The effects of farmers' adoption behavior of soil and water conservation measures on agricultural output

Effects of
farmers'
adoption
behavior

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Abstract

Purpose – This paper aims to build a theoretical model of the impact of farmers' adoption behavior of soil and water conservation measures on the agricultural output to analyze the impact of farmers' adoption behavior of soil and water conservation measures on agricultural output.

Design/methodology/approach – Based on the field survey data of 808 farmers households in three provinces (regions) of the Loess Plateau, this paper using the endogenous switching regression model to analyze the effect of farmers' adoption behavior of soil and water conservation measures on agricultural output.

Findings – Soil erosion has a significant negative impact on agricultural output, and soil erosion has a significant positive impact on farmers' adoption of soil and water conservation measures. Farmers adopt soil and water conservation measures such as engineering measures, biological measures and tillage measures to cope with soil erosion, which can increase agricultural output. Based on the counterfactual hypothesis, if farmers who adopt soil and water conservation measures do not adopt the corresponding soil and water conservation measures, their average output per ha output will decrease by 2.01%. Then, if farmers who do not adopt soil and water conservation measures adopt the corresponding soil and water conservation measures, their average output per ha output will increase by 12.12%. Government support and cultivated land area have a significant positive impact on farmers' adoption behavior of soil and water conservation measures.

Research limitations/implications – The research limitation is the lack of panel data.

Practical implications – Soil erosion has a significant negative impact on agricultural output, and soil erosion has a significant positive impact on farmers' adoption of soil and water conservation measures. Farmers adopt soil and water conservation measures such as engineering measures, biological measures and tillage measures to cope with soil erosion, which can increase agricultural output.

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Social implications – The conclusion provides a reliable empirical basis for the government to formulate and implement relevant policies.

Originality/value – The contributions of this paper are as follows: the adoption behavior of soil and water conservation measures and agricultural output are included into the same analytical framework for empirical analysis, revealing the influencing factors of farmers' adoption behavior of soil and water conservation measures and their output effects, enriching existing research. Using endogenous switching regression model and introducing instrumental variables to overcome the endogenous problem between the adoption behavior of soil and water conservation measures and agricultural output, and to analyze the influencing factors of farmers' adoption behavior of soil and water conservation measures and its impact on agricultural output. Using the counter-factual idea to ensure that the two matched individuals have the same or similar attributes, to evaluate the average treatment effect of the behavior of soil and water conservation measures, to estimate the real impact of adaptation measures on agricultural output as accurately as possible and to avoid misleading policy recommendations.

Keywords Agricultural output, Loess Plateau, Soil and water conservation measures, Soil erosion

Paper type Research paper

1. Introduction

Soil erosion has become a public hazard in the world, it is a serious threat to the human living environment. China is one of the countries with the most serious soil erosion in the world. The average loss of cultivated land due to soil erosion is about 66,666.67 ha per year. The total amount of soil erosion reaches 5 billion tons every year, resulting in economic losses equivalent to 3.5% of GDP (Xinhua News Agency, 2010). The total area of the Loess Plateau is 640,000 km², of which the area of soil erosion reaches 454,000 km². The sediment generated by soil erosion is about 1.6 billion tons per year, making it the most serious area of soil erosion in China (Wang, 2013). Therefore, choosing the Loess Plateau as the research area has certain representativeness. Soil and water loss has a far-reaching impact on China. Therefore, effective adaptation measures should be found to control soil and water loss and mitigate its adverse effects. The Chinese government attaches great importance to the control of soil erosion. In recent years, the Central Document No.1 has proposed to strengthen the control of soil erosion. In the field of agriculture, there is a significant coupling relationship between soil erosion and agricultural production. Agriculture is most sensitive to the changes in soil erosion. It not only causes a sharp decrease in the number of cultivated land but also causes land degradation and reduces the economic and ecological productivity of land (Ji, 2017). Farmers are the main undertakers and the most direct perceivers of ecological deterioration consequences such as soil erosion (Guo *et al.*, 2017). Therefore, soil erosion has the most significant impact on farmers based on natural resources (Zhao, 2014). Specifically, soil erosion brings more uncertainty to farmers in the process of agricultural production, and farmers face more external production risks (Chen and Xie, 2013). Correspondingly, farmers are the main body of soil erosion control and rural ecological construction (Li, 2017). Risk-averse farmers will adopt a series of soil and water conservation measures to reduce the adverse impact of soil erosion on agricultural output, so as to reduce the potential production loss and risk of soil erosion (Di Falco and Chavas, 2009).

