Incentives or restrictions: policy choices in farmers’ chemical fertilizer reduction and substitution behaviors

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Abstract

Based on 804 samples of farmers in Hubei Province, a typical major grain-producing area in China, this study empirically analyzed the effects of two different policy tools, i.e. economic incentives (subsidies) and order enforcements (regulatory restrictions), as well as the effects of their interaction, on farmers’ chemical fertilizer reduction and substitution behaviors. Samples were grouped according to the degree of concurrent employment to analyze the effects on different groups. The results show that (1) the influences of these policies on the behaviors were significantly positive; (2) after constructing the interactive variables of the policies, the influence of the order enforcement policy was no longer significant, but the influence of the interaction was significantly positive; (3) the low-degree concurrent employment farmers were more likely to be affected by the order enforcement policy, whereas the high-degree ones were more affected by the economic incentive policy; and (4) the behaviors of the low-degree ones were strongly affected by family management characteristics, whereas the high-degree ones were more affected by the farmers’ individual characteristics.

Keywords: economic incentive policy; order enforcement policy; chemical fertilizer reduction and substitution behaviors; concurrent employment level; China

1. INTRODUCTION

Chemical fertilizers can effectively promote the level of crop yield per unit and are an important means of agricultural production. However, excessive applications of chemical fertilizers not only increase heavy metals and toxic elements in soil, thus endangering the quality and safety of agricultural products, but also destroy soil structure, resulting in the reduction of products. In addition, untreated or simply treated sewage is directly discharged and becomes the main source of water eutrophication, further aggravating non-point source pollution (Zhu and Sun, 2008) and hindering the development of green agriculture. Therefore, the reduction and replacement of chemical fertilizers are important measures to alleviate the contradiction between production and environmental protection, as well as to realize the green transformation of agricultural development. Therefore, the path of implementation and the effects of these measures are of great concern.

To improve the rural ecological environment and utilization efficiency of agricultural resources, farmers’ fertilization behaviors must be regulated. Accordingly, the Chinese government has been encouraging the green transformation of agricultural production modes and constantly increasing support for chemical fertilizer reduction and replacement policies. Since 2008, the ‘no. 1 document’ of the central government has repeatedly put forward relevant policies on chemical fertilizer reduction and substitution, as well as green development. Since then, the Chinese Ministry of Agriculture issued the ‘Guidance on the Implementation of the Subsidy Project for Improving Soil Organic Matter’ and the ‘National Action Plan for Zero Growth in Chemical Fertilizer Use’

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and proposed the goal of ‘one control, two reductions and three basics’ in 2014. The supervision mechanism of environmental law enforcement has been improved, and the policy of ‘promoting governance with awards’ has been implemented to further standardize farmers’ fertilization behaviors. However, during agricultural production and operations, chemical fertilizer substitution entails a long return cycle for the improvement of soil and increase of yield. So, the net income resulting from increasing chemical fertilizer inputs to agricultural production is higher than replacing them with environmentally friendly fertilizers (organic fertilizers, soil testing formula fertilizers, green manure, etc.) in the short term. As ‘rational persons,’ farmers are more likely to choose the production mode with the large expected income in the short term, i.e. they are more willing to increase the inputs of chemical fertilizers to maximize their profits in the short term. Existing economic theory states that the policy system could effectively expand the farmers’ bounded rationality and increase their income expectations. Farmers with different individual characteristics respond differently to different policies, whose effects are also different (Huang et al., 2016).

The policy tools of government intervention in environmental governance have diversified development trends. Effective supervision and control of the green transformation of farmers’ production modes solely by administrative enforcement measures are difficult; so, economic incentive policy tools should also be applied (Zhu and Sun, 2008). The choice of policy tools is also directly related to the effectiveness of environmental governance. Therefore, the question is how do different policy tools affect farmers’ chemical fertilizer reduction and substitution behaviors? Also, how differently do they affect various populations? Which ones are effective at encouraging the desired behaviors? These are key problems to be solved not only to change farmers’ behaviors but also to encourage a green transformation of agricultural development in China.

2. LITERATURE REVIEW

Environmental problems cannot be effectively solved solely by market mechanisms. The government must formulate a series of policies to regulate stakeholders, so as to achieve the goal of coordinated development of the environment and economy (Callan and Thomas, 1996). In recent years, scholars have conducted considerable research on the external and internal factors that affect farmers’ green production behaviors. External factors include the natural, market and policy environments, whereas internal factors are comprised of farmers’ individual and family management characteristics.

Morris and Doss (1999) studied the acceptance of agricultural technology by farmers in Ghana and Africa and found that gender differences affected farmers’ use of agricultural chemicals by influencing their access to land, extension services and other resources. Yildirim (2007) investigated apple growers in Turkey and found that the age, level of education and planting experience of farmers significantly affected their green production behaviors. Using survey data of 632 farmers in Hubei Province, Huang et al. (2018) found that the proportion of agricultural income to total household income, the cognitive level of green agricultural production and external environmental factors, such as subsidies and incentives, had positive effects on the willingness of farmers to adopt green agricultural production. Ji et al. (2018), Zhang (2018) and Li et al. (2019) suggested that the scales of operation had significant positive effects on farmers’ organic fertilizer application behaviors. Yang et al. (2020) showed that farmers’ political identities, interpersonal trust and relationship networks significantly influenced their fertilization behaviors. Guo et al. (2018) suggested that larger areas of cultivated land owned by families increased the likelihood of their reduction of chemical fertilizers.

