34.

[23] Williams, H. (2017). Agricultural subsidies and the environment. In Oxford Research Encyclopedia of Environmental Science.

[24] Brown, C., Kovács, E., Herzon, I., Villamayor-Tomas, S., Albizua, A., Galanaki, A., ... & Zinngrebe, Y. (2021). Simplistic understandings of farmer motivations could undermine the environmental potential of the common agricultural policy. Land Use Policy, 101, 105136.

[25] Zhang, H., & Zhang, H. (2019). Paradigm shift in China's food security strategy. Securing the 'Rice Bowl' China and Global Food Security, 29-63.

[26] Vishnyakova, M. A., Seferova, I. V., & Samsonova, M. G. (2017). Genetic sources required for soybean breeding in the context of new biotechnologies. Trebovaniya k iskhodnomu materialu dlya selektsii soi v kontekste sovremennykh biotekhnologiy»], Agricultural Biology, 905-916.

[27] Jia, F., Peng, S., Green, J., Koh, L., & Chen, X. (2020). Soybean supply chain management and sustainability: A systematic literature review. Journal of Cleaner Production, 255, 120254.

[28] He, R., Zhu, D., Chen, X., Cao, Y., Chen, Y., & Wang, X. (2019). How the trade barrier changes environmental costs of agricultural production: An implication derived from China's demand for soybean caused by the US-China trade war. Journal of Cleaner Production, 227, 578-588.

[29] Feng Ye,Shengze Qin,Huanjiao Li,Zilin Li & Ting Tong. (2024). Policy-driven food security: investigating the impact of China's maize subsidy policy reform on farmer' productivity. Frontiers in Sustainable Food Systems.

[30] Bingying Li,Guiliang Tian,Xuan Wu & Siyu Xu. (2023). Evaluation of Water Resources Tax Policy in China Pilot Areas Based on Three-Stage DEA Model. Open Journal of Business and Management(01), 90-107.

[31] Athanasios Petsakos & Stelios Rozakis. (2015). Calibration of agricultural risk programming models. European Journal of Operational Research(2),536-545.