Soil and water conservation measures are important adaptation measures for farmers to cope with and resist the potential risk of soil erosion. For example, farmers can cope with and reduce the production risk caused by soil erosion through the construction of engineering measures such as soil and water conservation projects, biological measures such as grain for green and grass and conservation tillage measures such as less tillage and no-tillage (Ying, 2018). To a certain extent, the control of soil erosion depends on farmers'

adoption behavior of soil and water conservation measures. Therefore, in recent years, the research on farmers' adoption behavior of soil and water conservation measures has become one of the hot topics in academic circles. A large number of studies have shown that individual characteristics (gender, age, education level, etc.), family management characteristics (income level, the scale of an agricultural operation, part-time behavior, number of the labor force), level of regional economic development, policy factors (agricultural technology training, extension system, government support, etc.) affect farmers' adoption behavior of soil and water conservation measures (Khisa *et al.*, 2007; Jara-Rojas *et al.*, 2012; Zhai and Hang, 2005). These studies have laid a theoretical foundation for this paper. However, scholars focus on the influencing factors of farmers' adoption of soil and water conservation measures, and there are few studies on the impact of soil and water conservation measures on agricultural output (Yang *et al.*, 2016; Cai and Cai, 2012). Farmers as a "rational economic man," the most important basis for farmers to adopt soil and water conservation measures is their cost-benefit situation. If the adoption of soil and water conservation measures can improve farmers' profits or production efficiency, then the measures will be quickly spread and adopted by many farmers. In a certain period of time, if the adoption of soil and water conservation measures can not bring economic benefits such as cost-saving and yield-increasing to farmers, it will greatly affect the promotion of the measures. Therefore, the output effect is particularly important when farmers adopt soil and water conservation measures to deal with soil erosion. In addition, as a loess plateau area with serious soil erosion, there are fewer kinds of literature to quantitatively study farmers' adoption of soil and water conservation measures based on the large-scale field survey data and even fewer kinds of literature to put the influencing factors and effectiveness evaluation of farmers' adoption of soil and water conservation measures in the same analysis framework (Feng *et al.*, 2017; Yang *et al.*, 2018; Yang *et al.*, 2016). So in the case of serious soil erosion in the Loess Plateau, do farmers adopt soil and water conservation measures to cope with soil erosion? In the process of adopting soil and water conservation measures, what are their effects and whether they can increase farmers' agricultural output? The answers to the above questions can encourage farmers to adopt soil and water conservation measures to cope with soil erosion, alleviate the adverse effects on agricultural production, stabilize agricultural production of farmers and ensure the sustainable development of the agricultural industry.

In view of this, this paper investigates the relationship between farmers' adoption of soil and water conservation measures and agricultural output in the Loess Plateau area where soil erosion is serious. To solve the above problems. The endogenous transformation model was used to analyze the impact of farmers' adoption of soil and water conservation measures on agricultural output, and to evaluate the average treatment effect of the adoption of soil and water conservation measures. The contributions of this paper are as follows:

- The adoption behavior of soil and water conservation measures and agricultural output is included in the same analytical framework for empirical analysis, revealing the influencing factors of farmers' adoption behavior of soil and water conservation measures and their output effects, enriching existing research.
- Using endogenous transformation model and introducing instrumental variables to overcome the endogenous problem between the adoption behavior of soil and water conservation measures and agricultural output, and to analyze the influencing factors of farmers' adoption behavior of soil and water conservation measures and its impact on agricultural output.

- Using the counter-factual idea to ensure that the two matched individuals have the same or similar attributes, to evaluate the average treatment effect of the behavior of soil and water conservation measures, to estimate the real impact of adaptation measures on agricultural output as accurately as possible and to avoid misleading policy recommendations.

Based on the research objectives, the structure of this paper is as follows: the first part is the introduction; the second part is the theoretical analysis; the third part is the data source, model construction and variable definition; the fourth part is the analysis of the empirical results; the fifth part is the conclusion and based on the above analysis results, put forward policy recommendations.

2. Theoretical analysis

Influencing factors of farmers' adaptation to climate change. Temperature and precipitation are important climatic factors that affect farmers' adaptive decision of climate change, farmers are willing to take more adaptive measures when the temperature rises and precipitation decreases (Deressa *et al.*, 2009). Truelove *et al.* (2015) found that farmers' perception of drought risk, awareness of the effectiveness of adaptation measures and social factors are the key factors affecting their climate change adaptation decision. Arslan *et al.* (2014) concluded that there is a positive relationship between climate change and conservation agriculture. Asfaw *et al.* (2016) concluded that when the difference between the maximum temperature and precipitation fluctuation in the growing season of crops increases, farmers will take measures to reduce the risk. Farmers will take various measures to adapt to extreme weather events (Chen and Xie, 2013; Habiba *et al.*, 2012; Huang *et al.*, 2015).