Farmers’ green production behaviors are also affected by their external environment, and intervention policies are the main measures for reducing fertilizer pollution. Cai et al. (2019) showed that family farms’ joining of cooperatives had positive effects on the choices of chemical fertilizer reduction modes. Wang et al. (2018) suggested that the government can encourage the reduction of chemical fertilizers through macro-control and relevant policies. Yang and Luo (2018) showed that national policies related to chemical fertilizer reduction, and substitution had significant effects on farmers’ willingness to adopt organic fertilizer substitution technology. Lee (2017) suggested that guidance system conditions are very important for farmers to participate in the agricultural production of green vegetables. Shiferaw and Holden (2015) suggested that the control effect on farmers’ green production is limited by the complete reliance on policy guidance. Huang et al. (2016) suggested the necessity of corresponding policies to effectively regulate farmers’ pesticide application behaviors, while government supervision and market incentives should complement each other. Zhan and Xu (2019) found that order enforcement policies had positive effects on both green agricultural total factor productivity and food security, i.e. the positive effects of ‘traditional productivity compensation’ generated by government supervision would offset the negative effects of ‘factor input containment’. Dong et al. (2019) suggested that relevant preferential policies, such as subsidies and tax relief, should be increased to promote the implementation of cleaner production in layer farms. Using extended decision experiment analysis, Si et al. (2019) studied the influences of different types of policies on farmers’ utilization of waste resources; the results of their probit model showed that government subsidy policies had significant positive effects on farmers’ utilization of waste resources.

Some studies showed that non-agricultural employment has very different effects on farmers’ adoption of green agricultural technology. One point of view believes that part-time farmers may

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1 Control of total agricultural water consumption, reduction of chemical fertilizers and pesticide applications, and basic utilization of plastic film, straw and livestock manure.
2 See the Circular of the State Council on printing and distributing the “13th Five-Year Plan” for ecological environment protection in December 2016, http://www.hubei.gov.cn/2018/zdly/201809/t20180906_1338698.shtml.
increase the adoption rate of environmentally friendly fertilizers, such as organic fertilizers, soil testing and formula fertilization technology, by broadening information access channels, improving production technology and enhancing their ability to pay for technology and resist risks (Zhang et al., 2009; Yu and Zhang, 2009; Zhao and Cai, 2012; Zhang et al., 2017). Another point of view believes that concurrent employment behavior shifts the focus of farmers’ employment to non-agricultural employment. This shift is not conducive to the adoption of green agricultural technology because it causes reductions in agricultural labor time and other agricultural production investments (Zhang et al., 2004; Chu et al., 2012; Liu and Kuang, 2012; Chu, 2015). Moreover, Wu et al. (2018) suggested that this shift would drive land circulation or cooperative operations through new agricultural operation subjects, thereby realizing large-scale agricultural production to achieve a reduction in the production of agricultural chemicals.

Scholars both at home and abroad have conducted considerable research into the factors influencing farmers’ green production behaviors, providing an effective reference for the study of farmers’ green production behaviors at the micro-level. The majority of existing studies focused on the effects of external factors, such as policy environment, and internal factors, such as farmers’ cognitive individual characteristics, on farmers’ green production behavior. However, little attention has been paid to the divergence in the effects of different policies, especially across different populations. In fact, farmers’ economic behavior is based on the pursuit of interest maximization. However, along the process, farmers are stimulated and constrained by the system and policy; therefore, optimizing the selection of policy tools has important effects on policy implementation.

Using a binary logistic model with 804 survey samples from Hubei Province, a main grain-producing area of China, this study analyzed the effects of two policies, i.e. economic incentives and order enforcements, as well as their interaction, on farmers’ chemical fertilizer reduction and substitution behaviors. The samples were grouped according to the degree of concurrent employment, and the effects of the policies on different groups of farmers were fully considered to provide a scientific basis for optimizing the selection of policies that reduce chemical fertilizer applications and encourage the substitution behaviors of farmers.

3. THEORETICAL FOUNDATIONS AND HYPOTHESES

In essence, chemical fertilizer reduction and substitution is a kind of agricultural management behavior driven by a farmer’s motivation to maximize utility (Schultz, 1964). Under the assumption that income represents utility, farmers make feedback adjustments according to trade-offs between costs and the net income of the previous year. As a means of government intervention and as a set of system rules of social games, effective policy guidance provides good guarantees for economic activities and enhances farmers’ expectations of incomes earned from the production of environmentally friendly fertilizers, thereby encouraging farmers’ chemical fertilizer reduction and substitution behaviors.

From the perspective of practice, two policy tools could be used by the government to intervene in the reduction of chemical fertilizers: regulatory restrictions and subsidy incentives. The former is known as order enforcement policy to restrain farmers’ behaviors through mandatory orders, including criticism and punishment of those who do not implement the desired behaviors. The latter is known as economic incentive policy, which increases the willingness of farmers to use environmentally friendly fertilizers by providing financial subsidies for organic, soil testing formula and other environmentally friendly fertilizers.

Order enforcement policies influence behavior by enhancing value cognition. First, effective policy guidance reduces information asymmetry and strengthens value cognition, which helps to determine whether or not farmers adopt new production methods (Guo and Zhao, 2017). The higher the cognition of the benefits and the accessibility of chemical fertilizer reduction and substitution, the more conducive would be the behavioral decision-making in applying environmentally friendly fertilizers. In areas with high policy support, farmers’ knowledge of chemical fertilizer reduction and substitution could be enriched by media publicity and extensive discussions, which could effectively reduce information asymmetry, as well as most risks and uncertainties, while strengthening the value cognition of chemical fertilizer reduction and substitution. Second, order enforcement policies create a restraint mechanism that reinforces the correct cognition and guide farmers to form correct values and behavioral awareness while reducing opportunistic behaviors, such as the ‘free-rider problem’ (Olson, 1965), and avoiding the ‘prisoner’s dilemma’ (Hartmann and Herb, 2014). Moreover, this policy promotes farmers with successful experience as models to emulate and enhances the willingness of other farmers to reduce chemical fertilizers.

On this basis, this study formulated a first hypothesis (H1): ‘order enforcement policies have positive effects on farmers’ chemical fertilizer reduction and substitution behaviors.’

Unlike order enforcement policies, economic incentive policies affect behaviors by improving farmers’ income expectations. First, subsidizing green production behaviors with cash grants is equivalent to offering additional income, thereby enhancing the willingness to change behaviors by improving income expectations and encouraging the use of environmentally friendly fertilizers. Second, this type of policy could reduce expected costs. Institutional economic theory states that institutions determine the resource structures and transaction costs of various economic activities (Akerlof, 1980). Under the guidance of this type of policy, individual farmers could more easily form consistent values and establish cooperation mechanisms, which not only enhances mutual recognition and reduces the transaction costs of reaching agreements but also gradually creates mutual benefits and trust mechanisms in long-term interactions. Farmers could more easily obtain financial capital, human capital and other resources; so, they would have higher income expectations, which would encourage the desired behaviors.
On this basis, this study formulated a second hypothesis (H2): 'economic incentive policies have positive effects on farmers’ chemical fertilizer reduction and substitution behaviors'.

The government could simultaneously use both policy tools, which may interact with each other to strengthen the effects on the desired behaviors. However, the effect mechanism of this interaction has to be identified. Hence, this study formulated a third hypothesis (H3): 'the interaction between economic incentive and order enforcement policies has significant effects on farmers’ chemical fertilizer reduction and substitution behaviors'.

The differences in the objects and mechanisms of different policy tools would have different effects on encouraging the desired behaviors. Therefore, these policies should be distinguished from each other, and their effects on different groups of farmers should be investigated in depth.

4. DATA, VARIABLES AND STATISTICAL ANALYSIS

4.1. Data sources
The data used by this study originate from a household survey conducted during 2018 by a project team from the Huazhong Agricultural University in Hubei Province, in which four prefecture-level cities—namely, Yichang, Qianjiang, Huanggang and Xiangyang, were selected as sample cities, while 34 villages from 13 towns were randomly selected for a field investigation. Located in the middle reaches of the Yangtze River, Hubei Province is a major food producer area in the central part of China and has relatively serious agricultural pollution. Therefore, its selection for investigation was typical. The project team’s questionnaire was articulated in four parts: (1) family agricultural management characteristics, (2) farmers’ individual characteristics, (3) farmers’ green production behaviors and (4) implementation of chemical fertilizer reduction and substitution policies. A random sample of the farmers was obtained, and the actual survey was conducted through ‘one-on-one’ interviews. The respondents were all decision makers in family agricultural production, and the survey samples were highly representative. To ensure validity, the time allotted for the completion of each questionnaire was ~20 min. After screening and sorting the answers, 804 valid samples were obtained. The regional distribution of the relevant sampled farmers is shown in Table 1.

| City          | Valid samples |
|---------------|---------------|
| Yichang       | 213           |
| Qianjiang     | 157           |
| Huanggang     | 201           |
| Xiangyang     | 233           |
| Total         | 804           |

4.2. Variables

4.2.1. Explained variables
Chemical fertilizer reduction and substitution behaviors. This study defined these behaviors as consisting of the replacement of chemical fertilizers with environmentally friendly ones (organic, soil testing formula, etc.). Whether or not to reduce and replace chemical fertilizers is a binary choice problem, so a binary logistic model was adopted. The relevant survey question was ‘do you exhibit chemical fertilizer reduction and substitution behaviors?’ The binary selection variable y was set to 1 for the affirmative answer and 0 for the negative one.