With regard to the output effect of agricultural technology, academic circles have studied different agricultural technologies in different ways. Cai and Cai (2012) used data collected from field surveys across four counties of Anhui province, OLS regression methods to analyze the impact of conservation tillage techniques on rice yield. Results showed that compared to farmers who adopted traditional farming techniques, farmers who adopted conservation tillage technology had higher rice yields of 93 kg/hectares. Feng *et al.* (2017) showed that farmers' climate change adaptation decision-making can increase agricultural output. Based on survey data collected from 660 apple farmers in 8 apple base counties in Shaanxi. Under counterfactual assumptions, the study finds that if farmers who adapt to climate change did not take adequate measures, their agricultural yield would reduce by 3.72%. Then, if farmers decide to take measures for adaptation, their agricultural yield would increase by 5.54%. Luo *et al.* (2013) based on the data collected from 221 rice-producing households located in the upper reaches of the Taihu Basin, evaluated their economic effects by estimating input demand and output supply functions. Research results indicate that keeping other variables constant, the yield of rice increased by 0.04% (kg/hectares) when the adoption rate of soil testing and formula fertilization technology increased by 1%. Yang *et al.* (2016) used a large-scale survey of 1,663 wheat plots of 889 households in five provinces in the NCP, built two-stage econometric models to quantitatively analyze the determinants of irrigation adaptation measures and assess the impacts of adaptation measures on wheat yield. They found that losses will reduce by 14.2% with an increase of 50% irrigation time (amounting to 0.9 irrigation times). Li *et al.* (2017) showed that conservation tillage technology had a significant positive impact on crop yield. Falco, *et al.* (2011) and Yesuf *et al.* (2008) took Ethiopian farmers as research objects and analyzed the impact of farmers' climate change adaptation decision-making on agricultural output. The results show that climate change adaptation decision-making can

increase farmers' agricultural output. Zhao and Cai (2013) showed that chemical control integrated pest management technology (IPM) and biological control IPM technology had a significant positive impact on rice yield. Finger *et al.* (2011) and Mainuddin *et al.* (2011) agreed to improve irrigation conditions will reduce the fluctuation of food production caused by climate change and increase grain production. Therefore, the impact of farmers' adoption behavior of soil and water conservation measures on agricultural output needs to be further evaluated and verified (Maddison, 2006).

As a rational economic man, farmers usually adopt engineering measures such as soil and water conservation projects, biological measures such as grain for green and grass and conservation tillage such as less tillage and no-tillage to reduce the potential impact of soil erosion. These adaptation measures mainly affect agricultural output through water conservation, soil conservation and fertilizer conservation (Figure 1). For example, in China, biological measures, such as grain for green and grass, can enhance the water storage and retention capacity of the soil, regulate runoff, reduce flood peaks, conserve water sources, conserve water and soil, fix and improve soil and improve soil erosion resistance. Conservation tillage techniques, such as less tillage and no-tillage, are mainly used in agricultural land. By adopting certain methods, soil resistance conditions can be further improved, the water absorption capacity of the soil can be increased and the water storage capacity of the soil can be promoted (Ying, 2018). It can protect the original soil layer structure, improve soil permeability, increase soil humus and organic matter, enhance soil fertility, prevent nutrient loss in soil, improve fertilizer utilization efficiency and then affect agricultural output (Feng *et al.*, 2017). The form of build a terrace around the water source can transform the "running paddy field, running fertilizer field and running soil field" into "protecting paddy field, protecting fertilizer field and protecting soil field."

In summary, farmers' adoption of soil and water conservation measures has a positive impact on agricultural output, but the impact needs to be further assessed. Based on the survey data of peasant households in areas with serious soil erosion, this paper uses the endogenous transformation model to analyze the impact of farmers' adoption of soil and water conservation measures on agricultural output.

3. Data sources, variable selection and model setting

3.1 Data sources

The data of this study came from the field survey of farmers in Shaanxi, Gansu and Ningxia provinces (districts) in the Loess Plateau from October to November 2016. Using a stratified random sampling method to select survey sites and farmers. Each province chooses 2–3 counties (districts), namely, Mizhi County, Yuyang District, Suide County, Xifeng District, Huan County, Yuanzhou District, Pengyang County, Xiji County. Each County (districts) chooses 1–5 townships (towns). Each town randomly chooses 2–5 villages. Each village randomly extracts 15–20 farmers, total 1,200 questionnaires are collected. The survey

Figure 1.
The influence
mechanism of
farmers' adoption
behavior of soil and
water conservation
measures on
agricultural output

contents cover the capital endowment of farmers and families, the occurrence of soil erosion, farmers' adoption of soil and water conservation measures and the input-output situation of agriculture. Questionnaires were obtained through face-to-face interviews with farmers. To evaluate the agricultural output of soil and water conservation measures, the same crops are needed. Among the sample farmers, the corn growers are the most. Therefore, 808 maize growers should be taken as an example to analyze the output effect of farmers' adoption of soil and water conservation measures. Among the sample farmers, the proportion of men is larger, accounting for 97.28% of the total sample. Most of them are between 41 and 60 years old, accounting for 75.37% of the sample peasant households. This shows that with the advancement of urbanization, most of the young and strong labor force choose to go out to work. At present, the age of rural peasant households is older, which is in line with the actual situation of the current rural areas. The education level of sample farmers is generally low, and the education level in junior middle school and below accounts for 90.47% of the sample. In total, 6.56% of peasant households joined cooperatives, with a low proportion. The basic situation of sample farmers is shown in [Table 1](#).

3.2 Variable selection and description

Dependent variable. The adoption behavior of soil and water conservation measures. Soil and water conservation measures are technical packages including engineering measures, biological measures and tillage measures. They are effective measures for farmers to cope with soil erosion. Farmers often choose one or several combinations of measures in production practice, and the adoption of these measures is considered as farmers' adoption behavior of soil and water conservation measures. **Agricultural output.** On the basis of relevant research results, the yield per unit area of maize was used as the index of agricultural output in this paper.