4.2.2. Explanatory variables
Explanatory variables include the order enforcement and economic incentive policies, as well as other control variables:

(1) Order enforcement policy: this is the government’s regulatory policy. The variables were measured with a five-point Likert scale (1 = not at all, 2 = to a lesser degree, 3 = neutral, 4 = to a greater degree, 5 = absolutely). The relevant survey question was ‘do you agree that the government’s supervision over chemical fertilizer reduction and substitution is strong?’

(2) Economic incentive policy: this is the extent to which the government subsidizes the reduction of chemical fertilizers. The variables were measured on the same scale. The relevant survey question was ‘do you think the government’s subsidies of chemical fertilizer reduction and substitution are perfect?’

(3) Control variables: based on an analysis of reality and the related literature (Norris and Batie, 1987; Gao et al., 2017; Shi and Cui, 2020), this study selected a group of indicators as control variables:

Individual characteristics. These include the level of education $X_3$ (years), gender $X_4$ (1: male; 0: female) and age $X_5$ (years).

Family agricultural management characteristics. These include the size of the agricultural labor force $X_6$ (number of people) and the area of cultivated land $X_7$ (hm$^2$).

4.3. Statistical analysis

4.3.1. Basic characteristics of respondents
Tables 2 and 3 show that 46.1% of the respondents lived on plains, whereas the remainder lived in mountainous or hilly areas; 61.94% were male, and 63.80% were younger than 60 years. Farmers with fewer than 6 years of education accounted for 51.87% of the total sample, whereas only 10.2% had more than 12 years of education, implying that the overall level of education was low.

4.3.2. Production characteristics
Only 34.83% earned annual incomes of more than RMB (Ren Min Bi) 70 000. Meanwhile, 50% of the households owned cultivated plots of $<0.4$ hm$^2$ each. Concurrent farmers were common in the investigated areas, and agricultural production had the characteristics of small-scale and diversified operating modes.
4.3.3. Chemical fertilizer reduction and substitution behaviors

Table 4 shows that 73.7% of the respondents were replacing chemical fertilizers with organic, soil testing formula and green fertilizers, as well as with water fertilizer integration and other technologies. Most respondents held positive attitudes toward green production modes. According to their degrees of concurrent employment, this study divided the respondents into two groups: high and low-degree concurrent employment, where the ratio of concurrent employment income to total annual household income is higher and lower, respectively, than the sample average. According to the survey data, the adoption rate of chemical fertilizer reduction and substitution technology by the low-degree group was significantly higher.

4.3.4. Implementation of policies

From the perspective of practice, two policy tools could be used by the government to promote the reduction of chemical fertilizers: subsidy incentives and regulatory restrictions. Regarding regulatory restrictions, 27.36% of the farmers believed that the government exercised strong supervision over chemical fertilizer reduction and substitution, while 33.58% believed the contrary, and the remainder was neutral. Regarding subsidy incentives, only 12.06% believed that the government provided sufficient subsidies for the purchase of green raw materials (environmentally friendly fertilizers), while 74.50% of the farmers believed the contrary, and the remainder was neutral.

5. RESULTS

5.1. Multicollinearity test

To ensure rationality and validity, this study tested the multicollinearity of each variable. Generally, VIF (variance inflation factor) > 3 indicates a certain degree of multicollinearity between variables, and VIF > 10 indicates a high degree. The order enforcement policy was chosen as the interpreted variable, while the remaining variables were considered as explanatory variables. The estimated results are shown in Table 5. The highest value of VIF is 1.248, indicating that the degree of collinearity is within a reasonable range and meets the requirements of a binary logistic regression.

5.2. Effects of different types of policies on farmers’ chemical fertilizer reduction and substitution behaviors

Four models controlled the influences of individual and family characteristics. In Models 1 and 2, the explanatory variables included only the order enforcement and economic incentive policy indicators, respectively. In Model 3, both types of indicators were included in the regression equation simultaneously. In Model 4, the interaction between the two policies was included. The regression results of each model are shown in Table 6. Prob > chi^2 and the significance level was 0, indicating that the models had high degrees of fit. A specific analysis of each model’s results is given below.

In Model 1, the effects of the order enforcement policy on chemical fertilizer reduction and substitution behaviors passed the significance test at the level of 1%, and the regression coefficient was 0.364, which indicates that this policy significantly promoted the desired behaviors, thereby verifying H1. The policy had a certain restraining effect on the behaviors. When any farmer refused to participate in the reduction and replacement of chemical fertilizers, they risked fines and damages to their reputation. The risk of economic losses and the pursuit of a unified identity motivated the farmers to practice substitution, enhancing their participation in green production. They also obtained indirect and non-material benefits, such as improvements in the competitiveness of their agricultural products and the reception of praise from other local residents (Yang, 2014). In summary,
the order enforcement policy increased the farmers’ chemical fertilizer reduction and substitution behaviors, verifying $H_1$.

In Model 2, the regression coefficient of the economic incentive policy variable is 0.090 and statistically significant at the 5% level, indicating that economic subsidies significantly promoted the desired behaviors. However, such behaviors entail high costs and create uncertainty about incomes in the short term. At this time, the sole use of market mechanisms to solve the problems of prices, the economic behaviors of both buyers and sellers and the decision-making of the participants are inefficient (William and Gary, 1980). However, the subsidies encouraged the desired behaviors by directly reducing the costs and increasing the incomes earned from green agricultural production. Economic rationality motivates farmers to take stronger initiatives and increase their participation in the reduction and replacement of chemical fertilizers (Huang et al., 2017). Therefore, economic incentives encourage farmers’ chemical fertilizer reduction and substitution behaviors, thus verifying $H_2$.

In Model 3, the resulting regression coefficients of 0.368 and 0.012 for the order enforcement and economic incentive policies, respectively, show that both had significantly positive effects on encouraging the desired behaviors to a certain extent, although the effects of each policy were different. According to the regression coefficients, order enforcement had a greater effect, which may have been the result of the increased capital and labor investments that could not be completely compensated by economic subsidies. Therefore, the effects of economic subsidy policies to encourage the desired behaviors are limited. Moreover, communities in China’s rural areas tend to be closely knit; so, farmers are relatively conservative and have a strong desire to save their ‘face’. To obtain the recognition and appreciation of others under the encouragement of a herd mentality, the concept of ‘face’ promotes green production behaviors (Shi et al., 2014). Order enforcement policies restrict farmers’ behaviors through criticism, punishment, public recognition, etc. When farmers respond to the call to actively participate in chemical fertilizer reduction, they meet the utility goal of pursuing group identities. The order enforcement policy is obviously better at encouraging the desired behaviors; hence, $H_1$ and $H_2$ are further verified.

In Model 4, the interaction between both policies was included. The results show that the effects of the two types of policy variables on the desired behaviors were still positive, although the effect of the order enforcement policy was no longer significant and the regression coefficient of the interaction term was significantly positive at the 1% level, indicating that the influence of this policy gradually weakened when both policies were implemented. A possible explanation is that the combination gives rise to the incentive effect of the market mechanism. A regulation relying only upon administrative means for its implementation is prone to government failure. The interaction had a significant positive effect on the desired behaviors, thus verifying $H_3$.

Regarding control variables, the effects of the scale of operations and quantity of agricultural labor on desired behaviors are significantly positive, indicating that larger scales and quantities result in a stronger willingness of farmers to reduce chemical
fertilizers and substitute them with environmentally friendly fertilizers. The effect of the age variable is significantly negative, indicating that, with increasing age, the willingness for the desired behaviors tends to weaken. The regression coefficients of gender and level of education are positive but not significant, indicating that male farmers or higher levels of education do not result in a stronger willingness to replace chemical fertilizers with environmentally friendly fertilizers.

5.3. Effects of policies on farmers with different degrees of concurrent employment

Driven by accelerated industrialization and urbanization, a large number of rural farmers work concurrently in cities and towns. The differences in the resource endowments of the farmers are gradually widening, and the trend of their differentiation has become increasingly evident, leading to different behavioral decisions (Deng et al., 2013). In the current Chinese context, an exploration of the effects of policy factors on farmers’ behaviors from the perspective of the differences in the degrees of concurrency is of practical significance. Therefore, according to the proportion of the concurrent incomes to the total income of the farmers, the sample was divided into two groups, i.e. low- and high-degree concurrent employment (where the ratio of concurrent employment income to total annual household income is lower or higher, respectively, than the sample average), to explore the effects of the two policies under different concurrent degrees.

Table 7 shows that the effects of policy factors on the desired behaviors are quite different between the two groups. In Model 5, the effects of the order enforcement policy and the interaction term on the behaviors of the low-degree group were significantly positive at the 1% level, whereas those of the economic incentive policy were not significant. In Model 6, the effects of the economic incentive policy on the high-degree group were significantly positive at the 5% level, whereas those of the order enforcement policy and the interaction item were not significant. There are clear differences in the influencing mechanisms of the policy factors for both groups. The low-degree group is more vulnerable to the order enforcement policy, whereas the high-degree group is more affected by economic subsidies. A possible explanation is that the high-degree group usually has higher non-agricultural incomes and limited time to engage in agricultural production and does not treat agriculture as its main means of livelihood and pays more attention to short-term income; hence, it is more

\begin{table}
\centering
\caption{Application of chemical fertilizer reduction and substitution technology.}
\begin{tabular}{lcc}
\hline
 & Total & Degree of concurrent employment \\
 & & High-degree group & Low-degree group \\
Applying (%) & 73.76\% & 80.50\% & 61.54\% \\
Not applying (%) & 26.24\% & 19.50\% & 38.46\% \\
\hline
\end{tabular}
\end{table}

\begin{table}
\centering
\caption{Multicollinearity diagnosis.}
\begin{tabular}{llll}
\hline
 & Model & Collinearity statistics & \\
 & & Tolerance & VIF \\
Economic incentive policy & 0.951 & 1.052 \\
Education & 0.801 & 1.248 \\
Gender & 0.858 & 1.165 \\
Age & 0.857 & 1.167 \\
Agricultural labor force & 0.969 & 1.032 \\
Operation scale & 0.983 & 1.017 \\
\hline
\end{tabular}
\end{table}