Independent variable. Based on the relevant research results, this paper selected the severity of soil erosion, factor input, characteristics of peasant household and family endowment and instrumental variables as independent variables. This paper measures the severity of soil erosion by inquiring farmers' perception of the severity of soil erosion. Likert five-level scale was used to evaluate it. According to previous studies, this paper selected age, gender, education level, cultivated land area, whether to join cooperatives to represent farmers' capital endowment. The instrumental variables are government subsidies and mutual trust. Factor input chooses variables such as per ha fertilizer input, per ha pesticide input and per ha mechanical rental input. The definition and assignment of variables and descriptive statistical analysis are shown in [Table 2](#).

3.3 Model selection

Because it is impossible to simultaneously observe the agricultural output of the same farmer under the two conditions of adopting and not adopting soil and water conservation measures, it is impossible to directly evaluate the impact of adopting soil and water conservation measures on the agricultural output of the farmer households. Therefore, this paper must consider the identification of causal effects when determining econometric models. At the same time, this paper uses the survey data of farmers. Whether farmers adopt soil and water conservation measures is not a random distribution, but optimal decision-making is made under various conditions or constraints ([Cai et al., 2019](#)). Farmers' adoption behavior of soil and water conservation measures has strong endogeneity. If the assessment of the effectiveness of adaptation measures does not consider the existence of endogenous problems, the estimated results of the model will have some deviation, which will mislead the proposed policy. Therefore, how to estimate the treatment effect of soil and water conservation measures on agricultural output under the consideration of the probability of

Variable	Classified	Household	Ratio/%	Variable	Classified	Household	Ratio/%
Gender	Male	786	97.28	Education level	Illiteracy	179	22.15
	Female	22	2.72		Primary school	188	23.27
Age	Under 30 years old	13	1.61		Junior middle school	364	45.05
	31–40 years old	92	11.39		High school	74	9.16
	41–50 years old	246	30.44		College graduate or above	3	0.37
	51–65 years old	363	44.93	Agricultural income proportion	Under 25%	352	43.56
Cooperative or not	66 years old and above	94	11.63		25–49%	169	20.92
	Yes	53	6.56		50–74%	112	13.86
	No	755	93.44		Above 75%	175	21.66

Table 1.
Basic situation of
sample farmers

Table 2.
Explanations of
variable and
descriptive statistics

Variable	Variable specification	Mean	SD
<i>Dependent variable</i>			
Agricultural output	Expected output per ha of maize (500 g)	14,954.8358	8,661.9015
Adaptation measures	Whether a farmer has adopted or not? Yes = 1 and no = 0	0.7116	0.4533
<i>Factor input</i>			
Fertilizer	Fertilizer input per ha (USD/ha)	345.3040	306.7831
Pesticide	Pesticide input per ha (USD/ha)	46.7891	114.6373
Machinery	Machinery rental input per ha (USD/ha)	91.4791	155.1352
<i>Instrumental variables</i>			
Government subsidies	whether farmers get subsidies? Yes = 1 and no = 0	0.5735	0.3539
Mutual trust	The degree of mutual trust between people: no = 1, few = 2, general = 3, more = 4 and many = 5	3.7252	0.9975
<i>Endowment characteristics</i>			
Age	Below 20 = 1, 21–30 = 2, 31–40 = 3, 41–50 = 4, 51–65 = 5 and 66 above = 6	4.5371	0.8967
Education	Illiteracy = 1, primary school = 2, junior middle school = 3, high school = 4 and college graduate or above = 5	2.4233	0.9454
Gender	1 = male and 0 = female	0.9728	0.1628
Cultivated land area	Your cultivated and land area (ha)	0.8128	0.7581
Cooperatives	Whether farmers join cooperatives? Yes = 1 and no = 0	0.0656	0.2477
<i>External environment</i>			
Seriousness of soil and water loss	1 = no soil erosion, 2 = less serious, 3 = general, 4 = more serious and 5 = very serious	3.7026	1.4704

farmers adopting soil and water conservation measures, has become the key problem to be solved in this paper. To overcome the endogenous problem and avoid errors of the coefficients of evaluation, this paper used the endogenous switching regression model to solve the problem of sample selection bias caused by the heterogeneity of observable and non-observable factors.

First, constructing farmers' adoption behavior model of soil and water conservation measures. According to the expected utility theory, farmers adopt soil and water conservation measures in the context of soil erosion to maximize utility. A_{ia}^* is the potential net benefit of farmers' adoption of soil and water conservation measures, A_m^* is the potential net benefit of farmers' non-adoption of soil and water conservation measures, $A_i^* = A_{ia}^* - A_m^*$ is the expected utility difference between the two. If $A_{ia}^* > A_m^*$, i.e. $A_i^* > 0$, then farmers will adopt soil and water conservation measures, on the contrary, farmers will not adopt them. A_i^* can not be observed directly, but can be expressed as a linear function of observable exogenous variables. The model of farmers' adoption behavior of soil and water conservation measures is as follows:

$$A_i^* = C_i \eta + \nu_i \text{ when } A_i = \begin{cases} 1 & A_i^* > 0 \\ 0 & A_i^* \leq 0 \end{cases} \quad (1)$$

In formula [equation \(1\)](#), A_i^* represents the unobservable potential variable of farmers' adoption of soil and water conservation measures, A_i represents farmers' adoption behavior

of soil and water conservation measures and C_i represents the vector of exogenous factors affecting farmers' adoption behavior of soil and water conservation measures. η denotes the coefficients to be estimated; v_i denotes a random error term:

$$A_i = \alpha_0 + \alpha_1 X_i + \alpha_2 B_i + \alpha_3 IV_i + \varepsilon_i \quad (2)$$

In equation (2), A_i is the dependent variable, indicating whether farmers adopt soil and water conservation measures or not. If it is equal to 1, it means to adopt; if it is equal to 0, it means not to adopt and B_i represents the severity of soil and water loss, that is, the main purpose is to analyze the impact of the severity of soil and water loss on farmers' adoption of soil and water conservation measures. To ensure the identifiability of the endogenous transformation model, government subsidies and social trust are used as instrumental variables in farmers' behavior decision-making models of soil and water conservation measures. The reasons for choosing government subsidies as an instrumental variable are as follows: first, the implementation of government subsidies policy is the behavior of the main body above the village level, which only affects the farmers' adoption of soil and water conservation measures, but does not affect the final output of farmers; Second, in recent years, the government has continuously increased subsidies for soil erosion control. It is of great significance to evaluate the role of government subsidies in promoting farmers' adoption of soil and water conservation measures and to resist the negative impact of soil erosion. The reason for choosing social trust as an instrumental variable is that social trust only affects farmers' adoption of soil and water conservation measures, but does not affect farmers' final output. X_i is the capital endowment of peasant households, which includes age, education level, gender, whether to join cooperatives, cultivated land area. Cluster α denotes the vector of coefficients to be estimated and ε_i denotes the random error term.

Equation (1) shows that the adoption behavior of soil and water conservation measures (A_i) is an endogenous variable. If the least-squares method is chosen to estimate the impact of farmers' adoption of soil and water conservation measures on agricultural output, the results are biased. In addition, there may be unobservable factors that simultaneously affect the random error terms v_i, ε_i of equations (1) and (2). It leads to the correlation between error terms v_i, ε_i . If selectivity bias is neglected, the estimation results will be inconsistent. Propensity score matching (PSM) can solve this problem, however, it can only solve the heterogeneity of observable factors (Maddison, 2006), but can not solve the heterogeneity of unobservable factors. Therefore, the endogenous switching regression model (ESRM) is chosen to solve the sample selectivity bias caused by the heterogeneity of observable and unobservable factors (Falco, 2011).

Second, establishing an evaluation model of the effect of soil and water conservation measures on agricultural output. The specific econometric models are as follows:

$$Y_{ia} = \chi_{0a} + \chi_{1a}X_{ia} + \chi_{2a}B_{ia} + \chi_{3a}D_{ia} + \chi_{4a}A_{ia} + \theta_{ia} \quad (3-a)$$

$$Y_{in} = \chi_{0n} + \chi_{1n}X_{in} + \chi_{2n}B_{in} + \chi_{3n}D_{in} + \chi_{4n}A_{in} + \theta_{in} \quad (3-b)$$

The dependent variables Y_{in} in equations (3-a) and (3-b) denote the agricultural output (logarithmic in the operational model) of farmers who do not adopt soil and water conservation measures. Y_{ia} indicates the agricultural output of farmers who adopt soil and water conservation measures (logarithmic in the operational model). To explore the effects of soil erosion severity and soil and water conservation measures on agricultural output. In addition, D_i represents a set of traditional input variables (logarithm in operation model), namely, fertilizer input (USD/ha), pesticide input (USD/ha), machinery input (USD/ha) and

other inputs (USD/ha). The other variables are the same as those in the first stage. χ -cluster is the parameter to be estimated and θ is the error term.

Finally, evaluating the treatment effect of farmers' adoption of soil and water conservation measures. The endogenous switching regression model can estimate the average treatment effect of farmers' adoption of soil and water conservation measures by comparing the expected agricultural output of farmers and non-farmers in real and counterfactual scenarios.