\begin{table}
\centering
\caption{Effects of different types of policies on farmers’ chemical fertilizer reduction and substitution behaviors.}
\begin{tabular}{lcccc}
\hline
Variable & Model 1 & Model 2 & Model 3 & Model 4 \\
\hline
Order enforcement policy & 0.364*** & 0.090** & 0.012** & 0.205 \\
Economic incentive policy & 0.012 & 0.279* & 0.088*** \\
Order enforcement policy* & 0.016 & 0.02 & 0.016 & 0.014 \\
Economic incentive policy & 0.027 & 0.008 & 0.029 & 0.036 \\
Level of education & \(-0.007^*\) & \(-0.006^*\) & \(-0.006^*\) & \(-0.007^*\) \\
Gender & 0.022* & 0.0250* & 0.023* & 0.025 \\
Age & 0.004** 97.035 & 0.005* 79.254 & 0.004** 114.259 & 0.004* 163.18 \\
Agricultural labor force & 0.004** & 0.000 & 0.000 & 0.000 \\
Scale of operation & 0.004 & 0.000 & 0.000 & 0.000 \\
Chi² & 0.000 & 0.000 & 0.000 & 0.000 \\
Prob: chi² & 0.000 & 0.000 & 0.000 & 0.000 \\
\hline
\end{tabular}
\end{table}

Note: Interpreted variables are binary variables of 'do you exhibit chemical fertilizer reduction and substitution behaviors?'; 10\% significance; \(\ast\) 5\% significance; and \(\ast\ast\ast\) 1\% significance.

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Table 7. Regression results of different groups.

|                        | Model 5 (Low-degree group) | Model 6 (High-degree group) |
|------------------------|-----------------------------|-----------------------------|
| Order enforcement policy| 0.119***                    | -0.102                      |
| Economic incentive policy| 0.22                        | 0.326**                     |
| Order enforcement policy × economic incentive policy | 0.105***                   | -0.069                      |
| Level of education     | 0.016                       | 0.020                       |
| Gender                 | 0.027                       | 0.034**                     |
| Age                    | -0.005                      | -0.008*                     |
| Agricultural labor force| 0.068*                      | 0.059                       |
| Scale of operation     | 0.012***                    | 0.016                       |
| Chi²                   | 103.194                     | 81.465                      |
| Prob > chi²            | 0.000                       | 0.000                       |

Note: ∗10% significance; **5% significance; and ***1% significance.

Sensitive to the effects of economic subsidies. However, the low-degree group has lived in the countryside for a longer time and treats agriculture as its main means of livelihood. Therefore, it pays more attention to group identity and is strongly influenced by the order enforcement policy.

Each control variable influenced the behaviors of both groups quite differently. The size of the agricultural labor force and the scale of operations had significant positive effects on the low-degree group, whereas gender and age had more significant effects on the high-degree group. This indicates that the behaviors of the former were strongly affected by family management characteristics, while those of the latter group were more strongly affected by individual characteristics.

5.4. Robustness check
The government’s main object for the promotion of green agricultural production is the working-age population (He et al., 2015). We removed males older than 60 and females older than 55 years from the sample and conducted another regression based on the control of individual and family management characteristics. Compared with the above-mentioned estimation results, the results obtained from this robustness test were consistent with regard to the significance and directions of influence. This clearly shows that our model was reasonable, and the results of the empirical analysis were generally stable.

6. CONCLUSIONS AND DISCUSSIONS

6.1. Conclusions
The main conclusions are as follows:

(1) Policy variables have significant effects on farmers’ chemical fertilizer reduction and substitution behaviors. After controlling farmers’ individual and family management characteristics, both policies showed significant positive effects.

(2) After constructing the interaction term variables of the policies, the effects of the order enforcement policy were no longer significant, whereas the interaction variables had significant positive effects on the behaviors. The adoption of comprehensive policy tools also had significant effects.

(3) The adoption rate of chemical fertilizer substitution technology was significantly higher for the low-degree concurrent employment group, which was more vulnerable to the effects of the order enforcement policy, whereas the high-degree group was more affected by economic subsidies.

(4) The influences of the control variables on the behaviors of both groups were quite different. The low-degree group was strongly affected by family management characteristics, whereas the high-degree group was more strongly affected by individual characteristics.

6.2. Discussion
From the conclusions of this study, we can draw the following implications:

(1) The two policies, i.e. economic incentives and order enforcement, have significant effects on farmers’ chemical fertilizer reduction and substitution behaviors. Therefore, comprehensive measures should be taken to encourage green production behavior, i.e. the government should pay attention to the economic incentive policy and innovate order enforcement policy tools, which are indispensable.