Output expectations of farmers who adopt adaptation measures (treatment group):

$$E[Y_{ia}|A_i = 1] = X_{ia}\chi_{1a} + B_{ia}\chi_{2a} + D_{ia}\chi_{3a} + \sigma_{ua}\lambda_{ia} \quad (4)$$

Output expectations of farmers who not adopt adaptation measures (control group):

$$E[Y_{in}|A_i = 0] = X_{in}\chi_{1n} + B_{in}\chi_{2n} + D_{in}\chi_{3n} + \sigma_{un}\lambda_{in} \quad (5)$$

At the same time, two counterfactual hypotheses are considered, that is, the output expectations of farmers adopting adaptation measures in the case of not adopting adaptation measures:

$$E[Y_{in}|A_i = 1] = X_{ia}\chi_{1n} + B_{ia}\chi_{2n} + D_{ia}\chi_{3n} + \sigma_{un}\lambda_{ia} \quad (6)$$

The expected output value of farmers who have not adopted adaptation measures in the case of adopting adaptation measures:

$$E[Y_{ia}|A_i = 0] = X_{in}\chi_{1a} + B_{in}\chi_{2a} + D_{ia}\chi_{3n} + \sigma_{ua}\lambda_{in} \quad (7)$$

Through [equations \(4\) and \(6\)](#), it is found that the treatment effect of the output of the farmers adopting adaptation measures as follows:

$$\begin{aligned} ATT_i &= E[Y_{ia}|A_i = 1] - E[Y_{in}|A_i = 1] \\ &= X_{ia}(\chi_{1a} - \chi_{1n}) + B_{ia}(\chi_{2a} - \chi_{2n}) + D_{ia}(\chi_{3a} - \chi_{3n}) + (\sigma_{ua} - \sigma_{un})\lambda_{ia} \end{aligned} \quad (8)$$

Through [equations \(5\) and \(7\)](#), it is found that the treatment effect of the output of the farmers not adopting adaptation measures as follows:

$$\begin{aligned} ATU_i &= E[Y_{ia}|A_i = 0] - E[Y_{in}|A_i = 0] \\ &= X_{in}(\chi_{1a} - \chi_{1n}) + B_{in}(\chi_{2a} - \chi_{2n}) + D_{in}(\chi_{3a} - \chi_{3n}) + (\sigma_{ua} - \sigma_{un})\lambda_{in} \end{aligned} \quad (9)$$

4. Empirical results and analysis

This paper used Stata 14.0 software and full information maximum likelihood method (FIML) to estimates the impact of farmers' adoption behavior of soil and water conservation measures on agricultural output. The results of the joint estimation of farmers' adoption behavior of soil and water conservation measures and agricultural output models are shown in [Table 3](#). The second column in [Table 3](#) is the estimation results of the factors affecting farmers' adoption of soil and water conservation measures. The third column is the estimated results of the factors affecting the agricultural output of farmers adopting adaptation measures. The fourth column is the estimated results of factors affecting the agricultural output of farmers who have not

adopted adaptation measures. The regression results in Table 3 show that the correlation coefficient σ_{ua} between the error items of the model of adaptation measures adopted by farmers and the error items of the model of agricultural output adaptive measures adopted by farmers, and the correlation coefficient σ_{un} between the error items of the model of adaptation measures adopted by farmers and the error items of the model of the agricultural output of farmers not adopt adaptive measures. The estimated values of $\sigma_{ua}\sigma_{un}$ are significant at a 1% level, which indicates that there is sample selectivity bias in the agricultural output model. Among them, the value of σ_{ua} is positive, which indicates that the output of the adopted farmers is higher than that of the general farmers in the sample, while the value of σ_{un} is negative, which indicates that the output of the non-adopted farmers is lower than that of the general farmers in the sample (Akpalu and Normanyo, 2014; Huang and Wang, 2014).

4.1 Regression analysis of the equation of farmers adopted soil and water conservation measures

Age has a significant negative impact on farmers' adoption of soil and water conservation measures, at the 1% statistical level. This indicates that the younger the farmers are, the more likely they are to adopt soil and water conservation measures because many soil and water conservation measures need a certain amount of labor input and young farmers are more competent. The old farmers are conservative and have poor physical strength. With the increase of the age of householders, their acceptance of new knowledge and information is slower and they are easier to be influenced by traditional habits and are often more resistant to new technologies (Kabil and Rainis, 2015), so they are unwilling to adopt soil and water conservation measures to

Variable	Agricultural output model		
	Adoption behavior model	Adopting adaptation measures	Not adopting adaptation measures
Factor input	—	0.0769*** (0.0247)	0.1252*** (0.0371)
<i>Instrumental variables</i>			
Government subsidies	0.0833*** (0.0309)	—	—
Mutual trust	0.0082 (0.0437)	—	—
<i>Endowment characteristics</i>			
Age	−0.2602*** (0.0593)	−0.0359** (0.0155)	−0.0384 (0.0252)
Education	−0.0348 (0.0539)	−0.0029 (0.0137)	−0.0079 (0.0219)
Gender	0.1372 (0.2947)	−0.0085 (0.0819)	0.0917 (0.1098)
Cultivated land area	0.0677*** (0.0096)	0.0053** (0.0026)	0.0125** (0.0050)
Cooperatives	0.1594 (0.2201)	−0.0233 (0.0516)	0.2277** (0.0881)
<i>External environment</i>			
Seriousness of Soil and Water Loss	0.1245** (0.0483)	−0.0179* (0.0118)	0.00004 (0.0200)
Cons	0.3951 (0.4915)	6.7105*** (0.1848)	6.1603*** (0.3085)
$\ln \sigma_{ua}$	—	−1.1003*** (0.0929)	—
σ_{ua}	—	1.1156*** (0.2549)	—
$\ln \sigma_{un}$	—	—	−1.1073*** (0.0416)
σ_{un}	—	—	−0.9689*** (0.1740)
LR	22.27***	—	—
Log-likelihood	−501.89655	—	—

Notes: ***, **, * respectively, indicate that the independent variables are significant at the confidence level of 1%, 5% and 10%. The figures in brackets are standard errors

Table 3.
Estimated results of
the agricultural
output model

adapt to climate change. The cultivated land area has a significant positive impact on farmers' adoption of soil and water conservation measures at the 1% statistical level. The larger the cultivated area is, it means that the main income source of farmers maybe agriculture, which has a strong dependence on farmland. Therefore, more attention is paid to agricultural management. Soil and water loss has a greater impact on farmers with large farmland area, so it is easy to adopt soil and water conservation measures for them. Soil and water loss has a positive and significant impact on farmers' adoption of soil and water conservation measures, at the 5% statistical level. This indicates that the more serious soil erosion is perceived by farmers, the more they will adopt soil and water conservation measures to cope with the impact and loss caused by soil and water loss. Instrument variable IV government subsidies have a positive and significant impact on farmers' adoption of soil and water conservation measures, at the 1% statistical level. This indicates that the higher the degree of government subsidies, the more farmers will adopt soil and water conservation measures and government subsidies will help farmers to adopt soil and water conservation measures when other factors remain unchanged. For engineering adaptation measures, farmers may need to invest a lot of money. Government subsidies can help farmers share part of the cost of adopting adaptation measures and promote farmers to adopt them. Biological adaptation measures mainly include afforestation, grass planting, etc. The state implements the project of returning farmland to forestry and grassland, compensates for farmers has promoted the adoption of adaptation measures. Because of the externalities of soil and water conservation measures, government subsidies have a significant incentive effect on farmers to adopt soil and water conservation measures.

4.2 Analysis of regression result of agricultural output equation

Soil and water loss has a significant negative impact on the agricultural output of peasant households adopting soil and water conservation measures. Under the premise of keeping other factors unchanged, soil erosion has a significant negative impact on agricultural output, at the 1% statistical level. Indicating that the more serious soil erosion is, the lower the yield of maize is. Input factors have significant positive effects on the agricultural output of both the adopt farmers and not adopt farmers. The estimation of traditional factor input variables has a significant effect and accords with economic intuition and expectations. The cultivated land area has a significant positive impact on the agricultural output of both the adopt farmers and not adopt farmers. The larger the cultivated land area is, the higher the enthusiasm of farmers in agricultural production, the more conducive to the increase of the output. Joining cooperatives has a significant positive impact on the agricultural output of non-adopted farmers, which indicates that joining cooperatives can increase the agricultural output of farmers, mainly because the technical personnel of cooperative organizations can provide training for farmers in agricultural production technology, help farmers effectively manage farmland and then increase agricultural output. The age of the head of the household has a negative impact on the agricultural output of the adoptive households, which indicates that with the increase of the age of the head of household, the output level of the farmers has decreased. This is mainly because the older the head of the household is, the more conservative the ideology is, which inhibits the improvement of its production efficiency, which is not conducive to the increase of the output.

4.3 Analysis of treatment effect

In this paper, [equations \(8\) and \(9\)](#) are used to calculate the treatment effect of farmers' adoption of soil and water conservation measures on agricultural output. The results are shown in [Table 4](#). Among them, (a) and (b), respectively, represent the expected agricultural output results that farmers actually adopt and actually do not adopt, corresponding to the above [equations \(4\) and](#)

(5), (c) and (d), respectively, represent the counterfactual hypothesis results, corresponding to equations (6) and (7). The last column in Table 4 shows the average treatment effect of farmers' adoption of soil and water conservation measures on agricultural output. The average treatment effect is significant at the level of 1%. From the perspective of average expected agricultural output, under the counterfactual assumption, when farmers adopt adaptation measures do not adopt it, the average agricultural output per ha will decrease by 0.1433 (2.01%). When farmers do not adopt adaptation measures adopt. Agricultural output per ha will increase by 0.9068 (12.12%). This shows that the adoption of soil and water conservation measures by farmers can increase agricultural output.

4.4 Robustness test

This paper further tests the robustness of the above results. The bivariate logistic regression model was used to estimate farmers' adoption behavior of soil and water conservation measures. The parameters of the farmer's agricultural output model are estimated by the least-squares method (OLS). The results of the model are shown in Table 5. The regression results of key variables are consistent with the previous conclusions, that is, the adoption of soil and water conservation measures can help increase agricultural output.