(2) The combination of incentives and mandatory policy tools could effectively encourage green production behaviors. Therefore, comprehensive policy tools should be used to intervene in agricultural production and optimize the policy support system. On the one hand, supervision and punishment should be exercised over farmers to form a policy thrust that promotes chemical fertilizer reduction and replacement. On the other hand, financial support, taxes and other incentives should be offered to those participating in the reduction and replacement of chemical fertilizers, thereby forming a policy gravity that promotes green production behaviors.

(3) The factors that affect the reduction and replacement of chemical fertilizers vary greatly among different groups. There-
fore, a ‘one size fits all’ policy should be avoided. Different policies for chemical fertilizer reduction and substitution should be formulated and implemented from the perspective of utility equilibrium. For the low-degree concurrent farmers, the supervision of agricultural green production should be strengthened, and the reputation mechanism should play a leading role in the reduction and replacement of chemical fertilizers. Meanwhile, a moderate scale of operation for agriculture should be developed to enhance the internal strengths of the low-degree ones who participate in chemical fertilizer reduction and substitution. For the high-degree ones, economic subsidies should be increased appropriately to strengthen the incentive effects of an economic subsidy policy. In addition, propaganda and education about green production should be strengthened to enhance the awareness of environmental protection and encourage the reduction and substitution of chemical fertilizers.

CONFLICT OF INTEREST

The Authors declare that there is no conflict of interest.

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REFERENCES

[1] Akerlof GA. A theory of social custom, of which unemployment may be one consequence. Quarterly Journal of Economics 1980;94:749–75. doi: 10.2307/1885667.
[2] Callan SJ, Thomas JM. Environmental economics & management: theory, policy, and applications. Cengage Learnign Press, 1996.
[3] Cai R, Wang ZY, Qian L, Du ZX. Does joining cooperatives promote family farms to choose environmentally friendly production methods? – Taking the reduction of chemical fertilizer and pesticide application as an example. China Rural Survey 2019;01:51–65 (in Chinese).
[4] Chu CH, Feng SY, Zhang WW. An empirical analysis of farmers’ adoption of environment-friendly agricultural technology – taking organic fertilizer and soil testing formula fertilization technology as an example. Chinese Rural Economy 2012;03:68–77 (in Chinese).
[5] Chu CB. Study on the adoption decision and adoption density of integrated pest control technology for farmers – an empirical analysis based on double hurdle model. Journal of Agrotechnical Economics 2015;09:117–27 (in Chinese).
[6] Dong JP, Zhang YY, Sun SM. The evolutionary game analysis of the intensity of government environmental regulation and the clean production behavior of layer farms. Heilongjiang Agricultural Sciences 2019;07:140–4 (in Chinese).
[7] Deng ZH, Zhang JB, Xu ZX et al. A study on Farmers’ cognition and behavior response in the improvement of rural living environment: Taking the main rice producing area of Dongting Lake Wetland Reserve as an example. Journal of Agrotechnical Economics 2013;02:72–9.
[8] Guo QH, Li SP, Li H. Study on the adoption behavior of farmers’ chemical fertilizer reduction measures from the perspective of social norms. Journal of Arid Land Resources and Environment 2018;10:50–5.
[9] Guo LJ, Zhao J. A study on farmers willingness of biological pesticide application from the perspective of cognitive conflict: an empirical analysis based on 639 rice farmers in Jiangsu. Journal of Nanjing Agricultural University (Social Sciences Edition) 2017;17:123–33 (in Chinese).
[10] Gao Y, Wang N, Li XF, Wang YH. Decision analysis on the adoption of soil management technology for farmers’ eco-friendly farmland – a case study of Shandong Province. Issues in Agricultural Economy 2017;38; 38–47+110–111: (in Chinese).
[11] Huang ZH, Zhong YQ, Wang XL. Study on the impacts of government policy on farmers’ pesticide application behavior. China population, resources and environment 2016;8:148–55 (in Chinese).
[12] Huang YZ, Luo XF, Li RR, Zhang JB. Farmer cognition, external environment and willingness of green agriculture production—based on the survey data of 632 farmers in Hubei Province. Resources and Environment in the Yangtze Basin 2018;27:680–7 (in Chinese).
[13] Hartmann E, Herb S. Opportunity risk in service triads: a social capital perspective. International Journal of Physical Distribution and Logistics Management 2014;44:242–56.
[14] Huang WH, Qi ZH, Wu LY et al. Determinants of farmers willingness and behavior to engage in ecological circular agriculture: market returns or policy incentives? China Population, Resources and Environment 2017:27:69–77 (in Chinese).
[15] He K, Zhang JB, Zhang L et al. Interpersonal trust, institutional trust and farmers’ willingness to participate in environmental governance: based on the example of agricultural waste recycling. Management World 2015;5:75–88 (in Chinese).
[16] Ji L, Xu CC, Li FB et al. Impact of farmland management on fertilizer reduction in rice production. Resources Science 2018;40:2401–13 (in Chinese).
[17] Li ZL, Luo XF, Qiu WW. Land scale, tenure security and adoption of organic fertilizer of farmer: a mediation and moderated model. Resources and Environment in The Yangtze Basin 2019;28:1918–28 (in Chinese).
[18] Liu ZP, Kuang YP. An analysis of the influencing factors of farmers’ willingness to adopt “two oriented agriculture” technology – taking the experimental area of “two oriented society” as an example. Journal of Agrotechnical Economics 2012;06:57–62 (in Chinese).
[19] Lee J. Farmer participation in a climate-smart future: evidence from the Kenya Agricultural Carbon Project. Land use policy 2017;68:72–9.
[20] Morris ML, Doss CR. How does gender affect the adoption of agricultural innovations? The case of improved Maize technology in Ghana. Annual Meeting of the American Agricultural Economics Association 1999; 8–11.
[21] Norris PE, Batie SS. Virginia farmers’ soil conservation decisions: an application of tobit analysis. Southern Journal of Agricultural Economics 1987;19:79–90.
[22] Olson M. 1965. The Logic of Collective Action: Public Goods and the Theory of Groups. Harvard Univ. Press.
[23] Si RS, Pan ST, Yuan YX, Lu Q. Effect of environmental regulation on the behavior of farmers to recycling the dispose wastes. Journal of Arid Land Resources and Environment 2019;33:17–22 (in Chinese).
[24] Schultz TW. 1964. Transforming Traditional Agriculture. Yale University Press.
[25] Shi ZM, Wu LF, Kuang ZY. How face consciousness reverses selfish behavior – the influence of social value orientation on ecological consumption. Journal of Marketing Science 2014;10:59–81 (in Chinese).
[26] Shi ZH, Cui M. Heterogeneity influence of individual difference on different green production behaviors of farmers: Based on the comparison of labor age and risk preference on green production technology of labor intensive type and capital intensive type. West Forum 2020;30:111–19 (in Chinese).
[27] Shiferaw B, Holden ST. Policy instruments for sustainable land management: the case of highland smallholders in Ethiopia. Agricultural Economics 2015;22:217–32.
[28] Wang Y, Zhu YC, Zhang SX, et al. What could promote farmers to replace chemical fertilizers with organic fertilizers. *Journal of Cleaner Production* 2018;199:882–890.