Continue to use PSM for robustness tests. Using Stata 14.0 software to estimate the propensity score of the logit model, the dependent variable is "whether farmers adopt soil and water conservation measures" and the independent variable is farmers' capital endowment, government subsidies and external environment. The estimated results are

Average expected agricultural output (kg/ha) logarithm	Adopting adaptation measures	Not adopting adaptation measures	ATT	ATU
Adopting farmers	(a) 7.1103	(c) 6.9669	0.1433***	—
Not adopting farmers	(d) 7.4801	(b) 6.5732		0.9068***

Note: ***indicates significant at 1% level; ATT, ATU indicate the average treatment effect corresponding to the adoption of farmers and the non-adoption of farmers, respectively

Table 4.
Analysis of
treatment effect

Variable	Adoption behavior model	Agricultural output model
Soil erosion	0.199*** (0.068)	−0.013** (0.007)
Adoption of Soil and Water Conservation Technology		0.232** (0.099)
Other variables	Controlled Pseudo $R^2 = 0.2116$ Log-likelihood = −595.39879 LR $\chi^2(11) = 319.53$ ***	Controlled F-values = 7.58 Adjust $R^2 = 0.2369$ Prob > F = 0.0000

Notes: ***, **, * respectively, indicate that the independent variables are significant at the confidence level of 1%, 5% and 10%. The figures in brackets are standard errors

Table 5.
Robustness test

shown in Table 6. The regression results of key variables are consistent with the previous conclusions, which shows that the results are robust.

In this paper, Stata 14.0 statistical software was used to evaluate the effect of soil and water conservation measures adopted by peasant households through the PSM nuclear matching process. The specific statistical results are shown in Table 7. Empirical results showed that the average ATT of treatment effect between the treatment group and the control group was 0.4852, which indicated that the agricultural output of farmers who adopt soil and water conservation measures was 7.53% higher than that of farmers who did not adopt adaptation measures. That is to say, the average output of maize per ha could be increased to some extent by adopting soil and water conservation measures.

5. Conclusion and enlightenment

5.1 Conclusion

This paper constructed a theoretical model of the impact of farmers' adoption of soil and water conservation measures on agricultural output. Based on the field survey data of 808 corn growers in three provinces (regions) in the Loess Plateau, using the endogenous switching regression model analyzed the effect of farmers' adoption of soil and water conservation measures on agricultural output. The following conclusions are drawn:

- Soil and water loss has a significant negative impact on maize yield, and soil erosion has a significant positive impact on farmers' adoption of soil and water conservation measures.

Table 6.
Estimated results of
logit model with
propensity score

Variable	Coefficient	Standard error
Age	−0.4453***	0.1082
Education	−0.1254	0.0997
Gender	0.2171	0.5303
Cultivated land area	0.1749***	0.0194
Agricultural machinery	0.2043	0.1725
Soil erosion	0.1881**	0.0882
Mutual trust	0.1942**	0.0928
Government subsidies	0.4623*	0.2549
Cons	0.0965	0.8686
Log-likelihood		−364.97403
LR $\chi^2(8)$		240.75
Pseudo R^2		0.2480
Prob > χ^2		0.0000

Note: ***, **, * respectively, indicate that the independent variables are significant at the confidence level of 1%, 5% and 10%

Table 7.
Estimated results of
average treatment
effects of soil and
water conservation
measures

Adoption of soil and water conservation technology	Coefficient	Z	Standard error
Average treatment effect in control group (ATT)	0.4852***	6.93	0.07
Average treatment effect of non-participants (ATU)	0.4284***	10.35	0.04
Random average processing effect (ATE)	0.4683***	9.07	0.05

Notes: The standard errors here are calculated by the bootstrap command in Stata 14.1; ATU represents the average treatment effect of non-participants; ATE represents the expected treatment effect of randomly extracting an individual from the population

- Farmers adopt soil and water conservation measures to cope with changes in soil erosion, which can increase agricultural output. Based on the counterfactual hypothesis, if farmers who adopt soil and water conservation measures do not adopt corresponding soil and water conservation measures, their per ha output will decrease and if farmers who do not adopt soil and water conservation measures adopt corresponding soil and water conservation measures, they are per ha output will increase.
- Government subsidies and cultivated land areas have significant promoting effects on farmers' adoption of soil and water conservation measures.

5.2 Recommendations

Based on the above research results, this paper draws the following policy implications:

- Soil and water loss significantly affects the adoption of soil and water conservation measures and reduces agricultural output. The relevant government departments should provide farmers with more information and knowledge on soil and water loss, deepen farmers' awareness of soil and water loss and promote farmers to adopt adaptation measures.
- Strengthen support for farmers to adopt soil and water conservation measures. At present, the proportion of water and soil conservation adaptation measures adopted by peasant households is relatively low. According to the survey experience, it is mainly limited by the factors of high technology cost. Therefore, it is necessary to give adequate consideration to the cost and benefit of water and soil conservation measures. It is necessary to provide appropriate economic support to reduce the cost of water and soil conservation measures adopted by peasant households as far as possible. Then, give full play to the benefits of technology, encourage farmers to adopt soil and water conservation measures and then alleviating the negative impact of soil erosion on agricultural production.
- When formulating policies, the government should consider the impact of farmers' and family endowment characteristics on the adoption of water and soil conservation measures, such as promoting the land transfer of farmers and better encouraging farmers to adopt soil and water conservation measures.

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