[29] Wu YY, Xi XC, Tang X et al. Policy distortions, farm size, and the overuse of agricultural chemicals in China. *Proceedings of the National Academy of Sciences of the United States of America* 2018;115:7010–5.

[30] William WB, Gary JS. Economic competition and political competition: a comment. *Public choice* 1980;35:27–36.

[31] Yang YR, He YC, Li ZL. Social capital and the use of organic fertilizer: an empirical analysis of Hubei Province in China. *Environ Sci Pollut Res* 2020;27:15211–222. doi: https://doi.org/10.1007/s11356-020-07973-4.

[32] Yang YR, Luo XF. The influence of reduction and substitution policy on the adoption of organic fertilizer substitution technology model for farmers – an empirical analysis based on the survey data of tea growers in Hubei Province. *Journal of Agrotechnical Economics* 2018;10:77–85 (in Chinese).

[33] Yu YH, Zhang JY. Willingness of farmers to adopt rice IPM technology and its influencing factors – based on survey data of Hubei Province. *Chinese Rural Economy* 2009;11:77–86 (in Chinese).

[34] Yang LX. Game analysis of government supervision and farmers’ environmental protection behavior in rural non-point source pollution control. *Ecological Economy* 2014;30:127–30 (in Chinese).

[35] Zhu ZL, Sun B. Study on the control of agricultural non-point source pollution in China. *Environmental Protection* 2008;08:4–6 (in Chinese).

[36] Zhan JT, Xu YJ. Environmental regulation, agricultural green productivity and food security. *China population, resources and environment* 2019;29:167–76 (in Chinese).

[37] Zhang L, Chen C, Zhan JT. Analysis on the access and demand of farmers’ agricultural technology information – based on the sample survey of 411 counties in 13 major grain producing provinces. *Agricultural economic problems* 2009;31:78–84+111 (in Chinese).

[38] Zhao LG, Cai SK. Willingness of farmers to adopt rice IPM technology and its influencing factors – based on survey data of Hubei Province. *Agricultural economic problems* 2012;33:50–57+111 (in Chinese).

[39] Zhang FH, Song XL, Huo M. The cognition of fruit farmers to over fertilization and the analysis of factors influencing the adoption of soil testing and formula fertilization technology – based on the survey of apple growers in 9 counties (districts and cities) of Shandong Province. *China Rural Survey* 2017;03:117–30 (in Chinese).

[40] Zhang YH, Ma JJ, Kong XZ, Zhu Y. Analysis on the influencing factors of farmers’ adoption of pollution-free and green pesticides – an empirical analysis of 15 counties (cities) in Shanxi, Shaanxi and Shandong. *Chinese Rural Economy* 2004;01:41–9 (in Chinese).

[41] Zhang CY, Chang Q, Huo XX. Can the moderate-scale management really reduce the production costs of agricultural products?—An empirical analysis based on 661 Shaanxi apple farmers. *Journal of Agrotechnical Economics* 2018;10:26–35 (in Chinese).